Environmental Engineering and Management Journal

August 2019, Vol. 18, No. 8, 1789-1798
http://www.eemj.icpm.tuiasi.ro/; http://www.eemj.eu

"Gheorghe Asachi" Technical University of Iasi, Romania

AEROBIC COMPOSTING OF MIXING SEWAGE SLUDGE WITH GREEN WASTE FROM LAWN GRASS

Oana Acatrinei–Însurățelu[1]*, Gabriel Buftia[1], Iuliana-Mihaela Lazăr[2], Lăcrămioara Rusu[2]

[1] "Vasile Alecsandri" University of Bacau, Doctoral School, 157 Marasesti Str., Bacau 600115 Romania
[2] "Vasile Alecsandri" University of Bacau, Department of Chemical and Food Engineering,
Marasesti Str. 157, Bacau 600115, Romania

Abstract

Biological decomposition process is an important goal in terms of pollution reduction. By composting, the organic waste can be converted into compost and can be used for agricultural purposes, to improve the soil quality. The present study aimed to evaluate the behavior of materials such as sewage sludge and green waste during composting, their compatibility in mixtures and the quality of the end product. Also, the study highlighted the technical and operational characteristics of a composting system on a laboratory scale. The main advantage of this laboratory scale experiment is the reduced processing time and the fact that it can be fast adapted to different experimental conditions. The pilot scale experiment allowed to investigate the dynamics of main parameters during the composting process and provide the basis for an efficient design process. The elaborated composting process is a convenient, cost-effective and environmentally friendly process for biodegradable organic waste management, being also a feasible and controllable process. The best intervals for physico-chemical parameter values that were obtained at the end of the composting process are: pH in the range of 8.2 ÷ 8.6; moisture content in the range of 59.9 % ÷65.8 %; organic matter in the range of 81.9 % ÷91.6 %; the C/N ratio in the range of 17.5 ÷ 18.7. The obtained results show that all composting variants lead to the production of a quality compost that can be used in agriculture.

Key words: bioreactor, compost, environment, green waste, sewage sludge

Received: July, 2018; Revised final: February, 2019; Accepted: May, 2019; Published in final edited form: August, 2019

1. Introduction

Waste management strategies is an important goal in terms of pollution abatement, that lead to a number of environmental, social and economic challenges (Aprilia et al., 2012; Onwosi et al., 2017). For the organic waste management, different techniques are used: incineration, pyrolysis and gasification, waste disposal in landfills, composting and anaerobic digestion. According to the directive of the European Union (EC Directive, 1999), organic waste will have to be reduced to a certain extent; it implies a choice of one of the several methods for their treatment. Among the organic waste treatment processes, the cheapest and most effective is considered to be the composting process. On another hand from point of view of environmental protection the safe method of recycling the organic waste is the composting process. Nowadays the fertilizer plays a key role in a sustainable agriculture (Andrea and Mentore, 2017; Ryckeboer et al., 2003; Sarkar et al., 2016).

The frequent use and the important quantities of chemical fertilizer can cause sever environmental pollution. However, the biofertilizer obtained by composting process has been identified as an alternative to chemical fertilizer (Bonoli and Dall'Ara, 2012; Farrell and Jones, 2010). Generally, the composting process is defined as a biological decomposition process of the heterogeneous organic

---

[*] Author to whom all correspondence should be addressed: e-mail: oanaacatrinei88@gmail.com; Phone: +40 0756875651

waste in controlled conditions of moisture, temperature, and aeration. By composting, the organic waste can be converted into compost and can be used to improve the soil quality, for agricultural purposes; also, it can be used in bioremediation of contaminated soils (Bonoli and Dall'Ara, 2012; Onwosi et al., 2017; Oudart al., 2015).

The final product of the composting process is called composting and has the potential to be used as soil amendment for various applications. Compost can significantly improve soil fertility, texture, aeration, nutrient content, and water retention capacity in the soil. With its beneficial features, compost offers a variety of potential applications and can be used by several market segments (Diaz, 2007; Gandahi and Hanafi, 2014; Popescu, 2005).

The composting process includes two major steps, the first stage is called the "active step", dissolved organic matter that is the source of carbon and energy for microorganisms, and during the second phase called "secondary fermentation phase" organic macromolecules such as humic substances. All of these reactions are based on numerous biological, thermal and physico-chemical phenomena and involve oxygen consumption but generate heat, water and carbon dioxide (Kokkora, 2008; Zheng et al., 2013).

The composting process can be accelerated by additional air extraction. Open composting systems require air aspiration from the bottom of the composting pillar. The released air must be passed through compost filters to avoid unpleasant odors. Under the ventilation force, compost time can be reduced 2 times when homogenized materials are present in the composting process (Bardos, 2014; Barral et al., 2007; Lasaridi et al., 2006; Pascu, 2009).

Aerobic composting can be done in the simplest, cost-free, small scale and in their own households as close as possible to the inhabited area. This can also be done near the landfill, open field (with relatively low costs) (Aprilia et al., 2012; Narita et al., 2005; Pascu, 2009; Francesca et al., 2017).

Monitoring method was generally used for simulation and optimization of the process in order to develop an efficient composting process. The monitoring of the process parameters is an efficient tool for the understanding of the dynamic interaction between the composting mechanisms, to modify the composting process, which can lead to a mathematical model in order to predict the stability of compost products, and then assuring the obtaining a good quality compost for agriculture use (Boldrin et al., 2010; Gigliotti et al., 2012; Khalil et al., 2011).

The present study aimed to evaluate the behavior during composting of materials such as sewage sludge and green waste and their compatibility in mixtures and the quality of the end product. Also, this study highlighted the technical and operational characteristics of a composting system on a laboratory scale. In order to achieve the goal, the following objectives were set: the construction of a composting bioreactor to enable the composting process to be improved, obtaining a four compost variants using green waste and sewage sludge , the parameters monitoring during the composting process, quality evaluation of the obtained composts.

