OBTAINING BIOFERTILIZER BY COMPOSTING VEGETABLE WASTE, SEWAGE SLUDGE AND SAWDUST

L. DUMITRESCU[1] **I. MANCIULEA**[1]
A. SAUCIUC[1] **C. ZAHA**[1]

Abstract: *Municipal waste is a growing concern in the world through the large quantity produced every year, the environmental problems and the costs of their storage. Composting is a technique frequently used to recycle a large variety of organic by-products transforming them into fertilisers useful for the soil. Monitoring different physical-chemical parameters showed the effect of the substrate on the microbiological activity and on the formation of the final compost. The purpose of this study was to analyze the steps of the organic matter biodegradation during composting and to establish the most important parameters of the composting process.*

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

1. Introduction

Organic residues-wastes from human, animal, agricultural and industrial establishments, posing serious environmental and health problems can be managed besides storage, incineration and pyrolysis, by anaerobic/aerobic fermentation, producing biogas, respectively compost. The advantages of these processes are that they minimize damage to the environment and produce economically valuable products from wastes [1], [4], [6].

Composting is generally defined as the biological oxidative decomposition of organic constituents in wastes under controlled conditions which allow development of aerobic micro-organisms that convert biodegradable organic matter into a final product sufficiently stable for storage and application without adverse environmental effects. The main products of aerobic composting are CO_2, H_2O, mineral ions and humus. Also the process destroys pathogens, converts nitrogen from unstable ammonia to stable organic forms and reduces the volume of waste [7], [8].

Because composting is an efficient method for recycling waste, this study has a great relevance for Braşov county that has to manage, every year, larger quantities of biodegradable waste, both as domestic waste (96882 tones in 2008) and sewage sludge (43750 tones in 2008).

Treating the effluent generates sludge rich in organic and mineral compounds (N and P) and in lipids. When sludge is disposed becomes a source of pollution. The lack of chemical, biological and biochemical stability of the sludge causes environmental problems (contamination of groundwater by leachate, pollution of the air with malodorous gases etc.). The research aims at contributing to better

[1] Chemistry Dept., *Transilvania* University of Braşov.

understanding the interactions between components of the various wastes and to achieve a database on the possibilities of recovery vegetables waste and sewage sludge, in combination with sawdust, in a clean product compost, with a higher nutritive value for plants and grains, and a very good amendment of the physical and chemical properties of soil. Monitoring different physical-chemical parameters showed the effect of the substrate on the microbiological activity and on the formation of the final compost.

2. Experimental

To investigate the composting process of vegetable waste mixed with sewage sludge and sawdust 4 samples of 1 kg of biodegradable organic matter were made, each sample having different amounts of vegetable waste, sewage sludge and sawdust as follows:

Sample 1 (S1): 100% vegetables waste (equal quantities from potatoes, carrots, cabbage, apples, and banana) and H_2O to achieve optimum moisture content (60%);

Sample 2 (S2): 90% vegetables waste (the same mixture and ratios as sample 1), 10% sewage sludge from cleaning station Braşov and H_2O;

Sample 3 (S3): 90% vegetables waste (the same mixture and ratios as sample 1), 10% sawdust and H_2O;

Sample 4 (S4): 80% vegetables waste (the same mixture and ratios as sample 1), 10% sewage sludge, 10% sawdust and H_2O. In the first stage, vegetables wastes were mixed with a hand blender to obtain homogeneous and fine particles of organic matter which allow a fast decomposition.

The samples were submitted on containers made of PET, with big feeding surfaces to allow a good contact between composting material and atmospheric oxygen for an efficient and easy aeration. The aeration process was made by manual mixing, at least once a day.

Every week, within each experiment, from all the samples fractions of organic matter were taken and the *pH* and the content of carbohydrates, amino-acids and enzymes were determined.

2.1. Analytical Methods

All the analyses were performed in a compost extract made with distilled water. The extract was obtained by mixing 10 g of organic matter, transformed into a puree with a mortar with 100 mL hot distilled water. The content of the balloon was filtered and for each determination 10 mL of filtrate were used.

The pH was measured in the filtrate solution using the *pH*-meter 340 I/SET.

The carbohydrates content was determined by iodine-metric method - Wilstäter-Schull method [5] - which is based on oxidation of aldehyde group with iodine in alkaline medium.

The amino-acids content was determined by Sorensen method [5]. Because of the amphoteric character of amino acids, the carboxyl group can be titrated with NaOH solution only after the amino group has been blocked by condensation with formaldehyde.

The *enzymatic activity* was analyzed by oxidation with $K_2Cr_2O_7$ and H_2O_2 in the presence of H_2SO_4 [5].

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

3. Results and Discussion

3.1. *pH* Variation During Composting

In all four samples, *pH* values exhibited a slight decrease during the first 11 days, followed by a rise in the next 21 days (Figure 1). The *pH* initially decreased due to the degradation of the organic matter leading to the production of organic and inorganic acids [3], [5], [8], [9].

