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THE INFLUENCE OF THE COMPOSTING METHOD AND THE PLANT BIOMASS ADDITION ON COMPOST QUALITY

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Abstract

Home composting could be proposed in order to improve the management of organic fraction of municipal solid waste (OFMSW) or biowaste especially in rural areas. In addition, different wild plants biomass with some ecological properties may be added as raw material, bulking agent and compost quality improver during composting. In order to assess the compost quality obtained in such conditions, a study in four small boxes (1.2 m x 0.8 m x 1.0 m.), made from local materials (wood and mesh from raffia), was carried out for a period of four months. A quantity of 550 ± 5 kilo of different precomposted OFMSW was introduced in each box. The compost was manually aerated with a fork two times per month. The compost temperature was registered daily by soil thermometers. In the 2nd month of the composting period, 10 kilos of fresh nettle (Urtica dioica L.) was added in one of the boxes. For compost quality assessment there were made chemical and physical analysis, maturity tests and microbiological analysis in order to identify the presence of pathogens.

***Key words**: biodegradable waste, compost, home composting, maturity, germination index.*

INTRODUCTION

According to the framework waste legislation (Directive 2008/98/EC), since 2018, all urban and rural Romanian communities have been connected to centralized solid waste collection and management system services that are based on an integrated, hierarchical system, with waste prevention as the highest priority. Large amounts of municipal solid waste are collected daily.

One of the objectives of the Romanian National Waste Management Plan (NWMP, 2017) is to reduce the municipal biodegradable waste disposal, with a target for 2020 of 35% of the total amount produced in 1995. Also, separate waste collection is a permanent goal, and the agricultural use of products resulting from the treatment of biowaste by composting and/or anaerobic digestion is strongly encouraged (NWMP, 2017). In this regard, there is a growing interest of the Integrated Waste Management Centers (IWMC) in composting the organic fraction of municipal solid waste (OFMSW). But the large quantities of Organic Household Waste (OHW) that are source-separated at home and collected weekly in many rural areas could be composted at home and not transported away for treatment. The combined option of source-separated biodegradable waste and home composting may be seen as a valuable prevention action that contributes to reducing the generation of household waste (Puyuelo et al., 2013; Tatàno et al., 2015) and promoting the active participation of citizens in waste management and in the development of a self-management of organic waste (Ballardo et al., 2020) with low environmental impacts regarding emissions of greenhouse gases (Andersen et al., 2012; Ermolaev et al., 2014) that may reduce the operational waste management cost (Puyuelo et al., 2013) of rural communities. In addition, in the long run, the construction of landfills will affect smaller areas, and the sustainability of that process, as well as the environment resilience, will increase.

Composting the organic fraction of municipal solid waste (OFMSW) or biowaste is one of the most environmentally friendly technologies

(Barrena et al., 2014). It gained an important role in municipal solid waste management worldwide, and the compost may be used as soil conditioner as well as fertilizer. In order to provide crops with both nutrients and organic matter, it must be of high quality. But industrial composting requires high costs for building platforms, providing equipment, ensuring selective collection of waste and guaranteeing environment protection conditions. Therefore, especially in rural areas, home composting presents some potential benefits such as the avoidance of collection and transportation of biowaste (Barrena et al., 2014; Faverial and Sierra, 2014; Vázquez and Soto, 2017).

Home composting has been traditionally used in Romania, especially for manure and garden waste co-composting in the small family farming or in horticulture. But composting of organic household waste is less common. For villages, it can be much more attractive and sustainable to adopt home composting, especially where people have large gardens and can use compost for landscaping or for the production of fruits and vegetables for own consumption. Adopting composting of own organic waste can reduce the overall household waste management costs of communities, hold people responsible for waste production, and help increasing the sustainable use of resources.

The objective of this research was to evaluate the quality of the OFMSW compost produced in experimental conditions, and of the OHW compost produced in home composting natural conditions. For this objective, physico-chemical analyses were conducted, and a seed germination test was carried out.

