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STEPS IN ORGANIC FRACTION OF MUNICIPAL SOLID WASTE COMPOSTING AND COMPOST QUALITY EVALUATION

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Abstract

The amount of solid waste generated in Romania has increased in recent years mainly because of the people lifestyle. Since 2015, all local communities are working for a sustainable waste management using composting as the main method of recycling the organic fraction of municipal solid waste (OFMSW). Composting is a way of obtaining a product from the biological oxidative transformation of OFMSW with less carbon and nitrogen, but more stable, which is called compost and that could enhance plant growth. This paper refers to quality evaluation of compost produced from OFMSW within Covasna-Boroşneu Mare Integrated Waste Management Centre. There were used empirical methods, physical and chemical analysis, germination tests with cress (Lepidium sativum L.) and plant growing tests with lettuce (Lactuca sativa L). No presence of ammonia was identified within empirical test, and the C/N ratio has a typical value for a mature compost but, in the seed germination tests and plant growing tests the plants are dead. The phytotoxicity could be explained by the higher salts content of compost or by other substances that haven't been analiyzed.

Key words: *compost mixtures, compost maturity, germination test, plant growth test, salts content.*

INTRODUCTION

The amount of household waste generated both, in urban and rural areas of Romania, has increased in the last 30 years mainly not because of demographic growth but because of the changes in people lifestyle and the increase of consumption. Recently (2016), in Romania, the average production of municipal waste was of 261 kg/capita and, in 2017, the average increased at 272 kg per capita (Eurostat, 2017). Nevertheless, these quantities are under the European Union (EU) average, which was of 486 kg/capita in 2017. However, the quantities are high and, in addition to the remarkable increase of wastes generation, their diversity, their polluting capacity, the dangerousness and the environmental impact should be considered in order to implement an appropriate management strategy (Oliveira et al., 2017). The major problem of the waste management in Romania was related especially to the selective collection which has not been widely deployed. Thus, a large amount of waste reached to landfill which is not an environmentally friendly method. Romania has a recycling rate (including composting) of 13%, while the elimination rate on landfill is of 69%. Based on an analysis of the existing and firmly planned policies in the area of waste management, Romania is considered at risk of missing the 2020 target of 50% preparation for re-use/recycling of municipal waste (CE, 2018). There are several treatments available which can produce valuable products such as biofuels, energy and fertilizers. However, if the waste management framework does not operate efficiently, OFMSW may be unnecessarily wasted (Mihai & Ingrao, 2018). For that reasons, since 2015, with the new Romanian National Plan for Waste Management (HG 942/2017), all local communities are working for a sustainable waste management. In many cases, composting was introduced as the main method of recycling the organic fraction of municipal solid waste which is considered a suitable waste management method in many European countries (Kapanen & Itävaara, 2001) and the most environmentally friendly technologies (Barrena et al., 2014).
Composting is a way of obtaining a stable product from biological oxidative transformation, similar to that which naturally occurs in the soil (Bertoldi et al., 1983), a sum

of complex metabolic processes performed by different microorganisms that, in the presence of oxygen, use nitrogen (N) and carbon (C) available to produce their own biomass (Roman et al., 2015). If is correctly handled, composting (Bertoldi et al., 1983) provides a hygienic transformation of organic wastes in a homogeneous material which occurs under aerobic conditions (presence of oxygen), with adequate moisture and temperature, the recycling of nutrients, and the consequent reuse of the organic fraction of the waste, thus reducing environmental pollution (Oliveira et al., 2017; Azim et al., 2018). In this process, additionally, the microorganisms generate heat and a solid substrate, with less carbon and nitrogen, but more stable, which is called *compost* and that could enhance the plant growth (Komilis et al., 2011; Roman et al., 2015).

