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CORRELATIONS BETWEEN COMPOSTING CONDITIONS AND CHARACTERISTICS OF COMPOST AS BIOFERTILIZER

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Abstract: *Among the conditions determined by various authors for compost to be used as agricultural fertilizer are: pH 6-9, EC less than 3.5mS/cm, C/N ratio 26-35 and a GI above 80-85%. This study analyses three samples of composts with different percentage of vegetable waste, sewage sludge and sawdust. The samples were tested at the Transilvania University laboratory for 9 weeks and the test results fit the conditions mentioned above: pH 8.12-8.57, EC 1.97-3.04 mS/cm, C/N ratio 25.9-32.8 and GI 128.6-189.5% for radish seeds and 100-182% for cabbage seeds. These test results along with the evolution of FTIR spectra of the compost samples confirm the potential for compost samples to be used as fertilizers in agriculture.*

Key words: *composting, sawdust, sewage sludge, vegetable waste.*

1. Introduction

The compost quality evaluation has been based on properties categorized as physical (odor, temperature), chemical (pH, electrical conductivity, C/N ratio, carbohydrates content, amino acids content), biological (plant bioassay-germination test), microbiological (respiration analysis), spectroscopic (NMR and infrared methods) etc. [6].

In the absence of simple and reliable compost maturity indices there is a risk of producing and using composts that might possibly not have attained full maturation [16].

The soil-application of non-stabilized organic materials could affect both crops and the environment because of the presence of phytotoxic compounds [1], [3], [5], [10], [14].

Maturity Index is an evaluation procedure to describe the degree of decomposition and completeness of a compost process. The maturity Index relies on any two or more test methods performed concurrently on the same sample. Test methods that are applicable are those which have demonstrable relevance to stability and maturity.

pH is extremely important for microorganism nutrients, heavy metals solubility and generally speaking for microorganisms metabolism. According to literature [9], [13], [21] pH should be between 6 and 9. The low pH during the process results in corrosion, odor, slow decomposition and thus inefficient use of

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the facilities, low compost quality and difficulties in attaining temperatures high enough for proper sanitization [25].

Electrical conductivity (EC) is associated with the release of easily decomposable compounds into the solution and indicates if the account for the total soluble ions in composts may endanger the quality of compost used as fertilizer. The literature recommends electrical conductivity values between 2.0 and 3.5 mS/cm as optimal for using compost as fertilizer in agriculture [10], [4], [20], [22], [14], [26].

For the parameter C/N ratio, Mote and Griffis [15] proved the C/N ratio should be 26-35 at the end of the composting process.

Germination index (GI) is used in literature as an indicator to evaluate compost's phytotoxicity and stability [17]. Germination test represents the most sensitive parameter to evaluate the nutrient content, the toxicity and the maturity of compost.

It is considered that a germination index (GI) of 80-85% or a relative seed germination (RSG) over 60% prove the maturity of compost non toxic for plants growing [19].

This study presents three samples of composts with different percentage of vegetable waste, sewage sludge and sawdust. The samples can be successfully used as fertilizers in agriculture because the results of the lab tests fit within the values indicated by literature.

2. Experimental

The composting process was a lab scale experiment conducted at Biochemistry Laboratory at *Transilvania* University of Braşov. The raw materials used for composting process were vegetable waste, beech sawdust and sewage sludge. The composition of the samples is presented in Table 1.

The parameters of raw materials were previously determined and reported [27-28].

In order to obtain good quality compost, the composting process was carefully monitored through the following steps:

- monitoring the most important parameters of the composting process: (a) physical parameters: pH and EC, (b) chemical parameters, determining the composition of organic substrate: C/N ratio;
- investigating the biodegradation process of organic matter through FT-IR spectra analysis;
- performing the germination test with radish and cabbage seeds.

Samples of vegetable waste, sewage sludge and sawdust submitted to composting were mixed with a blender to obtain a homogeneous size of grains of organic matter, that allows the rapid biodegradation, and store in open 5 liter PET containers and shaken every day for efficient aeration.

Within each experiment, samples were taken every week, all the analyses were determined in a compost extract 10% in distilled water. The extract was stirred 15 minutes to achieve extraction. Subsequently, the digest was filtered and samples of 10 mL were used for each determination.

FT-IR analysis of the biodegradation products was performed with a Spectrometer BX II (Perkin Elmer, 2005).