2. Materials and methods

2.1. Composting materials. Collection and preparation of waste for composting

The waste that was used as the raw material for composting process in the present investigation were green waste, and anaerobically stabilized sewage sludge. The green waste consisting of lemon grass cuttings and fallen leaves collected from the garden area of University “Vasile Alecsandri” of Bacau. After initial screening, green waste was dried at environmentally temperature for 24 h. For further experiments and analyses the green waste were minced to the size of 1 cm. The anaerobically stabilized sewage sludge was collected from municipal waste water treatment plant (The Regional Water Company Bacau, Romania). These raw materials were analyzed for determining moisture content, dry matter, pH, electrical conductivity and heavy metal content.

2.2. Experimental system and protocol. Composting bioreactor

A composting bioreactor (Fig. 1.) made of plastic material with a capacity of 10 L was used to perform the experiments. The bioreactor is provided with four inlets (with a diameter of 29 mm) for mounting the connectors, three of these inlets are used for introducing the measuring sensors and the 4th inlet can be used to introduce a flexible tube for aeration. Taking into account the fact that the control of aeration is necessary so that the system maintained aerobic conditions without excessive drying of the composting material the 4th inlet can also be used, for the evacuation of the gases produced during the composting process.

At the bottom, the bioreactor is provided with an orifice in which a tube has been fitted to remove and recirculate the leachate in order to maintain the required humidity in the composting process. In order to suspend the compost layer and to prevent small particles from falling to the bottom of the bioreactor, a system consisting of a plastic grid covered with a mesh (1 mm holds size), placed on a support system formed from four legs. This system placed at the bottom of the bioreactor allowed that the compost gases to flow uniformly through the composting matrix from the bottom to the top of the reactor.

For the thermal isolation of the bioreactor, a 3 mm aluminized EPE (Expanded polyethylene) foil (the aluminized EPE foil is obtained by applying an aluminized polyester film to one of the expanded polyethylene foam foil surfaces) was used.

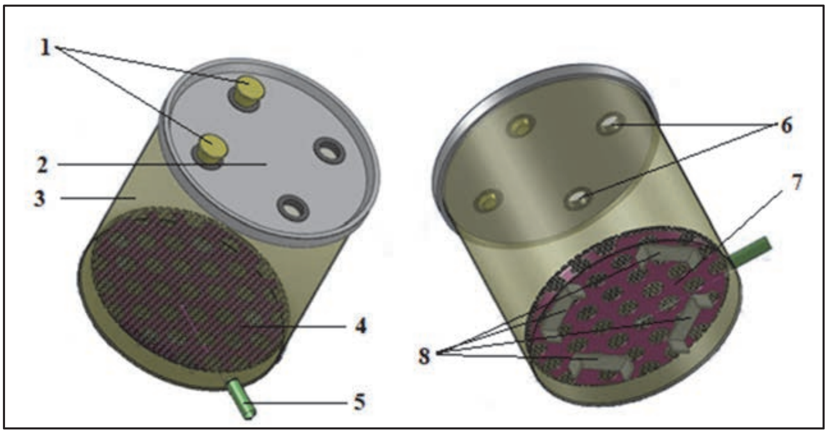

Fig. 1. Composting bioreactor - Isometric view (drawing made in SolidWorks): 1 - Inlet caps; 2 – Removable top; 3 - Bioreactor body; 4, 7, 8 - Composting layout system (mash, plastic grid, support system); 5 – Leachate leakage tube; 6 – Inlet.

The composting bioreactor presented above was used in the experimental procedure. The compostable organic matter (green waste, anaerobically stabilized sewage sludge) was introduced in different ratio (table 1). Before the composting process, the raw materials were homogenized and analyzed in triplicates in order to determine the following parameters: the moisture content, dry matter content, pH, electrical conductivity and the heavy metal content. Each bioreactor is equipped with perforated rubber stoppers to allow the insertion of sensors used for measuring the temperature, the oxygen and carbon dioxide concentration during the composting process.

The use of this type of experimental bioreactor allows both observation and monitoring in detail of all phases of composting and correction of the parameters when is necessary (the quantity of water, the temperature).

2.3. Experimental procedure for composting

During the composting process, aeration was performed by manual mixing, which took place daily in the first 15 days, during the thermophilic phase once every four days and once per week during the maturation phase. The moisture content was kept constant at about 55-60%. According to Gajalakshmi and Abbasi (2008; Gómez-Brandón et al. (2008), the ideal moisture content for the composting process should be in the range of 45-60%.

In this study four variants were designed with the same proportion of green waste and sewage sludge using water as the wetting agent. The difference between these variants consists in using a pretreatment (autoclaving at 120^{0}C for 20 minutes) that can be applied to both green waste and sewage sludge to be used in the process (Table 1). In detail, the four variants of composting process, presented above, were obtained as follows: Variant 1 (the material was made up of green waste that has been subjected to a heat pretreatment at a temperature of 120°C for 20 minutes and untreated sludge); Variant 2 (the material was made up of sludge that has been subjected to a heat pretreatment at a temperature of 120°C for 20 minutes and untreated green waste); Variant 3 (sludge and green waste subjected to the same pretreatment); Variant 4 (sludge and green waste without treatment).

Table 1. The variants which were used in the composting process

Compost	*The ratio of compost materials*		*The wetting agent*	*Composition of variant*
	GW	*SS*		
Variant 1	2	1	Water	GW autoclaved + SS
Variant 2	2	1	Water	GW + SS autoclaved
Variant 3	2	1	Water	GW and SS autoclaved
Variant 4	2	1	Water	GW + SS

GW – green waste
SS – anaerobically stabilized sewage sludge

The pretreatment has been used to determine whether the microorganisms present in the raw materials have a major influence on the composting process.

In the case of the green waste it was autoclaved in order to determine the influence of the various species of microorganisms present naturally in this type of waste on the composting process. According to Ling et al. (2017), in the green waste was identified a bacterial community mainly formed by Firmicutes that were the most abundant phyla bacteria identified, followed by Actinobacteria and Proteobacteria. In this study, the authors report that the predominant genera of bacteria were Clostridium (Clostridia, Firmicutes) and Ureibacillus (Bacilli, Firmicutes) and showed the influence of bacterial species on the composting process through their dynamic modifications in different stages of composting. In the case of sewage sludge the purpose of the pretreatment was to determine the influence of the resistant microorganisms present in this type of waste after anaerobic fermentation on the composting process.