Using organic fertilizers, such as compost, in order to improve the soil content in organic matter and consequently the long-term soil fertility and productivity became widespread around the world. Organic waste composting benefits for soil structure and fertility, as well as for plant growing have been more and more emphasized. Compost application can reduce some of the negative consequences that urbanization has upon soil properties and processes, and can improve carbon storage, patterns of nutrient cycling and nutrient use efficiency, water capacity of the soil, as well as biocontrol of pathogenic microorganisms (Termorshuizen et al., 2006; Trillas et al., 2006). The humic substances formed during the composting process promote the building of soil fertility, and there is an actual increase in organic matter content in the soil (Bertoncini et al., 2008). For a good compost quality, composting process must be conducted with the respect of some important parameters (substrate mixture, C/N ratio, temperature, aeration, humidity etc.). Two properties are usually used for the characterization of compost quality namely "stability" and "maturity".

Compost stability is related to the microbial decomposition or microbial respiration activity of the composted matter (Iannotti et al., 1993). Maturity of compost indicates the presence or absence of phytotoxic effects on crops (Komilis et al., 2011). Immature composts are usually phytotoxic (mostly due to the production of organic acids but not only) and may have a negative impact on plant growth (Epstein, 1997). Applying immature compost as soil fertilizer can inhibit seed germination, destroy roots, prevent plants from growing, decreases the oxygen concentration and redox potential and increases the mineralization rate of the organic carbon in soil (Said-Pullicino et al., 2007). Moreover, it is known that mature composts can better sustain the biological pest control, while immature composts can't (Ling et al., 2010). Applying incompletely decomposed waste or non-stabilized and immature composts on soils may lead to immobilization of nutrients necessary for plants and can cause phytotoxicity that can be defined as a delay in seed germination, an inhibition of plant growing or any other adverse effect caused by specific substances (phytotoxins) or inappropriate growing conditions (Baumgarten & Spiegel, 2004).

Stability and maturity of compost cannot be established by a single parameter (Bernal et al., 2009). Moreover, due to the variation of materials and composting technologies, it can't be available one single method to appreciate the compost stability and maturity (Benito et al., 2003; Chang & Chen, 2010). Thus, several methods and tests were proposed to evaluate these two compost quality properties (Epstein, 1997; Aslam et al., 2008; Azim et al., 2018): empirical methods, such as appearance, color, smell, granulometry, texture, temperature (Jimenez & Garcia, 1989); physical techniques, such as self-incineration after moisturizing (Brinton et al., 1995), respirometric methods (Barrena Gomez et al., 2005; Tremier et al., 2005; Scaglia & Adani, 2008) and sieving tests; physical and chemical analyses, such as moisture, KCl pH (Avnimelech et al., 1996), C/N ratio (Jimenez & Garcia, 1989) and the NO_3^-/NH_4^+ ratio, humification index (humic acids/fulvic acids ratio) (Veeken et al., 2000; Jouraiphy et al., 2005; Huang et al., 2006), water-soluble carbon concentration, dissolved organic carbon (Zmora-Nahum et al., 2005); colorimetric and spectroscopic methods (UV-Visible, Fluorescence), FTIR - Fourier transform infrared, NMR - Nuclear Magnetic Resonance) (Lim & Wu, 2015); biological studies on plant growing (Said-Pullicino et al., 2007; Cesaro et al., 2019).

There are also several phytotoxicity tests used for the estimation of compost maturity as follows: germination tests (including root assessments) (Zucconi et al., 1985), growth tests (assessment of top-growth and sometimes root mass), germination and growth combinations, and other methods such as enzyme activities (Herrmann & Shann, 1993). Germination tests indicates an instant degree of phytotoxicity, while growing tests will be affected by the changes in the stability or maturity of the compost tested: in the early stages there may be damaging effects on growth and beneficial effects later, with different conclusions depending on the time of assessment (Zucconi & Bertoldi, 1987).

This study was conducted in order to complete the master studies and is a small part of a research regarding the quality of different types of compost that could be used as soil amendments. This paper focus on the assessment of compost phytotoxicity using some empirical methods, physical and chemical parameters, seed germination test and plant growth tests. The compost originated from an aerobic treatment of organic fraction of municipal solid waste.