The pH was measured in the filtrate solution using the pH-meter 340 I/SET and electrical conductivity with Conductometer 315 I/SET.

Composition of the three samples of compost Table 1

Sample	Vegetable waste	Sewage sludge	Sawdust	Tap water
Sample1	1 kg	0.1 kg	0.1 kg	1.8 kg
Sample2	1 kg	0.2 kg	0.1 kg	1.95 kg
Sample3	1 kg	0.1 kg	0.2 kg	2.1 kg

C/N ratio was determined with analyzer TruSpec CHN (Leco Elementar, 2008).

Germination test was performed with dry sample of compost added to the soil and seeds of radish (*Raphanus sativus)* and cabbage (*Brassica oleracea)* [27-28].

3. Results and Discussions

3.1. pH evolution

The evolution of pH during the composting process of three samples is presented in Figure 1.

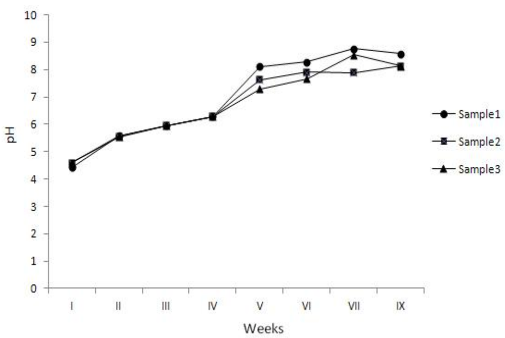

Fig. 1. *Evolution of pH values during the composting process*

At the beginning of the composting process, in the first couple of weeks, the three samples of composts show an acidic pH as a result of organic acids being released from biodegradation of polycarbohydrates by Krebs cycle [7], [12]. During the composting process all three samples showed continuous increase of pH values (strong in week IV-VII) as a result of biodegradation of organic acids [12] and biodegradation of organic matter containing nitrogen (proteins, amino acids etc.) leading to formation of amines and ammonia salts through mineralization of organic nitrogen [8], [11].

The complexity of content of compost samples and the sawdust acting as inhibitor of bacterial activity during composting, lead to an increase in pH slowly but constantly to alkali values (8.12-8.57).

3.2. Electrical conductivity evolution

The evolution of EC for the three samples of composts is presented in Figure 2.

The general tendency of EC for all three samples of composts was to increase during the composting process.

Usually a higher value of EC could be an indication of high nutrient elements presence, or a slower decomposition of the organic matter therefore a lower release of mineral salts into the solution in the process of biodegradation of biomass waste [2-3]. As it shown in Figure 2, the higher content of sawdust in the three samples, the lower the value of EC was determined throughout the composting process, proving a slower biodegradation of biomass waste in time (strong from week VI-IX) due to higher content of polymer lignin etc. difficult for microorganisms to biodegrade. Sawdust also retains the mineral salts in its structure.

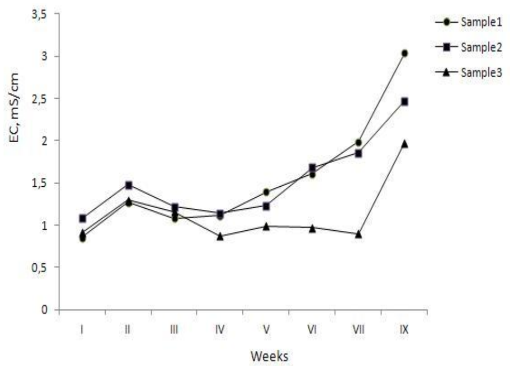

Fig. 2. *Evolution of Electrical conductivity values during the composting process*

3.3. C/N ratio

C/N ratio is a very important parameter of compost maturity and stability and its variation for all three samples of composts is presented in Figure 3.

During the composting process, C/N ratio decreased for all three samples of composts, as shown in Figure 3, because the total N content increased faster than organic C content. This proved again a rich microbial activity to biodegrade proteins and amino acids in simpler compounds such as amides, amines etc., and a slower biodegradation of poly carbohydrates due to inhibiting influence of sawdust over micro organisms' activity.

The highest values of C/N ratio can be found in Sample3 richer in sawdust, respectively with higher content of organic carbon.

