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COMPOST QUALITY AND NITROGEN MINERALIZATION DYNAMICS DURING THE MATURITY STAGE OF LAVENDER WASTE COMPOST

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Abstract

The interest of Romanian small farmers in lavender cropping is increasing. Many of them have also developed lavender processing lines so that the small industry around this species is growing. Additionally, the amounts of generated waste have also increased, but many arguments support the composting of this waste: good management of organic matter in the circular economy, identification of beneficial effects of compost, other than those known about composts obtained from biodegradable waste, etc. In our studies we composted lavender waste together with manure from small ruminants (sheep and goats). Both lavender waste and manure were collected from several small farms in Southern Romania, and the composting process was carried out in a system of 3 paddocks within also a small ecological farm. In addition to the evolution of the composting process and its parameters, the dynamics of nitrogen mineralization were analyzed. The compost reached the stage of maturity after 4 months of composting, and during the maturation the dynamics of nitrogen (N) mineralization were evaluated, and the physicochemical properties and the phytotoxicity of the resulting compost were also analyzed.

Key words: *compost, compost maturity, lavender, nitrogen mineralization dynamics.*

INTRODUCTION

In general, the production of organic waste is growing and the need to dispose it ecologically is increasing. Transforming this waste into organic fertilizer through composting is the most successful system used until now (de Bertoldi et al., 1983).

Composting can be viewed as the sum of complex metabolic processes carried out by different microorganisms that, in the presence of oxygen, use available nitrogen (N) and carbon (C) to produce their own biomass. In this process, additionally, the microorganisms generate heat and a solid substrate, with less carbon and nitrogen, but more stable, which is called compost (Roman et al., 2015; Azim et al., 2018). Mature composts obtained from organic waste can be used to increase soil fertility by improving their physical, chemical and biological properties, making it possible to reduce the consumption of synthetic fertilizers (Reimer et al., 2023). Besides, composts can be applied without potential danger for soils (González-Prieto, 1993).

Studies have also shown that repeated application of composted organic matter to cropland led to an increase of the microbial biomass and enzymatic activity. Long-lasting application of organic fertilizers increased organic carbon by up to 90% versus unfertilized soil, and up to 100% versus chemical fertilizer treatments. Repeated application of composted materials enhances soil organic nitrogen content by up to 90%, storing it for mineralization in future cropping seasons, often without inducing nitrate leaching to groundwater (Diacono et al., 2011).

Some authors have shown that compost application to soil resulted in an overall low nitrogen efficiency, partially due to a lack of synchronization between plant nitrogen demand and soil nitrogen release (Erhart et al., 2005; Lehtinen et al., 2017; Reimer et al., 2023). However, it has been also shown that, in the spring, the soils fertilized with compost have a higher mineral N content (Erhart et al., 2005; Tits et al., 2014; Reimer et al., 2023). Therefore, it is necessary to know the availability of nutrients, and especially N in compost, to come up with strategies to meet the nutrient needs of crops, and at the same time to protect the environment (Hartl et al., 2001).

There are many studies on nitrogen mineralization in e compost-fertilized soils, but fewer on nitrogen mineralization during the composting process. Thus, in this paper we will present some results obtained in a first study that we proposed to carry out in order to follow the mineralization of nitrogen during the maturity period of the compost.

MATERIALS AND METHODS

Composting materials and experimental design

The experimental site was located in Pelinu village, in Călărași county, which is in the South-East part of Romania (44°27′46″N 27°0′48″E). The climate of the region is temperate continental with a homogeneous regime, characterized by very hot summers and relatively cold winters. In 2021, the average annual temperature was 12.5°C, and annual precipitation was 712.8 mm (INS, 2023).

The raw materials for composting were undistilled lavender flower stalks (*Lavandula angustifolia* Mill.) and biomass resulting from the distillation process, and sheep and goat manure. Lavender waste was collected from several farms in Ialomița County and Călărași County, Romania, and sheep and goat manure was collected from two different farms in Călărași County, Romania. The experiment was established in November 2023. Three compost piles were made inside some paddocks (Photos 1, 2 and 3), each one with different mixture. The composting process took place for 4 months. The compost recipes were: C1: ±33% (kg/kg) sheep manure, ±33% (kg/kg) goat manure, and ±33% (kg/kg) wheat straws; C2: ±33% (kg/kg) sheep manure, ±33% (kg/kg) goat manure, and ±33% (kg/kg) distilled lavender stalks, and C3: ±33% (kg/kg) sheep manure, ±33% (kg/kg) goat manure, and ±33% (kg/kg) undistilled lavender biomass.