Further increasing of *pH* is caused by: (a) decomposition of organic matter containing nitrogen (organic nitrogen mineralization), leading to formation of NH_3 which reacts with water and forms NH_4OH that neutralized the existent acids;

(b) de-amination reaction of aminoacids released from proteins forming ammonia.

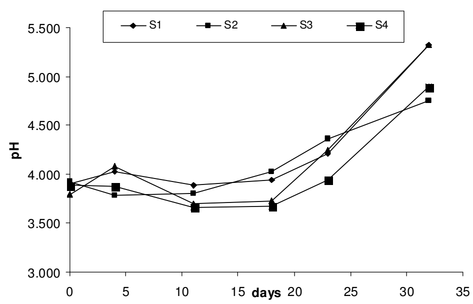

Fig. 1. *pH variation during composting*

It can also be noted that after 32 days of composting, samples S1 and S3 have higher *pH* values compared to the other samples (S2 and S4). This can be caused by the sewage sludge presence in S2 and S4, having both higher content in carbohydrates and aliphatic structures with long carbon chains (fatty acids) easy to be biodegraded to acid compounds. This trend is confirmed by FT-IR analysis.

3.2. Carbohydrates Content Variation

Carbohydrates are special substances from plants which result from photosynthesis process. They represent over 50% of the dry matter of plant bodies, as simple sugars - monocarbohydrates or complex sugars - polycarbohydrates. Glucose is the most important and widespread monocarbohydrate, being in dicarbohydrates structures (sucrose, cellobiose, maltose) and polycarbohydrates structures (starch, cellulose) [2], [5].

Biodegradation of polycarbohydrates is an oxidative process which generates energy (by exothermic reactions). In the presence of enzymes, the polycarbohydrates are split into monocarbohydrates which are decomposed into simpler compounds with lower molecular mass.

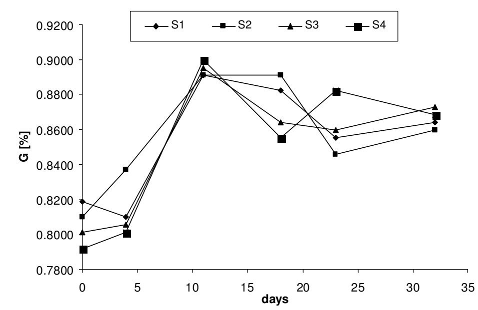

Fig. 2. *Carbohydrates content variation*

Analyzing Figure 2, it can be observed an oscillation of carbohydrates concentration.

It can also be observed that if at beginning, samples 1 and 2 had the highest amounts of easy degradable carbohydrates, in time (after 11 days of composting and at the final moment of the process), samples S4 and S3 having larger amounts of polycarbohydrates and also aromatic polymer lignin, which decompose slowly but continuously in a longer period of time, will have greater values of monocarbohydrates, also increasing the quality of compost. This behaviour is the result of a better biodegradation of polycarbohydrates due to the presence of sawdust (source of sugars and enzymes), respectively sewage sludge, as source of extra enzymes for biodegradation.

3.3. Amino-Acids Content Variation

Amino acids represent the fundamental structural unit of proteins and nucleic acids. There are almost 200 amino acids but only 23 of them are used for protein biosynthesis. Of all living organisms, plants can synthesize, and therefore contain, the greatest number of amino-acids, especially widespread in fruit seeds, plant roots, and conifers [3], [5].

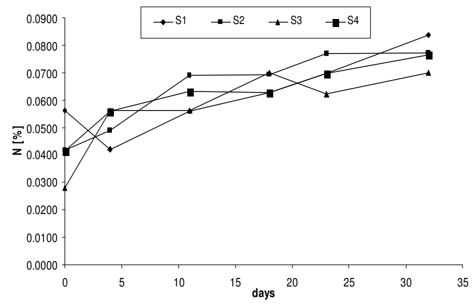

Fig. 3. *Amino-acids content variation*

During decomposition of organic matter by aerobic fermentation, free proteins from vegetable waste are decomposed, in presence of enzymes, in amino-acids. That's why the concentration of amino-acids increases during the 32 days of composting (Figure 3). It can be observed that the biodegradation of proteins during composting, releasing amino acids, varied as follows: S3 > S4 > S2 > S1. The presence of lignin components in the sawdust structure in S3 contributed to a better biodegradation process, increasing the amino acids content both in S3 and S4.

3.4. Enzymatic Activity Variation

The enzymes are macromolecular compounds, acting as biocatalysts for all the biochemical transformations from metabolism. Enzymes are found mainly in young plants, leaves, seeds in state of germination, fruits. They are absolutely necessary in the biodegradation process of carbohydrates (carbohydrases), lipids (lipases) and proteins (proteinases).

The presence of micro-organisms into the sewage sludge determined an increase of enzymes content especially in samples S4 and S3. This aspect is very interesting when intent to recycle the sludge by composting. The final compost samples still preserve large quantities of enzymes, varying as follows: S3 > S2 > S4 > S1.