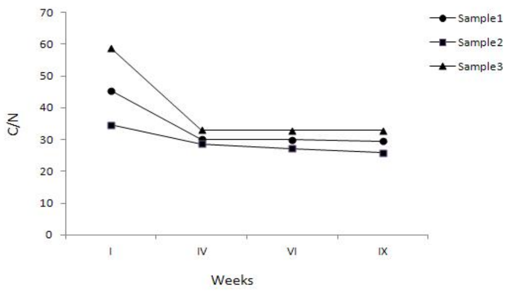

Fig. 3. *Evolution of C/N ratio during the composting process*

3.4. FTIR spectra analysis

FTIR spectra analysis confirmed the biodegradation of complex compounds, i.e. poly carbohydrates and proteins into simpler compounds such as: carboxylic acids and their derivatives, alcohols, phenols, carbonyl compounds etc. The analysis presented in Figure 4 is in accord with the literature [23-24], [18].

As shown in Figure 4, the common absorption bands for all three samples of composts are the following:

- 3290.51 cm^{-1} absorption band specific to complex compounds, respectively O-H stretching H bonded in poly carbohydrates and N-H stretching in proteins, amino acids etc.

Compared to the beginning of composting process, at the end of it (9th week as shown in Figure 4), the vibrations were not so intense anymore, proving a decreasing of content in complex compounds due to their biodegradation into

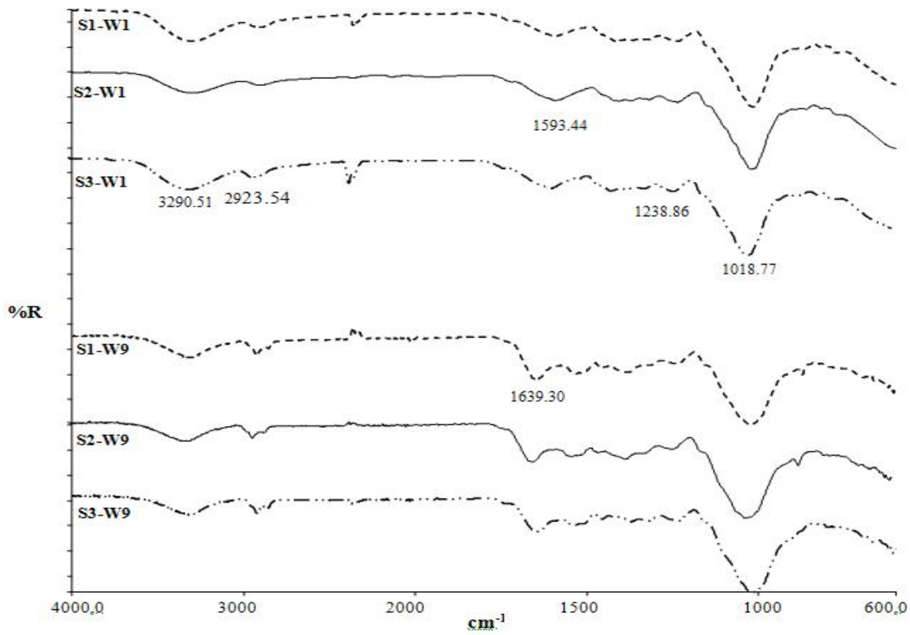

Fig. 4. *The evolution of FTIR spectra during the composting process. S1-W1: Sample1 - Week1; S2-W1:Sample2 - Week1; S3-W1: Sample3 - Week1; S1-W9: Sample1 - Week9; S2-W9: Sample2 - Week9; S3-W9: Sample3 - Week9*

simpler compounds such as amines, amides, carboxylic acids etc.

- 2923.54 cm^{-1} absorption band specific to aliphatic C-O stretching and aliphatic C-H stretching in carboxylic acids, could be linked to C/N ratio decreasing, especially with the content of organic C.

- An absorption band that almost doesn't exist at the beginning of the composting process but is well shaped at the end of process is 1639.30 cm^{-1}, specific to C=O stretching in amide I band, carboxylic acids, lactams etc.; N-H bending (scissoring) in amide II band [23]; COO^- stretch in amino acids Na^+ salts and NH_3^+ δ symmetrical.

The evolution of this absorption band during the composting process showed a high content of total N because of the biodegradation of compounds containing N (amides, lactams, amines etc.).