The composts temperature was measured every 3 days during the composting, and the piles were manually turned periodically during which the moisture was evaluated and completed to.

Photo 1. C1 – sheep and goat manure and wheat straws

Photo 2. C2 – sheep and goat manure and distilled lavender stalks

Photo 3. C3 – sheep and goat manure and undistilled lavender biomass

Phytotoxicity evaluation assay

There are several methods (chemical, physical and biological) that have been developed, by different authors, for compost maturity assessment (de Bertoldi et al., 1983; Peña et al.; 2020). Phytotoxicity test is one of the sensible methods used to evaluate the compost that will be used as soil fertilizer (de Bertoldi et al., 1983).

In order to assess the maturity of our composts, a laboratory incubation experiment was designed following the methodology slightly adapted from that proposed by some authors. The phytotoxicity level for all 3 compost recipes was evaluated in day 138 and the day 156 from the initiation of the composting process.

Compost samples were mixed with distilled water (1:10 weight/volume ratio - 10 g sample of compost and 100 mL distilled water) (Tiquia et al., 1997; Walter et al., 2006; Barral & Paradelo, 2011), the mixture was homogenized for 10 min and left to rest for 24 h. The aqueous extract was passed through a filter paper, and from each filtrate were extracted 3 tubes of 12 mL which were centrifuged at 4000 rpm for 20 min. In Petri dishes (94 mm diameter) with filter paper as support laid previously, it was added 4 ml of each compost solution obtained (Charles et al., 2011) and 20 seeds of garden cress (*Lepidium sativum* L.) (Tiquia et al., 1997; Barral & Paradelo, 2011; Cesaro et al., 2019) were spread (Photo 4). The experiment was done in 3 replicates for each compost (Tiquia et al., 1997; Barral & Paradelo, 2011; Cesaro et al., 2019). For control, another set of 3 replicates were made (Charles et al., 2011), applying distilled water instead of the filtrate. All 12 plates were placed for 48 h at 25°C in the incubator (Walter et al., 2006; Miaomiao et al., 2009; Barral & Paradelo, 2011; Cesaro et al., 2019). Finally, the number of germinated seeds was recorded, and the root length was measured (Photo 5).

Germination index (GI%) was determined by counting the average root length (RL) as well as the average number of germinated seeds (GR) in every sample and comparing with the control treatment. The GI% was calculated using the equation (Cesaro et al., 2015):

$$GI\% = 100\,x\,\frac{number\ of\ germinated\ seeds\ in\ extract\ x\ root\ length\ in\ extract}{number\ of\ germinated\ seeds\ in\ control\ x\ root\ length\ in\ control}$$

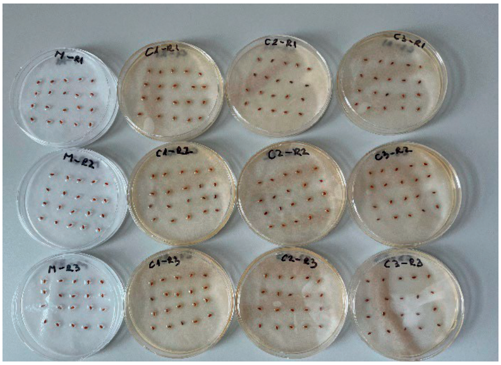

Photo 4. Garden cress (*Lepidium sativum* L.) seeds before incubation

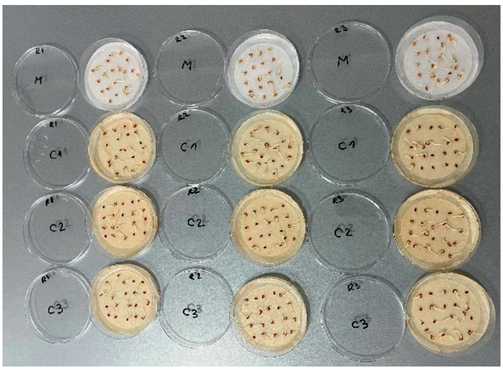

Photo 5. Garden cress (*Lepidium sativum* L.) seeds after incubation

Laboratory analysis of nitrogen

After 78 days since the compost piles were made, over a period of 3 months, samples were taken from all 3 piles, in days 78 - 92 - 104 - 118 - 132 - 146 - 174. From each pile were taken 3 samples of 1 kg each (total of 9 samples) which were analyzed for humidity, mineral N (NO_3^--N and NH_4^+-N), total nitrogen (N_t) and total carbon (C_t). The NO_3^--N was determined potentiometrically according to ICPA (1983), NH_4^+-N was determined through distillation according to ICPA (1981), and N_t and C_t were determined using a Vario MACRO Cube elemental analyzer.