MATERIALS AND METHODS

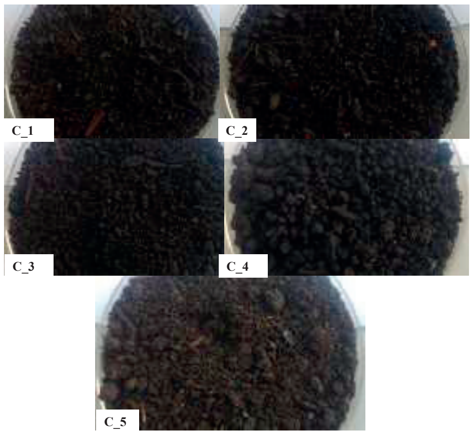
This section aimed to describe the composting facilities, the sampling methods and the analyses (Pictures 1 and 2).

Four compost were produced from organic fraction of municipal solid waste collected from an Integrated Waste Management Center. The OFMSW were in different stages of early composting at the collection time. During composting, the substrates were manually aerated with a fork, two times per month, the temperature was monitored daily using a thermometer and some bulking agent (dehydrated nettle plants) were added in box 2, one month after composting had started (the objective of this addition is not presented in this work).

1- Wood composting box lined with raffia mesh.
2- The four wood boxes loaded with the compost substrate.
3- Thermometers used for temeperature control.
4- Dehydrated nettle plants.

Picture 1. Facilities and compost production

One organic household waste compost was produced in rural natural aerated pile conditions for one year.



Picture 2. C_1, C2, C3 and C_4 - OFMSW compost, and C_5 - OHW compost used in the study

Physico-chemical analyses of compost were conducted within the soil pollution control laboratory of the Research Institute for Pedology and Agrochemistry in Bucharest. Moisture and dry matter were determined by gravimetric method. The pH was determined through the potentiometric method in 1/5 aqueous suspension. The total forms of mineral elements were determined by wet mineralization (H_2SO_4+H_2O_2) using the HACH Digesdahl method. The total nitrogen (N) was determined using the Kjeldahl method; the total phosphorus (P) was determined by spectrophotometry and the potassium content (K) was determined using the flam-photometric method; the total salt content and the electrical conductivity (EC) were determined using Romanian standard methods (STAS 7184/7-87, STAS 7184/12-88 chapter 2.1.6. and chapter 2.1.7; PTL 18); 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. The heavy metals were determined through atomic absorption spectrometry in hydrochloric solution after the mineralization of the samples with strong acids. Laboratory methodology was used.

Samples of each compost were prepared for microbiological analyses. From each sample, 10 grams of compost were mixed with 50 ml of distilled water that was sterilized. The mix was stirred for 1 hour, and after that it was placed for 1-2 hours for sedimentation. Dilutions were made from the supernatant (- 2) and the Compact Dry discs were sown according to the manufacturer's instructions. Compact Dry discs were used to identify and quantify: *E. coli* and coliforms and *Salmonella*. The samples were incubated for 24 hours at the temperature specified by the manufacturer Compact Dry.

For phytotoxicity tests, a compost extract was prepared using 100 g of each compost and 150 ml of distilled water.

The experiment was set up on 2.03.2020 in 6 variants, and for each variant 4 replicates were performed. The germination test was made with cress (*Lepidium sativum*) seeds.

Picture 3. Compost extract

The compost extract was obtained by mixing a 100 g sample of compost with 110 ml of distilled water. The mixture was well stirred and left to rest overnight. The next day, the mixture was centrifuged for 15 minutes at 6000 rotations/minute. After centrifugation, the supernatant (Picture 3) was no longer passed through filter paper, but was pipetted and placed in the test tubes.

A filter paper with a 100 mm diameter was inserted in the Petri dishes and 25 cress seeds were placed on it. In each Petri dish, 5 ml of supernatant was added over the seeds. A control variant with distilled water was prepared. All variants were prepared in four replicates.