The variables used for investigation of the composting process at laboratory scale were: the oxygen and carbon dioxide content, the temperature of the mixture, the electrical conductivity and the pH. These parameters were monitored for a period of 120 days.

2.4. Analytical methodology

2.4.1. Determination of pH

In the case of sewage sludge, the pH was determinate according to standard procedure (ISO 10390/2005), using WTW pHotoFlex® pH device. In the case of the compost was necessary the following steps: 10 g of air dried compost sample was introduced in a 250 mL Erlenmeyer flask containing a 50 mL distilled water, after that the suspension was stirring for 1 hour, the pH meter electrode was placed in the compost solution and the value of the pH was read when it was stabilized (Ameen et al., 2016; Gabhane et al., 2012; Mello et al., 2015; Ranalli et al., 2001).

2.4.2. Determination of electrical conductivity

The electrical conductivity was determinate according to standard procedure, using WTW InoLab 740i device. The solution of compost was made in the same mode that was presented in paragraph „determination of pH" (Ameen et al., 2016; Herity, 2003; Michailides et al., 2011; Onwosi et al., 2017).

2.4.3. Determination of moisture content

10 g of compost sample was weighed in a glass Petri dish. The glass Petri dish was placed in an oven set at 105^{0}C till a constant weight is reached and cooled in the desiccator. The difference between final weight and initial weight gave the moisture content (Ciuperca et al., 2015; Onwosi et al., 2017; Pan et al., 2012).

2.4.4. Determination of heavy metal content

The determination of the heavy metal content was made according to the procedure described by international standards (SR EN 14082, 2003) and (Haroun et al., 2007) using a flame atomic absorption spectrophotometer (Varian AA 240FS).

For determining the heavy metal content, the samples (1g weight) were calcined at 450°C for 3.5 hours. After calcination, ash is dissolved in exactly 30 mL volume of nitric acid (65%) and hydrochloric acid (37%). Then the solution is mixed and heated on a sand bath at 150 ° C until the residue is completely dissolved.

After the complete digestion of the samples, it's were allowed to cool, then the resulting solution was filtered and placed in a 50 mL volumetric flask, filling the volume with distilled water. The digested samples were then analyzed in order to determine the heavy metal content: Pb, Cr, Cu, Cd, Zn and Ni (Haroun et al., 2007; Hua et al., 2009; Stefan et al., 2014).

3. Results and discussion

3.1. Characterization of raw materials used in experiments

The materials that were used in the composting process, were analyzed in order to determine its basic parameters and its content of heavy metal. The obtained results are presented in Table 2.

It can be seen from Table 2 that metals with high toxic potential (Cd, Pb, Cr) are not present in green waste.

3.2. Monitoring of composting parameters

3.2.1. Temperature monitoring

The monitoring of temperature carried out during 120 days. The aeration was conducted manually by mixing the compost once a week. The temperature was monitored every four days.

The temperature dynamics for the four variants of composting process is shown in the Fig. 2.

The experiment started with 12–15°C temperature for all variants of composting process. There is a rise in temperature in the first 33 to 37 days for all four variants. The highest recorded values for the temperature were 66.2ºC and 65.9ºC, obtained for variant 4 on day 33 and respectively for variant 2 on day 37. Then the temperature decreased and values become close to 25-28ºC after 69 days. Starting with day 73 the temperature decreases slowly so at the end of the composting period the temperature values reach 22-23ºC. The similar results, a temperature peak value around 70ºC, were obtained by (Oudart et al., 2015), for composting animal manure in naturally aerated piles. In generally the temperature profiles during composting process followed a typical pattern exhibited by many composting systems in which organic waste is used (Gabhane et al., 2012; Hogland et al., 1996; Onwosi et al., 2017; Sarkar et al., 2016).

Table 2. Characterization of raw materials used in composting process

Waste	*Parameters*									
	Moisture content [%]	*Dry matter [%]*	*pH [pH-unit]*	*Electric conductivity [µS/cm]*	***Cd***	***Cu***	***Pb***	***Zn***	***Cr***	***Ni***
					[mg•kg^{-1}]					
GW	50.5	49.5	7.99	-	ND	12,03	ND	65.3	ND	ND
SS	89.3	10.7	7.98	2.18	9.8	182	10.5	1170	459	86.5