MATERIALS AND METHODS

Composting materials and compost production

The compost was produced by classical method of mechanical aerated piles within the Covasna-Boroşneu Mare Integrated Waste Management Centre. The municipal solid wastes were not selected at source but within the Waste Management Centre which is a hard and expensive process. The organic substrates for composting were: vegetal waste resulted from urban parks, pruning of trees and shrubs, gathering of tree and shrub leaves, grass clippings and organic materials, food waste from households. The composting material was arranged in prismatic shaped piles, aerated using a machine and sprinkled with leachate diluted with water in order to ensure moisture. The composting process lasted 5 months. Samples of compost were taken in plastic bags, from eight different places of the compost pile. All these samples were mixed and homogenized into a final sample of approx. 40 l. Then, the compost was sieved out using different sieves and various granulation compost were obtained: fine granulation, <8 mm, about 50%, medium granulation, 8-20 mm, about 40% and high granulation, over 20 mm, about 10%). At the end, the compost with fine granulation (<8 mm) was sieved out using sieves with about 4 mm holes. Thus, from the 40 l compost sample, around 5-6 liters with granulation of 0-4 mm were obtained and used afterwards in the experiments.

The compost physical and chemical characteristics were analyzed within the Laboratory for Soil Pollution and Rehabilitation of the Research Institute for Pedology and Agrochemistry of Bucharest. For this study, no metal analysis were provided.

Compost quality evaluation

In this study, for compost quality assessment we used (i) empirical methods (appearance, colour, smell, granulometry, temperature), (ii) physical and chemical analysis (bulk density, moisture, pH, C/N ratio, total N content), (iii) seed germination test and (iv) plant growth tests.

Empirical methods

The compost was analyzed at the end of the composting process regarding the appearance, color, smell, granulometry and the temperature.

Physical and chemical analyses

Several physical and chemical analyses of the compost were done: moisture; dry matter (gravimetric analyses); total forms of mineral elements: wet mineralization (H_2SO_4+H_2O_2) using HACH Digesdahl method; distillation and dosing of nitrogen (N) using Kjeldahl method; dosing of phosphorus (P) was performed by spectrophotometry and the potassium content (K) was determined using the flam-photometric method; total salts content; the organic matter content was determined through dry oxidation (LOI - loss on ignition), thus measuring the calcination losses (600°C, 2 h) and then the content in total organic C was calculated by multiplying the obtained result by 0.54.

Experimental design and statistical analyses

Seed germination test design

In order to perform the germination test we used cress (*Lepidium sativum* L.) seeds and compost tea. The compost tea was produced in a vessel by mixing 1 l of compost with 1 l of distilled water (pH 6.56; EC - electric conductibility = 0.00) and left for 24 hours, in which period it was mixed a few times. The resulting juice (compost tea) was filtered and poured into a 1-liter clear glass bottle. Petri dishes with a 9-cm diameter were used, where a filter paper layer was inserted and moistened with compost tea.

There were carried out 4 treatment variants (V) in 4 replicates: V_1: 100% compost tea; V_2: 50% compost tea + 50% distilled water; V_3: 25% compost tea + 75% distilled water; V_4: 100% distilled water.

The cress sowing was done in 16th of May 2018. In Petri dishes there were sowed 50 cress seeds on filter paper layer moistened with compost tea. The seeds were placed in rows, then covered with filter paper and moistened with the compost tea prepared for each treatment variant. All Petri dishes were placed for germination at natural room temperature conditions which was 22°C ± 2°C.

The seed germination happened in 19th of May, but in the next day, the seedlings started to die. From 21st to 28th of May, each day the dead seedlings were counted (Photo 1). For each variant there was calculated the death seedlings average of the four replicates. The number of death seedlings was correlated with the number of days that passed from the germination day.