The Petri dishes (Picture 4) were inserted in the incubator at 25°C for 48 hours. After 48 hours, the number of germinated plants for each variant and replicate was registered, the length of the radicles was measured and the germination index was calculated according to the formula proposed by Gariglio et al., 2002:

$$GI\ \% = G/G_0 \times L/L_0 \times 100, \quad (1)$$

where:

GI % = germination index;

G = the number of plants that germinated in the compost extract;

G_0 = the number of plants that germinated in the distilled water;

L = the average length of the radicles in the compost extract;

L_0 = the average length of the radicles in the distilled water.

Picture 4. Germination test

RESULTS AND DISCUSSIONS

The physico-chemical characteristics and the key nutrient content analyzed in the compost samples are presented in Table 1. The pH values of compost ranged between 7.39 (C_1) and 8.17 (C_2). Mature compost should have pH values between 6 and 8 (Mustin, 1987; Zmora-Nahum et al., 2007; Papadopoulos et al., 2009; Barrena et al., 2014; Zhang et al., 2018; Cesaro et al., 2019). According to the Italian Regulation for compost classification (Legislative Decree n. 75/2010 cited by Cesaro et al., 2019), the threshold limits for pH values are 6 and 8.5. Considering the $N\text{-}NH_4^+/N\text{-}NO_3^-$ ratio values, two of our composts (C1 - OFMSW and C5-OHW) fall into the "very mature" category, and the other three (C2, C3 and C4 - OFMSW) in the "mature" category (Brinton, 2000).

All five composts were characterized by high contents of N, P, K. Thus, the total N content ranged between 1.04% (C_5) and 1.61% (C_3), the total P content ranged between 0.35% (C_1) and 1.14% (C_4), and the total K content ranged between 1.48% (C_5) and 2.89% (C_2). These values are related to the dry matter. According to Mustin (1987), the mature compost (140 days), obtained from urban household wastes, could have a total N content between 0.85% and 1.1% of the dry matter, a total P content between 0.2% and 0.35% of the dry matter and a total K content between 0.25% and 0.40% of the dry matter. Recent studies (Vázquez et al., 2015) reported total N content of 1.3% and 2.0% in composts that were obtained from organic wastes collected in a decentralized way. The same authors reported total P content between 0.49% and 0.53%, while the total K content ranged between 1.30% and 1.80%.

The five tested composts had Ca contents between 1.18% (C_1) and 3.39% (C_2) of the dry matter, which is according to the values reported by other authors (Mustin, 1987; Vázquez et al. 2015). Also, the total Mg content ranged between 0.53% (C_1) and 0.82% (C_2). According to Mustin (1987), the total Mg contents of the mature compost obtained from OFMSW should range between 0.25% and 0.40% of the dry matter. Relatively similar values were also reported by Vázquez et al. (2015).

The values of electrical conductivity (EC) and salt content of the composts are presented in Table 2. The EC values of the composts resulted from OFMSW ranged from 2090 μS/cm for C_4 to 4330 μS/cm for C_2. In fact, the value registered for C_2 is more than twice as high as the one registered for C_3 and C_4. The compost resulted from OHW (C_5) has an EC value of around 2660 μS/cm, which is relatively similar to C_3. Unlike other types of organic wastes, OFMSW tends to lead to a compost with high salt content, and the EC can exceed the threshold of 4000 μS/cm (Lasaridi et al., 2006). Zhang et al. (2018) point out to the EC increase of the compost resulted from co-composting of sewage sludge mixed with OFMSW. As OFMSW increases, the EC also increases, reaching 3200 μS/cm when the OFMSW share is of 85%. Barrena et al. (2014) reported an average EC value of 7200 μS/cm in the industrial compost obtained from OFMSW, unlike the home compost, which had an average value of 3900 μS/cm. The composts obtained from the biodegradable fraction of the municipal wastes, even if the wastes are source separated, can present high levels of inorganic salts compared with other substrates (Barrena et al., 2014). This may be due to a high degree of decomposition of the organic matter, especially rich in protein, which leads to the accumulation of various water-soluble salts (Barrena et al., 2014; Zhang et al., 2018). The plants are negatively affected by the excess of salts in the soil, and sodium (Na) can be harmful to the soil structure (Hargreaves et al., 2008). Thus, EC determination is necessary before establishing and applying some compost doses obtained from OFMSW in crop cultivation, because a high salt content, respectively an EC with high values, can lead to toxic effects when too high doses of compost are used.