GW – green waste; SS – anaerobically stabilized sewage sludge; ND – not detected

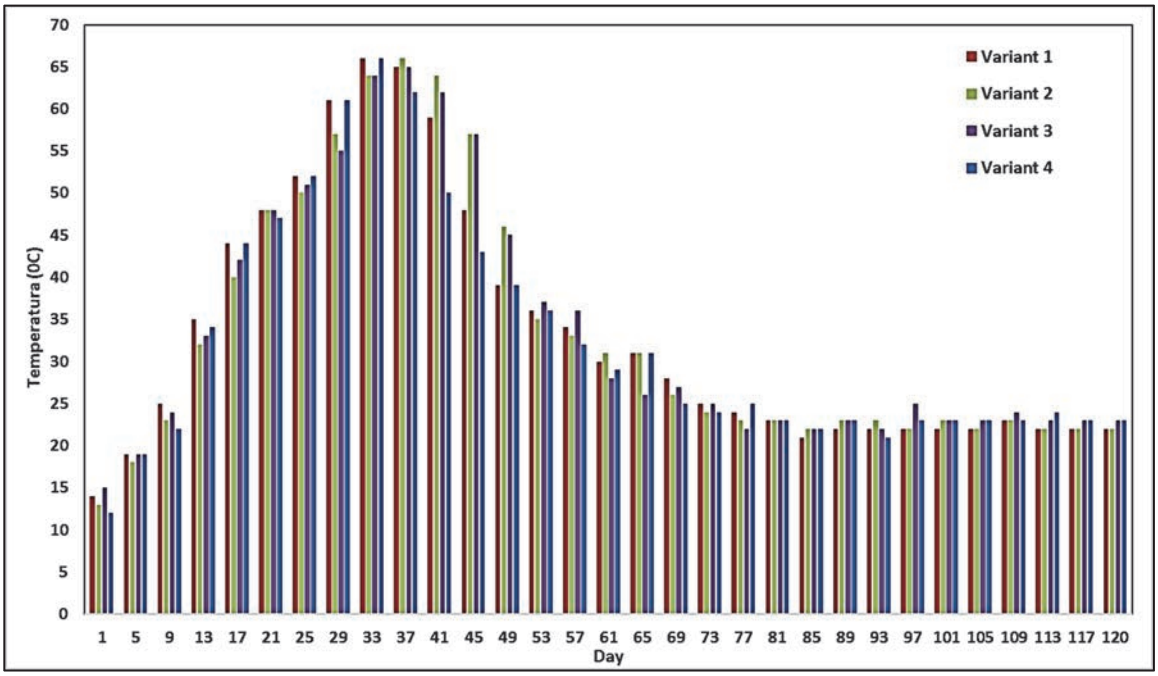

Fig. 2. Observed dynamics of the temperature during composting process for all variants

In the case of green waste composting with additives additions that were carried out in thermocol boxes the maximum values (53, 51ºC) of temperature was observed during thermophilic phase when were used jaggery and polyethylene glycol treatments (Gabhane et al., 2012).

Taking into account the dynamics of temperature the composting process can be divided in three phases namely mesophilic, thermophilic and maturation stage. The three degradation phases were observed in all four variants. From day 73 begins the compost maturation process. During the maturation phase of the compost, the temperature has a relatively constant value for all four variants.

3.2.2. pH monitoring

The evolution of pH during the composting process is presented in Fig. 3. The initial pH of the mixture that was used in the composting process was in the range of 5.9 – 6.7. An increase in pH-unit was observed in the thermophilic phase. The mature composts resulting from the process had pH units ranging from 8.1 to 8.3. According to (Gigliotti et al., 2012; Said-Pullicino D, 2007), during the composting process, mineralization of proteins and amino acids normally leads to the development of ammonium or ammonia which helps to increase pH. When the pH of mature compost decreases, it indicates the formation of humic substances (Zenjari et al., 2006).

3.2.3. Electrical conductivity monitoring

Fig. 4 shows the electrical conductivity (EC) profile of the four compost variants during the composting process. In the case of variant 4 the initial value of EC was 312 $\mu S\bullet cm^{-1}$ after which there is an increase of up to 581 $\mu S\bullet cm^{-1}$ at the end of the thermophilic phase and finally reached 568 $\mu S\bullet cm^{-1}$.

For variant 1 the initial value of EC was 321 $\mu S\bullet cm^{-1}$, then increased up to 601 $\mu S\bullet cm^{-1}$ and reached the value of 594 $\mu S\bullet cm^{-1}$ in the last day. The initial EC value for variant 2 was 325 $\mu S\bullet cm^{-1}$. The highest value of EC 615 $\mu S\bullet cm^{-1}$ was reached in day 90, it decreased until 593 $\mu S\bullet cm^{-1}$ in the final day. For compost variant 3, the initial value of EC was 332 $\mu S\bullet cm^{-1}$, it increases during the composting process, reaching maximum value 615 after 80 days and at the end of the composting process yielding a value of 568 $\mu S\bullet cm^{-1}$.

Experimental results show that the highest electrical conductivity values were observed after 80 – 90 days and this fact can be attributed to the release of mineral salts, the organic matter mineralization and the water evaporation. The difference in the initial conductivity of the compost variants with the same material ratio could be attributed to the inhomogeneity of raw materials. An increase in EC during the composting process was also found by (Zhang et al., 2018) in the case of co-composting sewage sludge and organic fraction of municipal solid waste at different proportions.

3.2.4. Monitoring of carbon dioxide level

The CO_2 emission profiles depends on the initial ratio of biodegradable carbon. For the four variants the CO_2 emission dynamics matched with the corresponding temperature dynamics. The CO_2 emission rate decreased with the stabilization of the biodegradable organic matter in the maturation stage of compost. The evolution of CO_2 emissions during the composting process is shown in Fig. 5.

The greatest values of CO_2 emission were recorded starting day 14 until day 28 in the period when de thermophilic phase reached maximum of intensity. In the maturation phase the CO_2 emission remained relatively constant. A similar profile in CO_2

emission witch was also similar to their temperature variation was found by (Zhang et al., 2018).

3.2.5. Monitoring of oxygen level

The composting process should be kept aerobic in order to reduce offensive odors it is necessary to ensure that oxygen is supplied to the material. The oxygen level is an important factor which influencing composting process thus (Gao et al., 2009) explain that low aeration can lead to anaerobic conditions and as well the highest aeration may result in failure to meet the conditions for the thermophilic phase, which would lead to a low rate of decomposition of organic matter. During the composting process the oxygen level was daily monitored, the obtained results are shown in Fig. 6.