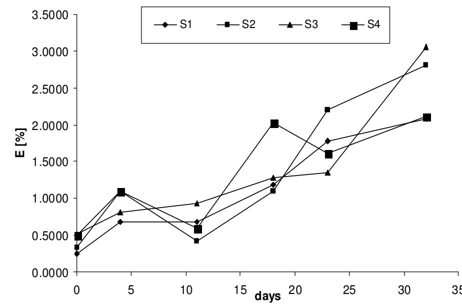

Fig. 4. *Enzyme content variation*

3.5. FT-IR Analysis

The FTIR spectra of the four compost samples at different stages show the locations of similar peaks but the relative intensities of the absorbance are seen to change during the composting process. The interpretation of the recordings is based on the data of numerous studies [1], [3], [4], Table 1.

The spectra of the four samples offer the same general pattern except that the intensity of certain bands differs.

During composting, the initial strong absorbances around 1040-1160 cm^{-1}, corresponding to the polycarbohydrates present in high levels in domestic waste, decreased as result of the biodegradation of polycarbohydrates to monocarbohydrates (as already was evidenced by glucose content determination).

In the same way, the absorbances at 2900-3300 cm^{-1} attributable to long chain aliphatic structures (lipids, proteins) decreased during composting process, as result of biodegradation of proteins and long chain fatty acids from lipids.

In contrast, other structures which absorb at about 1650-1675 cm^{-1} (aromatic compounds such as carboxylic acids, aldehydes, ketones, amides) and aromatic components released from lignin biodegradation absorbing in the 750-850 cm^{-1} region are formed.

Table 1

Attribution of absorbance bands (cm^{-1}) for FT-IR spectra

cm^{-1}	Attribution
3400-3600	N-H stretching vibration (amides, amines); O–H stretching vibration of OH group of alcohols, phenols, carboxylic groups
2900-3300	C–H stretching vibration of long chains aliphatic structures (fatty acids, waxes, other aliphatics
1650-1675	Stretching vibration of COO^- and C=O in amides, stretching vibration of C=O in ketones, aromatic carbohylic acids, quinones, stretching vibration aromatic C=C
1420-1460	Stretching vibration of C–H–, CH_2– and –CH_3 radicals in aliphatic structures; vibrations of alkyl bonds and of lignin
1040-1160	C–O–C stretching vibration of (poly)carbohydrates and aromatic ethers
750-850	Absorption bands of phenols, aromatic carboxylic acids, bending vibration aromatic C=O

These results show that during treatment, the microbial populations benefit from compounds that are easily assimilable and freely available in the medium i.e. mainly carbohydrates and lipids in all the four samples. At the end of the composting, in parallel with a decrease in aliphatic carbon, such as polycarbohydrates, an increase in the concentration of aromatic compounds, richer in functional groups such as the aromatic carboxylate ions, the C=O of aromatic amides, ketones, quinones and phenols was recorded [10], [11].

4. Conclusions

Our research established the possibility of recycling biomass waste by composting vegetables waste with sewage sludge and sawdust in order to obtain biofertilizer compost, with a high nutritive value for plants and good amendments of soil physical and chemical properties.

The composting process was monitored, by tests performed weekly on the four samples, and established interesting interactions/correlations between chemical structures of components of the various wastes and their biodegradation by composting. The microbial communities developed during composting had greater access to aliphatic structures, hence increasing the intensity of other structures such as the aromatics.

The FT-IR spectra showed a decrease of the absorbance of the easily assimilable compounds that are predominant in the initial mixtures (the carbohydrates (1040-1160 cm^{-1} and long aliphatic chains (2900-3300 cm^{-1}) and appearance of some other structures which absorbed at around 1650 cm^{-1} and 750-850 cm^{-1} probably of aromatic and peptidic origin [11].

The biodegradation percentage of poly-carbohydrates to monocarbohydrate (calculated from initial and final glucose content) was directly influenced by the chemical structure of the components present in the four samples and varied in order: S4 (88.0%) > S3 (82.4%) > S2 (57.5%) > S1 (52.2%).

The biodegradation of proteins to amino acids also can be correlated with the different composition of the four samples in composting process as follows: S3 (60%) > S4 (45.88%) > S2 (45.71%) > S1 (33.17%).

From these results it can be observed that the sawdust component (having an extra source of sugars and lignin component) and sewage sludge (having lipids and micro-organisms forming enzymes) improve the biodegradation process.

Germination index (GI) was used as an indicator to evaluate compost phytotoxicity and stability by determining relative seed germination and relative root elongation.

It is generally considered that phyto-toxicity is eliminated when GI reaches 80-85% [10]. In this study, GI gradually increased during the composting and in the final compost samples GI were: 141% (S1) > 117% (S3) > 111.2% (S4) > 108% (S2).

We can consider that composting vegetable waste together with sawdust and sewage sludge determined an improving both, of the rate of composting, and of the quality of the compost in terms of nutritive components.

Taking into account the main demand regarding the medium protection and the sustainable development, our research will be focused on developing new procedures for recycling wastes by composting, having in view possible constraints of the application of waste streams, e.g. the issue of heavy metal leaching of the product versus limits.

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