Heavy metal concentrations of analyzed compost samples are presented in Table 3. The heavy metal content of the five studied compost samples was below the values established by the German Standards for this kind of compost, except for zinc (Zn) content. The compost produced under natural conditions from source separated organic household waste (C_5) had the lowest content of heavy metals, and cadmium (Cd) was not detected. One of the four OFMSW compost (C_2) had the highest content of Zn (705.0) mg kg^{-1}, compared with 500 mg kg^{-1}, which is the German standard (Brinton, 2000).

Table 1. Physico-chemical characteristics and key nutrient content analyzed in compost samples

Sample	pH	H_2O (%)	MO (%)	C_{org} (%)	N (%)	Ratio C/N	$N\text{-}NH_4^+$ (mg/kg)	$N\text{-}NO_3^-$ (mg/kg)	Ratio $N\text{-}NH_4^+/N\text{-}NO_3^-$	P (%)	K (%)	Ca (%)	Mg (%)
C_1	7.39	52.53	25.08	9.60	1.12	8.55	153	494	0.310	0.35	1.82	1.18	0.53
C_2	8.17	51.68	38.59	14.30	1.41	10.14	163	937	0.174	0.99	2.89	3.39	0.82
C_3	7.63	46.81	35.36	15.04	1.61	9.34	166	332	0.500	0.97	1.77	2.21	0.62
C_4	7.94	47.24	36.78	13.98	1.52	9.20	168	218	0.771	1.14	2.10	2.64	0.62
C_5	8.00	44.64	24.83	9.71	1.04	8.82	86	910	0.095	0.46	1.48	3.11	0.80

Table 2. Salt content of analyzed compost samples

Sample	CO_3^{2-} (mg)	HCO_3^- (mg)	SO_4^{2-} (mg)	Cl^- (mg)	Ca^{2+} (mg)	Mg^{2+} (mg)	Na^+ (mg)	K^+ (mg)	EC (µS/cm)	Cdt.* residue (mg)	Mineral residue (mg)
C_1	3.6	127	121	202	15	10	41	435	2690	1138	954
C_2	6.6	224	488	299	27	18	116	855	4330	2237	2033
C_3	4.5	113	133	151	17	8	47	343	2150	945	817
C_4	4.5	175	116	157	17	5	42	368	2090	925	884
C_5	3.0	144	215	135	27	15	30	529	2660	1414	1099

*conductometric residue

Table 3. Heavy metal concentration of analyzed compost samples (mg/kg dm)

Sample	Cd	Cu	Cr	Co	Ni	Pb	Zn
C_1	0.76	50.7	70.0	13.3	21.6	27.1	415.0
C_2	1.56	131.1	63.7	11.0	25.3	29.7	**705.0**
C_3	1.45	107.4	110.2	12.6	22.8	31.4	460.0
C_4	0.67	117.3	147.9	12.9	19.0	25.9	433.0
C_5	nd*	34.5	34.7	9.9	19.9	10.5	351.0
German standards[1]	3.0	150.0	150.0	-	50.0	150.0	500.0
Spanish[2] limits for: class A class B class C	0.7 2.0 3.0	70.0 300.0 400.0	70.0 250.0 300.0	na** na na	25.0 90.0 100.0	45.0 150.0 200.0	200.0 500.0 1000.0
European Commission 2006 (Eco-label)[3]	1	100	100	-	50	100	300

*not detected; ** not available

[1] Heavy Metal Content in MSW vs. Source-Separated Compost in Relation to Standards (Source: Kraus & Grammel., 1992 in Brinton, 2000)

[2] Limits for Classes A, B and C in Spanish legislation RD 506/2013 (in Vázquez et al., 2017).