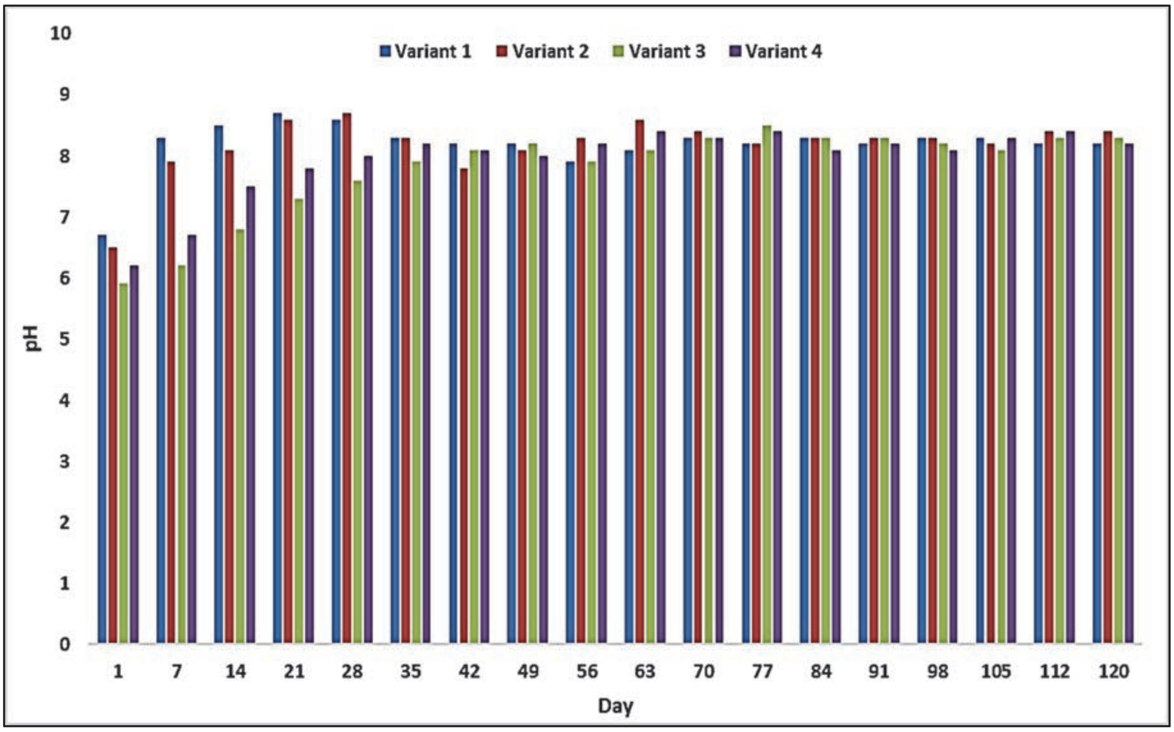

Fig. 3. Observed dynamics of the pH during composting process for all variants

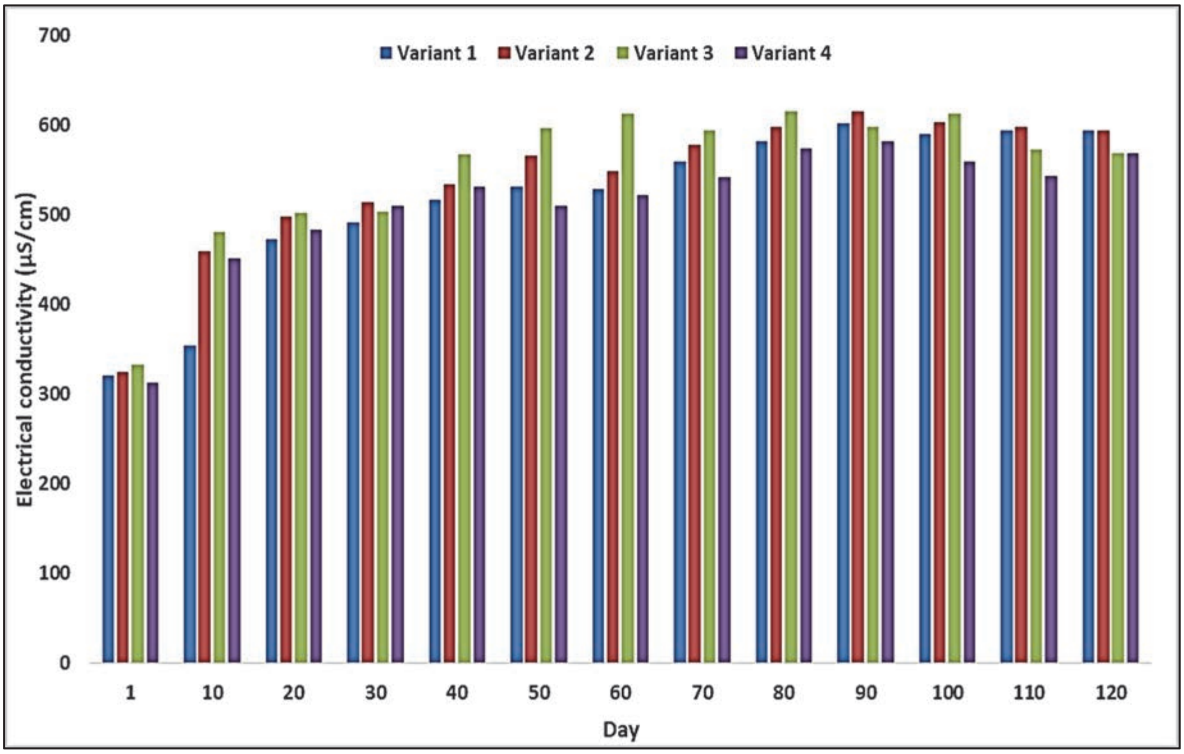

Fig. 4. Evolution of electrical conductivity during the composting process

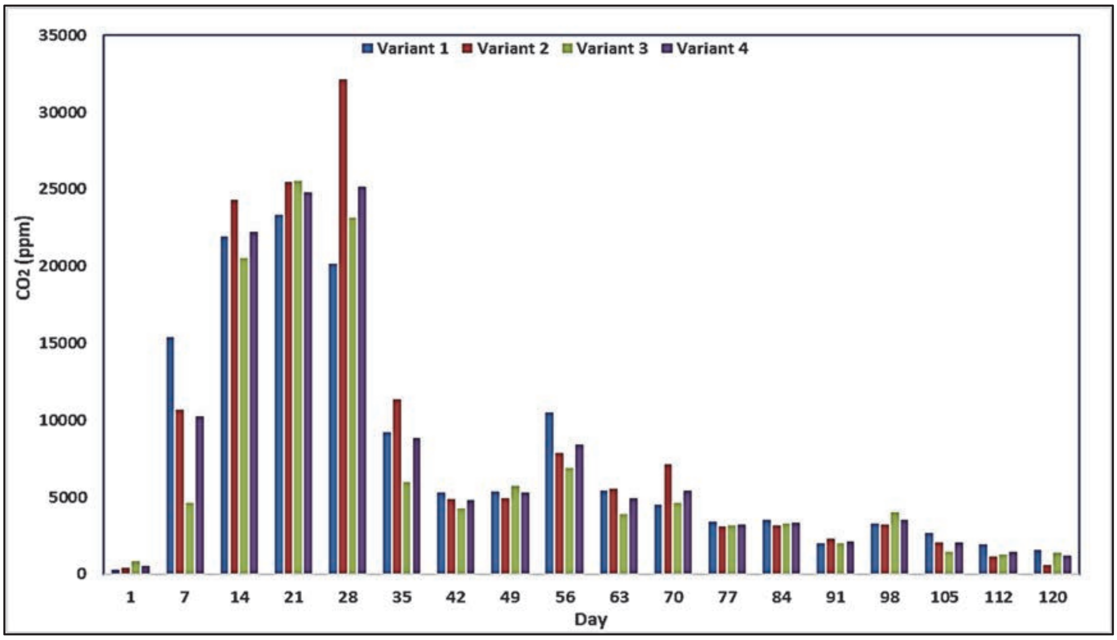

Fig. 5. Evolution of CO_2 emission during the composting process

The lowest content of O_2 was observed in day 45 for all composting variants, this being explained by the fact that the composting process is in the thermophilic phase. The maximum value for the oxygen concentration was obtained on the 30th and 90th days (21%) in the case of variant 3.