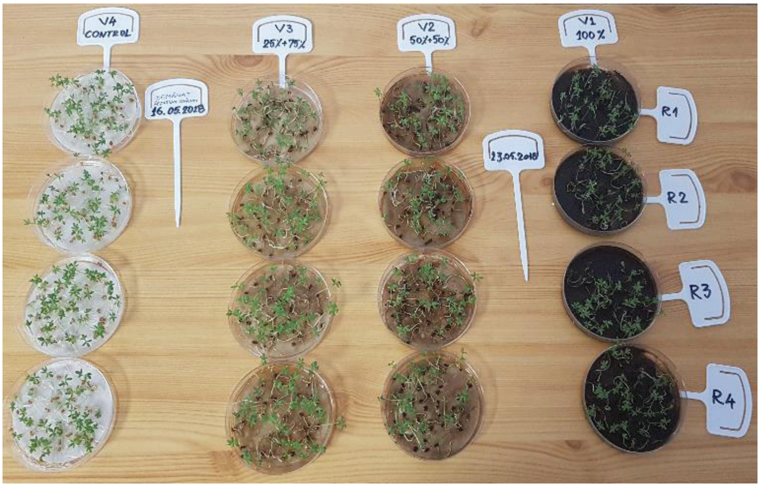

Photo 1. Cress (*Lepidium sativum* L.) seedelings in the fifth day after total germination

Plant growing tests design

For the plant growing tests there were prepared 4 treatment variants with different compost mixtures between OFMSW compost and a peat compost (Hawita Baltischer FT - Topfsubstrat): V_1 - 100% compost; V_2 - 75% compost + 25% Topfsubstrat; V_3 - 50% compost + 50% Topfsubstrat; V_4 - 25% compost + 75% Topfsubstrat. Lettuce seedlings (*Lactuca sativa* L. *var. capitata* L.) were planted on May 21, 2018 in rectangular pots of 7 x 7 x 6.5 cm. All experimental variants were made in four replicates. After planting the lettuce, the pots were watered with fresh water.

RESULTS AND DISCUSSIONS

Empirical methods

At the end of the composting process, the compost had a granular structure (Azim et al., 2018), dark brown colour and a pleasant smell, similar to recently ploughed soil, which could reveal the presence of actinomycetes in the last part of the composting process (Mustin, 1987). Also, the compost was easy to handle and the temperature was close to the ambient one or low. There was no ammonia smell and no organisms, such as arthropods, were found. However, some wood materials were found that did not decompose until the composting process was completed.

Physical and chemical characteristics

The compost physical and chemical characteristics are showed in Table 1. The bulk density of the compost was of 0.582 kg/dm^3. Typical wet bulk densities of the compost varies from 500 to 900 kg m^{-3} (Agnew & Leonard, 2003). The C/N ratio was about 16.43 which seems to be within the limits of the values reported in the scientific literature. According to Zmora-Nahum et al. (2005), composts are usually considered mature when C/N ratio is of 10-15, while Fung et al. (1999) defined as mature composts with C/N ratios of 17.5-20. Mustin (1987) stated that a compost from organic fraction of municipal solid waste, after 10 weeks, should have a C/N ratio between 18 and 19 which is in agreement with Bertoldi (1983) who reported that in mature compost the C/N ratio should be less than 20.

The compost pH was 8.67 which corresponds to the range of values from 7 to 9 that are indicated by Avnimelech et al. (1996) for the mature compost. But, in some other studies the limits between 5.5 and 8 are considered as optimal for the matter that can be composted (Bertoldi, 1983), and for an OFMSW mature compost (140 days) the pH was between 7.8 and 8.1 (Mustin, 1987; Komilis & Tziouvaras, 2009; Vázquez et al., 2015; Cesaro et al., 2019).

Table 1. OFMSW compost physical and chemical characteristics

	pH	U (%)	DM[1)] (%)	Organic carbon (%)	N-Kjeldahl (%)	P (%)	K (%)	C/N
Compost	8.67	34.62	65.38	17.26	1.05	0.30	2.21	16.43

[1)] DM: dry matter

In the case of compost tea, for each of the concentrations prepared for the proposed treatment variants of the seed germination test, the electric conductivity (EC) and the pH were analysed (Table 2). The compost tea at 100% electrical conductivity value was of 5200 µs cm^{-1} which is comparable with the values reported by Chelinho et al. (2019) for urban waste composts which were between 4300 and 6440 µs cm^{-1}. But, in many other studies there were reported low values of EC for OFMSW compost: 4220 µs cm^{-1} (Asquer et al., 2017), 3600 µs cm^{-1} (Vázquez et al., 2015), 3000 µs cm^{-1} (Zhang et al., 2018). With the dilution, the EC values dropped at 2900 µs cm^{-1} in compost tea 50% and at 1300 µs cm^{-1} in 25% compost tea.