The data were processed as the average of the 3 replicates, and the graphs were developed in Excel/MS Office.

RESULTS AND DISCUSSIONS

Composting process

The temperature of the four composts raised significantly in the first week (Figure 1), especially for C2 (sheep and goat manure and distilled lavender stalks) reaching 41°C, standing out the beginning of the thermophilic phase, which was followed by the cooling phase, when the temperature decreased rapidly until 4°C for C1 (sheep and goat manure and wheat straws) and the maturation phase, with temperature among 20 and 10°C (values similar with the outside temperature) (ICPA, 2016).

A standard composting process can be divided into four phases: the mesophilic phase, the thermophilic phase, the cooling phase, and the maturity phase (Ishii et al., 2000; Waszkielis et al., 2023). The duration of each phase is determined by process conditions, the composition of the raw materials, moisture content, temperature, aeration rate and oxygen availability (Waszkielis et al., 2023). In this experiment, the variation in temperature were observed and used as an indicator of transition between the composting phases.

Composting temperature is the result of the microbial activity, which can directly affect the decomposition of the organic matter (Kaiser, 1996; Tang et al., 2011; Peng et al., 2022). Generally, the temperature in compost rises immediately after piling and decreases drastically by turning (Zucconi et al., 1981; de Bertoldi et al., 1983; Kato et al., 2005; Qian et al., 2014) with a continuous variation until the composts reaches the maturity phase. Even though studies shown that high thermophilic temperature can be difficult to reach without adding composting additive (Liao et at., 2017; Peng et al., 2022; Ansari et al., 2023), no additional materials were used for this experiment.

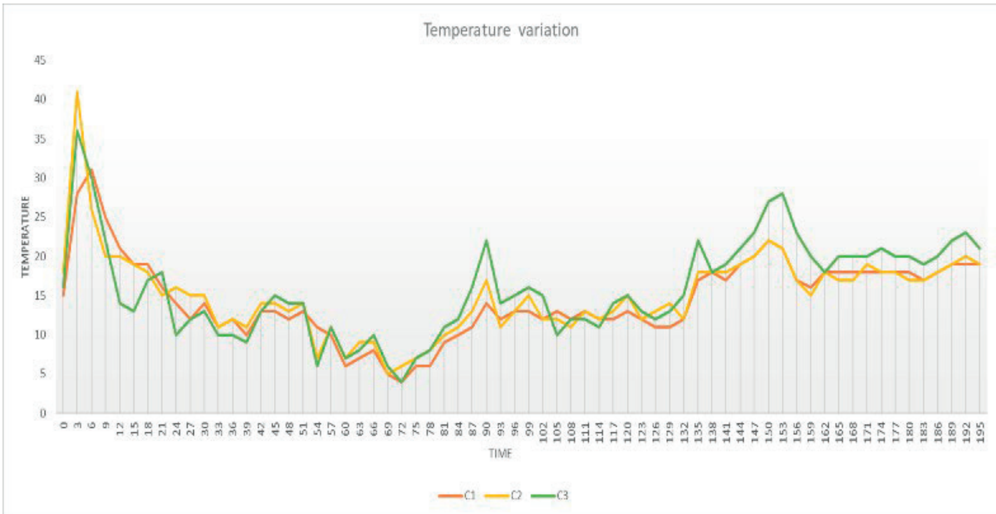

Figure 1. Temperature of C1, C2, C3 during the evaluation period

The humidity of our piles, during the analysis period, varied in the optimum range of 45% and 50% (Razmjoo et al., 2015; Azim et al., 2018), as followed: 51% and 57% for C1, 50% and 55% for C2, and 42% and 52% for C3 (Figure 2).

This is an indicator that the humidity was not a limiting factor for the composting process in this case, considering that the bacterial activity is limited when humidity is less than 30%, and humidity above 65% is decreasing the porosity of the compost resulting in an anaerobic growth and unpleasant odor emissions (Razmjoo et al., 2015; Azim et al., 2018).