3.3. Evaluation of parameters in biodegradation stages of organic matter

The compost substrates with different composition of organic waste have been prepared, monitored and characterized in order to finally obtain a compost that can be used in agriculture. To highlight the biodegradation stages, the way the composting process was carried out and the quality of the obtained compost, the samples subjected to composting were monitored throughout the experiment.

Therefore, the samples were taken and analyzed for the entire duration of the composting in order to determine the most relevant physico-chemical parameters. The physico-chemical parameters registered for the first day, for the thermophilic phase and the end of the composting are presented in the Table 3. The analysis of the obtained results for the four compost variants shows that there are no significant differences in the main quality characteristics of composts, which indicated the fact that the pretreatments of the raw materials do not influence the final characteristics of the obtained products. The use of compost in agriculture requires a C/N ratio between 12 and 18; taking into account this fact, can be concluded that the end products obtained in the four variants comply with this requirement.

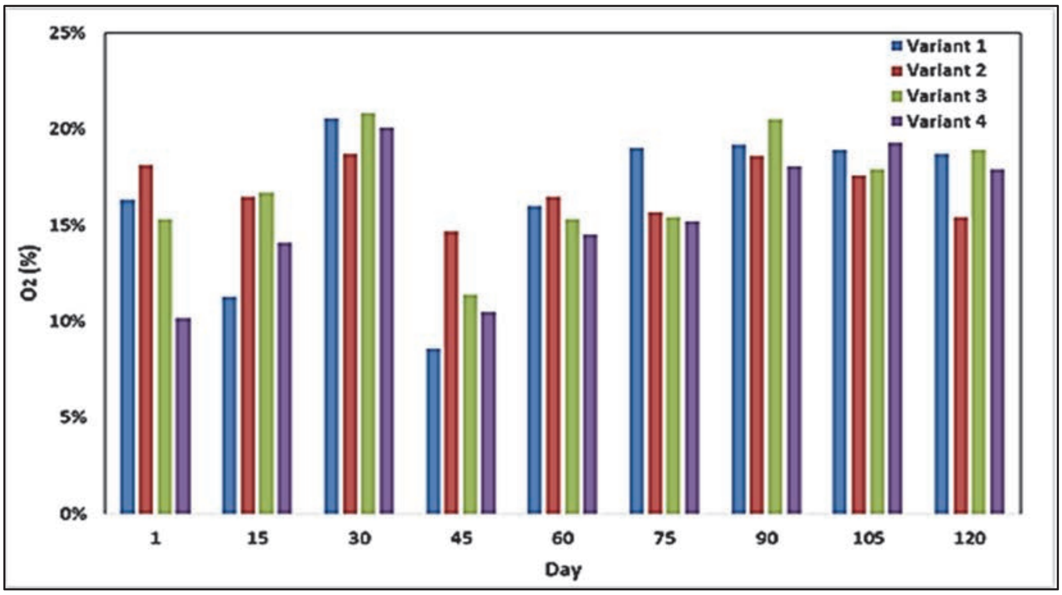

Fig. 6. Evolution of O_2 during the composting process

Table 3. The physico-chemical parameters recorded during the composting process

Compost	*pH*	*Electrical conductivity (µS/cm)*	*Moisture content (%)*	*Organic matter (%)*	*Volatile substance (%)*	*C/N ratio*
			Initial day			
Variant 1	*9.43*	*321*	*68.5*	*89.5*	*92.5*	*27.4*
Variant 2	*9.56*	*325*	*65.3*	*93,3*	*95,8*	*26.5*
Variant 3	*9.61*	*332*	*67.5*	*87.1*	*89.4*	*28.2*
Variant 4	*9.58*	*312*	*64.4*	*95.4*	*97.4*	*28.6*
			End of the thermophilic phase			
Variant 1	*8.40*	*516*	*66.5*	*86.5*	*89.6*	*19.8*
Variant 2	*7.96*	*533*	*63.4*	*91.9*	*94.4*	*21.1*
Variant 3	*7.91*	*567*	*65.8*	*83.6*	*85.5*	*20.4*
Variant 4	*8.12*	*531*	*60.4*	*93.6*	*97.1*	*21.5*
			End of maturation			
Variant 1	*8.3*	*594*	*65.8*	*83.7*	*89.1*	*17.5*
Variant 2	*8.4*	*593*	*62.3*	*89.2*	*94.1*	*18.7*
Variant 3	*8.6*	*568*	*64.8*	*81.9*	*85.1*	*17.9*
Variant 4	*8.2*	*568*	*59.9*	*91.6*	*96.7*	*18.3*

In the green waste composting process, literature suggests that adding materials or microorganisms lead either to the improvement of the characteristics of the final compost or to the reduction of composting time. In this study was used sewage sludge as co-composting material, the obtained results are comparable or better than those obtained using other types of materials as shown in the Table 4.

3.4. Heavy metal content

Based on the obtained results for heavy metal content of composts (Table 5) can be concluded:

- the values obtained for Cu and Cr are below the maximum allowable limits, therefore there is no risk of contamination;

- in the case of Zn, the obtained values range from 1536.66 mg/kg (variant 2) and 2030.83 mg/kg (variant 1), these values are considered to be exceeded for countries such as Poland, Switzerland, Belgium, Germany and Great Britain, but for countries like Romania, Italy, Spain and Denmark, the values obtained are below the maximum allowable limits;

- the results showed that the values obtained for Cd, Pb and Ni are below the detection limits of the device.