Table 2. Chemical analyses for OFMSW compost tea mixtures and distilled water

	EC (µs cm^{-1})	pH
Compost tea 100%	5200	8.67
Compost tea 50%	2900	8.55
Compost tea 25%	1300	8.45
Distilled water	0	6.56

The compost mixtures (OFMSW compost + Hawita Baltischer FT - Topfsubstrat) were analyzed regarding the total content of salts (TSC) and the pH. As it is shown in Table 3, the compost itself has high contents of salts (0.92%) and, as result, the pH values were high (8.67). But, in the compost mixtures, the total content of salts decreased from 0.92 ms cm^{-1} at 100% compost to 0.59 ms cm^{-1} at 25% compost. The pH values decreased from 8.67 at 100% compost to 7.37 at 25% compost. Unfortunately, only the total salt content was analyzed, which does not allow us to specify what kind of salts had a higher content.

Table 3. OFMSW compost and compost mixtures chemical analysis

	Total salts content (%)	pH
Compost 100%	0.92	8.67
Compost 75% + 25% Topfsubstrat	0.84	8.39
Compost 50% + 50% Topfsubstrat	0.68	7.62
Compost 25% + 75% Topfsubstrat	0.59	7.37

Seed germination test

As already said, the cress seed germination happened in 19th of May. Unfortunately, the seedlings began to die shortly after germination. For 10 days, from 21st to 28th of May the dead seedlings were counted. As we expected, no dead cress seedling was observed in the variant with distilled water (V4). But, in all variants with compost tea, the cress seedlings have died since the first day, and over the 10 days period their number has increased. Thus, as it could be observed in the Figure 1, the highest average number of dead seedlings was recorded in V4 (100% compost tea), from 22 dead seedlings in the first day to 46 seedlings in the tenth day. In the variant with 50% compost tea (V3), the average number of dead seedling in the first day was of 19, and in the tenth day was of 39. In the variant with 25% compost tea (V3), the average number of death seedlings was lower, 14 respectively, but has grown to 37 in the tenth day. Once the time pased, the number of dead seedlings raised (Figure 2). At the end of May, in the variant with 100% compost tea, almost all cress seedlings were dead (Photo 2). However, the death of seedlings was not caused by their age but by the presence of certain substances in the growing environment. As no presence of ammonia was identified within empirical test, and the C/N ratio has a typical value for a mature compost, the phytotoxicity could be explained by the higher content of salts (Komilis and Tziouvaras, 2009). In addition, some other substances that we didn't analiyzed, such as heavy metals, organic acids (Komilis and Tziouvaras, 2009) and/or high level of biodegradable organic substances mai cause toxic responses in the test (Kapanen & Itävaara, 2001).