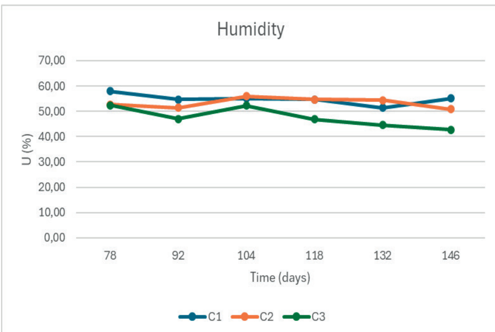

Figure 2. Humidity of C1, C2, C3 during the evaluation period

Optimum humidity during composting is hard to obtain, especially when composting outdoors. In practice, this issue is often solved by monitoring the temperature which can be a good indicator of the proper moment for the turning and watering the piles (Tiquia & Tam, 1998; Azim et al., 2018).

Phytotoxicity evaluation of compost extracts

The GI% for all 3 composts are shown in Table 1, and it can be seen that there were variations of the GI% both between the 3 types of compost, as well as between the 2 tests performed 18 days apart, however none of the composts presented phytotoxicity. As it is shown by Ravindran et al. (2017) and Milon et al. (2022), a GI% level of less than 50% indicates mild phytotoxicity, 50-80% indicates modest phytotoxicity, and >80% demonstrates no phytotoxicity.

Table 1. Germination index (GI %) for all 3 composts

	C1	C2	C3
Day 138	101%	86%	91%
Day 156	81%	80%	103%

The lowest values registered in all 3 composts were in C2 (80% and 86%), but these values reveal, however, the absence of phytotoxicity. During a peak of temperature of the compost, the toxicity of C3 increased and the toxicity of C1 and C2 decreased. This could be attributed to the biological degradation processes during the maturity stage, as there was still a residual amount of organic matter susceptible to decomposition (Cesaro et al., 2019).

Nitrogen dynamics

The N_t varies between 1.86% and 2.79% for all 3 composts (Figure 3), which is accordance with what was found by other authors who stated that the N_t can vary between 1% and 4% of the total dry matter weight of compost (Hirai et al., 1986; Willson, 1989; Kapetanios et al., 1993; Canet & Pomares, 1995; Bernal et al., 1998, Brinton & Evans, 2000; Azim et al., 2018).

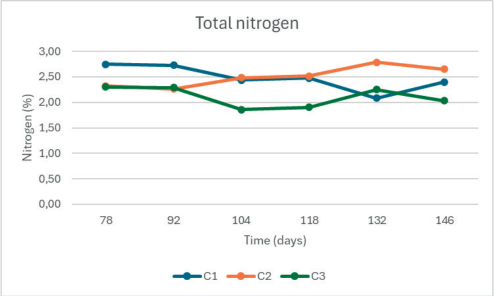

Figure 3. Changes in total nitrogen for different compost recipes

The total nitrogen in C1 and C3 showed a decrease in the last weeks of observation and only C2 showed a constant increase during that period.

Usually, the N content decreases during composting mostly because of ammonium volatilization, however it is recovered due to the mineralization of the OM and due to the activity of the nitrogen-fixing bacteria (de Bertoldi et al., 1983).

In the Glossary of Soil Science Terms published by the Soil Science Society of America (1997) mineralization is defined as "The conversion of an element from an organic form to an inorganic state as a result of microbial activity". For N, the first step is the conversion of organic N from organic matter (OM) to ammonium (NH_4^+-N) by a process called ammonification. Often, the NH_4^+-N is rapidly converted to nitrite (NO_2^-) and after that to nitrate (NO_3^--N) by the microbial process of nitrification. The amount of inorganic N (NH_4^+-N and NO_3^--N) originating from OM is named mineralized nitrogen. Nitrogen mineralization is a product of the amount of organic N and the N mineralization rate (NMR) (Gilmour, 2011).

In day 92 it can be seen an increase of ammonium, especially in C2 and C3 (Figure 4), which can be related to the rise of the temperature of the piles (Figure 1).

After day 104 the NH_4^+-N produced was either immobilized, as the piles were not turned anymore after this date (Michel & Reddy, 1998; Azim et al., 2018), either the NH_4^+-N was rapidly converted to nitrite (NO_2^-) (Müller et al., 1968; Gilmour, 2011).

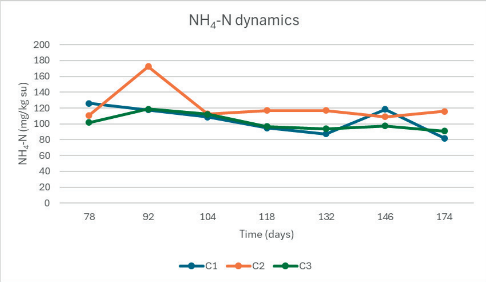

Figure 4. Changes in ammonium-N for different compost recipes

In all 3 composts the content of NO_3^--N decreased in the first part of the observation period (Figure 5). For C1, the drop from day 104 was more abrupt compared with C2 and C3, possibly, due to the lack of air. The piles were turned and aerated after day 104, therefore the nitrification process was restarted (Müller et al., 1968).