The heavy metal content of final composts was below the USEPA limits for compost application on the soils. Therefore, the obtained composts provide safe conditions for agricultural use.

4. Conclusions

From the tested variants, the best compost (in terms of aspect, color and smell) was obtained in the case of variant 1 and variant 3. The use of this type of experimental bioreactor allows both observation and monitoring in detail of all phases of composting and correction of the parameters when is necessary (the quantity of water, the temperature), during the composting process. The main advantage of this laboratory scale experiment is the reduced processing time and the fact that it can be fast adapted to different experimental conditions.

Table 4. The final C/N ratio for green waste composting process with different type of co-composting materials

Raw materials	*Study scale*	*Composting time (days)*	*Final C/N ratio*	*Reference*
GW + Sheep manure	Pilot	22	16-20	Ling Liu et al., (2017)
GW + Pig manure	Pilot	48	10.3	Arias et al. (2017)
GW+ PFW and UFW	Pilot	55	10.5	Oviedo Ocana et al. (2017)
GW+ Jaggery	Laboratory	21	10.0	Gabhane et al. (2012)

GW – green waste; PFW - processed food waste; UFW - unprocessed food waste

Table 5. Heavy metal content of the final compost

Heavy metals [mg•kg^{-1}]	*Variant 1*	*Variant 2*	*Variant 3*	*Variant 4*	*USEPA^{a}*	*WHO^{b}*
Cd	ND	ND	ND	ND	39	15-40
Cu	10.22	6.31	12.35	9.16	1500	100-1750
Pb	ND	ND	ND	ND	300	750-1200
Zn	2030.83	1536.66	1615	1468.8	2800	2500-4000
Cr	25.06	24.37	35.47	26.45	1200	-
Ni	ND	ND	ND	ND	420	300-400

[a] Standard limit for agricultural use of compost in accordance with US EPA (USEPA, 1995); [b] Standard limits for agricultural use of compost according to the WHO (WHO, 2006); ND – not detected

This concept at pilot scale experiment permits us to investigate the dynamics of main parameters during the composting process and to provide the basis for an efficient design process. The elaborated composting process is a convenient, cost-effective and environmentally friendly biodegradable organic waste management process that is a feasible and controllable process.

The experimental methodology that was used allows the monitoring and modification of parameters throughout the process, the physico-chemical analysis of the raw materials, the evaluation of the quality of the end product, the statistical processing of the data, based on accessible equipment and modern methods of analysis. The obtained results show that all composting variants lead to the production of a quality compost that can be used in agriculture, but to achieve this goal, further studies are needed to determine the germination index and phytotoxicity.

References

Ameen A., Ahmad J., Munir N., Raza S., (2016), Physical and chemical analysis of compost to check its maturity and stability, *European Journal of Pharmaceutical And Medical Research*, **1,** 84-87.

Andrea P., Mentore V., (2017), Organic waste valorization through composting process: a full-scale case study in maxixe, mozambique, *Environmental Engineering and Management Journal*, **16**, 1819-1826.

Aprilia A., Tezuka T., Spaargaren G., (2012), *Economic Evaluation of Household Solid Waste Management in Jakarta, Indonesia*, In: *Waste Management - An Integrated Vision*, Marmolejo L.F. (Ed.), InTech, 71-100.

Arias O., Viña S., Uzal M., Soto M., (2017), Composting of pig manure and forest green waste amended with industrial sludge, *Science of the Total Environment*, **586**, 1228– 1236

Bardos P., (2014), Composting of mechanically segregated fractions of municipal solid waste – a review, Sita Environmental Trust, On line at: http://www.compostinfo.info/content/SET%20Critical%20Review%20MSW%20Composting.pdf.

Barral M.T., Moldes A., Cendón Seijo Y., Díaz-Fierros Viqueira F., (2007), Assessment of municipal solid waste compost quality using standardized methods before preparation of plant growth media, *Waste Management & Research*, **25**, 99-108.

Boldrin A., Christensen T., Koerner I., Krogmann U., (2010), Composting: Mass balances and product quality, *Solid Waste Technology & Management*, **1**, 569 - 582.

Bonoli A., Dall'Ara A., (2012), A bioremediation case of an ex-quarry area restored by paper sludge, *Journal of Biotechnology*, **157**, 499-504.

Ciuperca R., Lazar G., Popa L., Nedelcu A., Stefan V., Zaica A., Petcu A., (2015), Organic plant and animal waste management system, *NMATEH - Agricultural Engineering*, **46**, 69-76.

Diaz L.F., De Bertoldi M., Bidlingmaier W., (2007), *Compost Science And Technology*, In: *Waste Management*, (Eds.), Elsevier Science, vol. 8.

EC Directive, (1999), Directive 1999/31/EC of the European Council of 26th April 1999, on the landfill waste, *Official Journal of the European Communities*, L182/1, 16.07.1999, Brussels.

Farrell M., Jones D., (2010), Food waste composting: its use as a peat replacement, *Waste Management*, **30**, 1495-1501.

Francesca B, Roberto D.G, Antonella P., Michela S., (2017), Waste management companies towards circular economy: what impacts on production costs?, *Environmental Engineering and Management Journal*, **16**, 1789-1796.

Gabhane J., William S.P, Bidyadhar R., Bhilawe P., Anand D., Vaidya A.N., Wate S.R., (2012), Additives aided composting of green waste: Effects on organic matter degradation, compost maturity, and quality of the finished compost, *Bioresource Technology*, **114**, 382-388.

Gajalakshmi S., Abbasi S.A., (2008), Solid waste management by composting: State of the art, *Environmental Science and Technology*, **38**, 311-400.

Gandahi A.W., Hanafi M.M., (2014), Bio-composting oil palm waste for improvement of soil fertility, *Sustainable Development and Biodiversity*, **3**, 209-243.

Gao M., Li B., Yu A., Liang F., Yang L., Sun Y., (2009), The effect of aeration rate on forced-aeration composting of chicken manure and sawdust, *Bioresource Technology*, **6**, 1899-1903.