- At the beginning of composting process all three compost samples presented strong deep structured absorption bands at 1050-1030 cm^{-1}, characteristic for cellulose [24]. This particular absorption band was even sharper at the end of composting process because it is specific also to C-O-C stretching in ethers and C-N stretching in amines and their salts, products obtained from biodegradation of carbohydrates proteins and amino acids.

3.5. Germination Index

Germination test was performed with dry samples of compost added to a determined amount of soil using seeds of radish (*Raphanus sativus)* and cabbage (*Brassica oleracea)* [27-28].

The compost samples for radish, respectively for cabbage were obtained by adding 10 g of dry compost to 60 g of dry soil and planting 20 seeds of radish, respectively cabbage. For the control samples the 20 seeds of radish, respectively cabbage, were planted in 60 g of dry soil.

All the samples were watered daily and after 7 days the counting of germinated seeds was done and the length of roots of all samples was measured for all the samples, both compost samples and control samples [19].

Figures 5 and 6 show the Germination Index (GI) and the Relative Seed Germination (RSG) for radish seeds and cabbage seeds.

The percentages of relative seed germination (RSG) and germination index (GI) were calculated as follows [29]:

$$RSG(\%) = \frac{number\ of\ seeds\ germinated\ in\ compost\ sample}{number\ of\ seeds\ germinated\ in\ control\ sample} \times 100,$$

$$GI(\%) = \frac{number\ of\ germinated\ seeds \times average\ root\ length\ of\ compost\ sample}{number\ of\ germinated\ seeds \times average\ root\ length\ of\ control\ sample} \times 100.$$

For radish, the results for RSG were 90-95% for all three compost sample, the lowest being 90% at Sample1, values far above the 60% required for compost to be non-toxic for plants growing [19]. Instead for cabbage the RSG variation was more significant, the lowest value of 50% was determined for Sample3, and the highest value of 65% being obtained for Sample2, while Sample1 was at 60%. Again the results for cabbage prove the slower release of nutrients to the soil, respectively to the seeds, of Sample3 with richest content in sawdust, this result confirming the EC determination above. All these results showed a good degree of maturity and stability for all three samples of composts which could allow them to be used as fertilizers in agriculture.

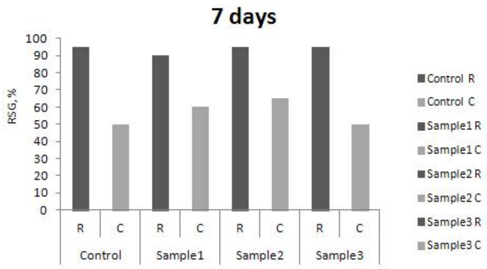

Fig. 5. *Relative Seed Germination (RSG) values for the samples of composts and control samples for Radish (R) and Cabbage (C)*

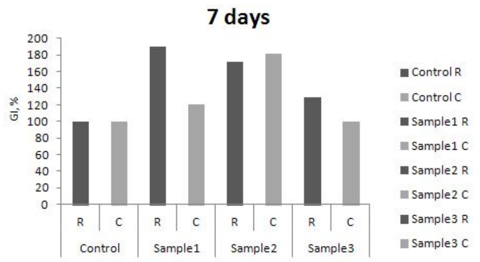

Fig. 6. *Germination Index (GI) values for the samples of composts and control samples for Radish (R) and Cabbage (C)*

4. Conclusions

- pH values and Electrical conductivity values for the three samples of composts at the end of composting process are optimal for agricultural purposes, respectively for Sample1 pH is 8.57 and EC is 3.04 mS/cm; for Sample2 pH is 8.12 and EC is 2.47 mS/cm and for Sample3 pH is 8.12 and EC is 1.97 mS/cm.
- C/N ratio at the end of composting process is 29.5 for Sample1; 25.9 for Sample2 and 32.8 for Sample3, all in the range previously described by literature as optimal for using the composts as fertilizers.
- The FTIR spectra confirms the biodegradation of complex compounds such as proteins, poly carbohydrates, amino acids etc. into simpler compounds like carboxylic acids, alcohols, phenols, amines and their salts, amides etc.
- For all three samples of composts for radish and for Sample1 and Sample2 for cabbage also, the Relative Seed Germination is over 60%, also the Germination Index is over 100% which proves all three samples are stable and mature and ready to use as fertilizers for agriculture.

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