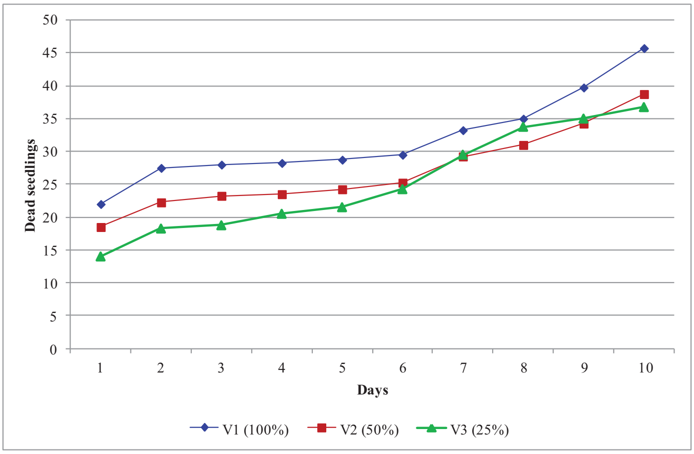

Figure 1. The daily average of cress (*Lepidium sativum*) dead seedlings

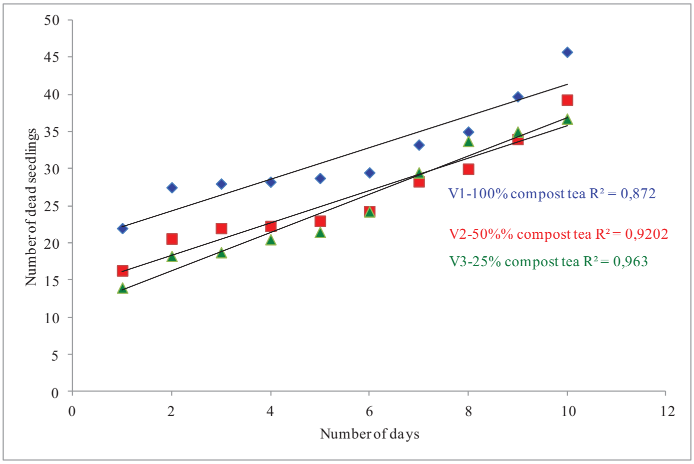

Figure 2. Correlation between number of days and number of dead seedlings of cress (*Lepidium sativum*)

Plant growing test

In the second experiment we used 40 days old lettuce (*Lactuca sativa* L.) seedlings produced on peat substrate in greenhouse (Photo 3) which were planted on May 21, 2018. The lettuce plants died 3 days after planting in the variant with 100% compost. After several days, the lettuce seedling planted in the variants with 50% and 25% compost died also (Photo 4). The most resistent to the growing support were the lettuce seedlings in the variant with 25% compost. Most likely the total soil salts content was very high, and the lettuce being a salts sensitive plant that could be the cause of which the plants suffered and finally died.

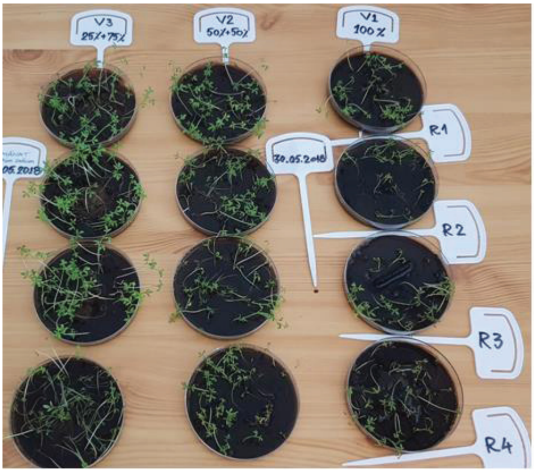

Photo 2. Dead cress (*Lepidium sativum*), seedlings in 30 of May 2018

Photo 3. Lettuce (*Lactuca sativa* L.) seedlings before planting

Photo 4. Dead lettuce (*Lactuca sativa* L.) seedlings after planting (from 21 to 30 of May 2018)

CONCLUSIONS

The composting process is considered a suitable waste management method and the most environmentally friendly technology. For a good compost quality, composting process must be conducted with the respect of some important parameters (substrate mixture, C/N ratio, temperature, aeration, humidity etc.). To be used as soil fertilizer, the OFMSW compost must be characterized by two essential properties, i.e maturity and stability. Using an incompletely decomposed waste or non-stabilized and immature composts on soils may lead to immobilization of nutrients necessary for plants and can cause phytotoxicity that can be defined as a delay in seed germination, an inhibition of plant growing or any other adverse effect caused by specific substances or inappropriate growing conditions. For the assessment of compost maturity different parameters and methods should be used.

In this study there were used some empirical methods, physical and chemical analysis, seed germination test and plant growth tests in order to assess the compost maturity. Empirical methods are not enough, and chemical analyzes should be extended to different substances that can be found in waste or that can be formed during the composting process which can have phytotoxic effects on plants. In addition, for a good compost quality, a proper separation at the source of the waste and a differentiated collection are required.

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