[3] European Commission, 2006. Commission Decision of 15 December 2006 establishing revised ecological criteria and the related assessment and verification requirements for the award of the Community eco-label to growing media. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32007D0064 (in Vázquez and Soto, 2015).

Compared to the limit values of the heavy metals content in the compost, for the compost quality classes A, B and C mentioned in the Spanish legislation (Limits for Classes A, B and C in Spanish legislation RD 506/2013 cited by Vázquez et al., 2017), none of the studied composts can be included in class A because of the high levels of Zn. Even C_5 had a content of 351.0 mg kg^{-1} compared to 200, which is the limit for the Zn in the Spanish A class. But, the heavy metals contents registered in the analyzed samples from the compost obtained from household organic wastes (C_5) are below the levels indicated by the European Commission Decision of 15 December 2006 establishing revised ecological criteria and the related assessment and verification requirements for the award of the Community eco-label to growing media. In these conditions, it can be applied on agricultural soils in quantities of up to 30 t/ha per year of dry matter (Vázquez et al., 2015).

Salmonella spp. and *Escherichia coli* (*E. coli*) are commonly used indicator species for human and animal pathogens (WRAP/PAS 100:2011).

Table 4. Compost sample pathogen analysis results

	Compost sample	CFU/10 g
Salmonella	C1	Nd
	C2	Nd
	C3	Nd
	C4	Nd
	C5	Nd
Italian Regulation for compost classification, Legislative Decree n. 75/2010 (in Cesaro et al., 2019)		Absent/25 g
WRAP/PAS100:2011 (upper limit)		Absent/25 g
		CFU/10 g
E. coli and coliforms	C1	$0,35x10^3$
	C2	$0,65x10^3$
	C3	Nd
	C4	Nd
	C5	$0,45x10^3$
Italian Regulation for compost classification, Legislative Decree (in Cesaro et al., 2019)		1000-5000/g
WRAP/PAS 100:2011 (upper limit)		1000/g

The results of the microbiological analyses (Table 4) revealed that thermophilic temperatures were not reached during any of the composting methods applied to the studied composts, which in fact was also reported by other authors (Barrena et al. 2014). In these conditions, the microbiological analyses indicated the presence of *E. coli* and coliforms in three of the composts, but their level was below the maximum thresholds allowed by various regulations (Wrap/PAS 100:2011; Italian Regulation for compost classification, Legislative Decree n. 75/2010). *Salmonella* was not detected in any of the composts. However, taking into consideration the presence of *E. coli*, in order to ensure a good hygiene of the compost, the conditions for reaching the thermophilic temperature must be ensured during composting.

The germination index (GI) had values over 60, which is the minimum threshold allowed by the Italian legislation, i.e. the lowest value was of 67.87% at C_2 and the highest value was of 83.89% at C_4. C_5 had a germination index of 70.5% (Figure 1). Similar values were also reported by other authors (Cesaro et al., 2019).

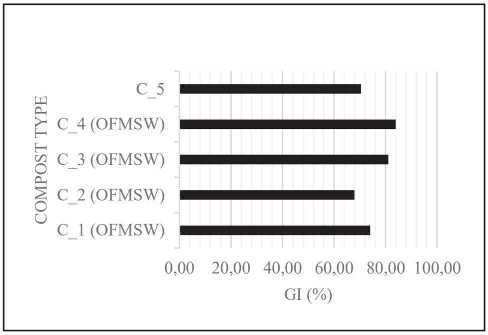


Figure 1. Germination index of five composts

CONCLUSIONS

According to the pH values, the $N\text{-}NH_4^+/N\text{-}NO_3^-$ ratio, the germination index and the microbiological indicators values, all composts used in this study reached the maturity. A more efficient separation of organic waste could prevent the presence of heavy metals, and for a good hygiene of the compost it should be possible to ensure thermophilic temperatures. In addition, home composting can be encouraged in rural areas where separation at source is more efficient.

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