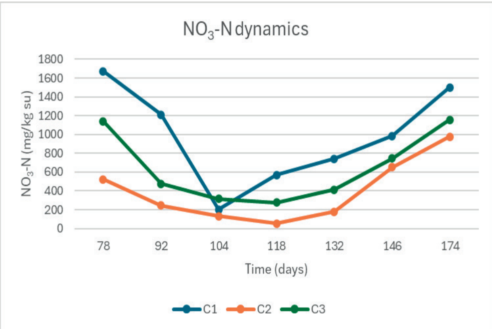

Figure 5. Changes in nitrate-N for different compost recipes

The NO_3^--N dynamics can serve as an indicator of N mineralization, immobilization, and leaching (Hartl et al., 2001), and an increase of NO_3^--N content can be a sign of the compost maturity as it was observed by other authors (Sánchez-Monedero et al., 2001; Azim et al., 2018), and it is also viewed as a way of conserving N in compost (Cáceres et al., 2018). During composting, a part of the mineral nitrogen is reincorporated into the active microbial metabolism, another part is incorporated into organic matter compost in their humification, and another one is released in the form of inorganic nitrogen matrix (Larsen & McCartney, 2000; Azim et al., 2018).

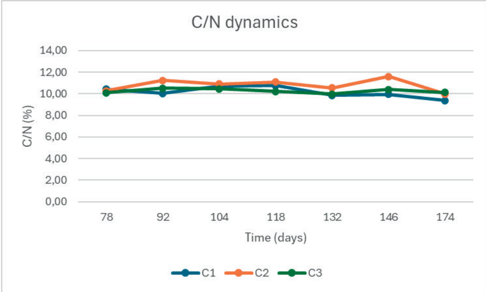

Figure 6. Changes in C/N ratio for different compost recipes

Microorganisms are known to use 30 parts of carbon for each part of nitrogen in the decomposition process (Choi, 1999; Azim et al., 2018). Carbon is serving both, as a source of energy and elemental component for microorganisms, and nitrogen is essential for the synthesis of amino acids, proteins and nucleic acids. This is why, a C/N ratio of 25-30:1 at the beginning of the composting process is ideal (Azim et al., 2018).
All 3 composts from our study showed small variations of the C/N ratio (Figure 6). The C/N ratio of C1 varied between 10.76 and 9.39, the C2 C/N ratio varied between 11.60 and 9.97, and the C3 C/N ratio was between 10.51 and 9.99. The compost C2 showed a constant growth rate both of C_t and N_t during the evaluation period (Figure 7 and Figure 3).

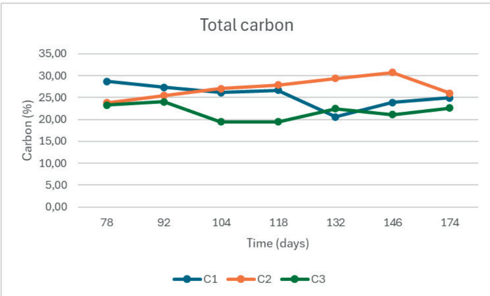

Figure 7. Changes in total carbon for different compost recipes

The C/N ratio is a parameter used mostly to assess the maturity of the compost (Albrecht, 2007; Azim et al., 2018), and the findings show that a C/N ratio around 10 is the value for a mature compost produced from organic matter and/or manure (Forster et al., 1993; Brinton & Evans, 2002; Azim et al., 2018).

CONCLUSIONS

The present study shows that co-composting lavender wastes and manure from small ruminants (sheep and goats) can lead to a good quality compost.

A major issue identified by researchers regarding the supply of the N to the plants on compost fertilized soils, is the synchronization of plant demand and N supply through mineralization, which usually occurs outside the cropping period (Reimer et al., 2023), therefore it is necessary to predict N mineralization to synchronize its release with plant demand (Ros et al., 2011). The results of our study indicate that the compost resulted from lavender waste can help conserving N and release it slowly, making it easily available for the plants.

However, our research will continue in this sense in order to increase knowledge and for a more accurate understanding of the processes, especially in relation to lavender waste composting and the effects of such compost.

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