Gigliotti G., Proietti P., Said-Pullicino D., Nasini L., Pezzolla D., Rosati L., Riccardo Porceddu P., (2012), Co-composting of olive husks with high moisture contents: organic matter dynamics and compost quality, *International Biodeterioration & Biodegradation*, **67**, 8-14.

Gómez-Brandón M., Lazcano C., Domínguez J., (2008), The evaluation of stability and maturity during the composting of cattle manure, *Chemosphere*, **70**, 436-440.

Haroun M., Idris A., Syed Omar S.R., (2007), A study of heavy metals and their fate in the composting of tannery sludge, *Waste Management*, **27**, 1541-1550.

Herity L., (2003), *A study of the quality of waste derived compost in Ireland*, MSc Thesis, Environmental Engineering, Queens University of Belfast.

Hogland W., Bramryd T., Persson I., (1996), Physical, biological and chemical effects of unsorted fractions of industrial solid waste in waste fuel storage, *Waste Management & Research*, **14**, 197-210.

Hua L., Wu W., Liu Y., Mcbride M.B., Chen Y., (2009), Reduction of nitrogen loss and cu and zn mobility during sludge composting with bamboo charcoal amendment, *Environmental Science Pollution Research International*, **16**, 1-9.

Khalil A., Hassouna S., Ashqar H., Fawzi M., (2011), Changes in physical, chemical and microbial parameters during the composting of municipal sewage sludg, *World Journal of Microbiology and Biotechnology*, **27**, 2359-2369.

Kokkora M.I., (2008), *Biowaste and vegetable waste compost aplication to agriculture*, PhD Thesis, Cranfield University, School of Applied Sciences, National Soil Resources Institute.

Lasaridi K., Protopapa I., Kotsou M., Pilidis G., Manios T., Kyriacou A., (2006), Quality assessment of composts in the greek market: the need for standards and quality assurance, *Journal of Environmental Management*, **80**, 58-65.

Ling L., Wang S., Guo X., Zhao T., Zhang B., (2017), Succession and diversity of microorganisms and their association with physicochemical properties during green waste thermophilic composting, *Waste Management*, **73**, 101–112.

Mello S.M.L, Bertoncini E.I., Abreu-Junior C., (2015), Composting sewage sludge with green waste from tree pruning, *Scientia Agricola*, **72**, 432-439.

Michailides M., Christou G., Akratos C., Tekerlekopoulou A., Vayenas D., (2011), Composting of olive leaves and pomace from a three-phase olive mill plant, *International Biodeterioration and Biodegradation*, **65**, 560-564.

Narita H, Lopez Zavala M., Iwai K., Ito R., Funamizu N., (2005), Transformation and characterisation of dissolved organic matter during the thermophilic aerobic biodegradation of faeces, *Water Research*, **39**, 4693-4704.

Onwosi C.O., Igbokwe V.C., Odimba J.N., Eke I.E., Nwankwoala M.O., Iroh I.N., Ezeogu L.I., (2017), Composting technology in waste stabilization: on the methods, *Journal of Environmental Management*, **190**, 140-157.

Oudart D., Robin P., Paillat, J.M., Paul E., (2015). Modelling nitrogen and carbon interactions in composting of animal manure in naturally aerated piles, *Waste Management*, **46**, 588-598.

Oviedo-Ocaña R., Dominguez I., Komilis D., Sanchez A., (2017), Co-composting of green waste mixed with unprocessed and processed food waste: influence on the composting process and product quality, *Waste Biomass Valorization*, **10**, 63-74.

Pan I., Dam B., Sen S.K., (2012), Composting of common organic wastes using microbial inoculants, *Biotechnology*, **2**, 127-134.

Pascu R.V., (2009), *Waste Management* (in Romanian), "Lucian Blaga" University Publishing House, Sibiu, Romania.

Popescu O., (2005), Methods and technologies for waste management - Thermal treatment methods (in Romanian), On line at: http://www.deseuri-online.ro/new/download/Trataretermica.pdf

Ranalli G., Bottura G., Taddei P., Garavani M., Marchetti R., Sorlini C., (2001), Composting of solid and sludge residues from agricultural and food industries, *Journal of Environmental Science and Health*, **36**, 415-436.

Ryckeboer J., Mergaert J., Coosemans J., Deprins K., Swings J., (2003), Microbiological aspects of biowaste during composting in a monitored compost bin, J*ournal of Applied Microbiology*, **94**, 127-137.

Said-Pullicino D., Gigliotti G., (2007), Oxidative biodegradation of dissolved organic matter during composting, *Chemosphere*, **68**, 1030-1040.

Sarkar S., Pal S., Chanda S., (2016), Optimization of a vegetable waste composting process with a significant thermophilic phase, *Procedia Environmental Sciences*, **35**, 435-440.

SR EN 14082, (2003), In determination of trace elemests. Determination of lead, cadmium, zinc, copper, iron and chromium by atomic absorption spectrometry (AAS) after dry ashing, On line at: https://magazin.asro.ro/standarde/ics-ierarhic/4/67.050/115342907.

Stefan V., Popa L., Ciuperca R., Petcu A.S., Zaica A., Lazar G., (2014). *Manure Fertilizers, Agrotechnical Recommendations*, Proc. of International Symposium ISB-INMA, *Agricultural and Mechanical Engineering*, Oct. 30-31, Bucharest, Romania, 387-392.

Zenjari B., El Hajjouji H., Baddi,G., Bailly J.R., Revel J.C., Nejmeddine A., Hafidi M., (2006), Eliminating toxic compounds by composting olive millwastewater–straw mixtures, *Journal of Hazardous Materials*, **138**, 433-437.

Zhang D., Luo W., Li Y., Wang G., Li G., (2018), Performance of co-composting sewage sludge and organic fraction of municipal solid waste at different proportions, *Bioresource Technology*, **250**, 853-859.

Zheng C., Zhao L., Zhou X., Fu Z., Li A., (2013), *Treatment Technologies for Organic Wastewater*, In: *Water Treatment*, Elshorbagy W., Chowdhury R.K. (Eds.), InTech, 249-286.