

Agnieszka OZIMEK¹ and Michał KOPEĆ¹

CHANGES OF FERTILIZER COMPONENTS AND HEAVY METAL CONTENTS DURING COMPOSTING PROCESS

ZMIANY ZAWARTOŚCI SKŁADNIKÓW NAWOZOWYCH ORAZ METALI CIĘŻKICH W TRAKCIE PROCESU KOMPOSTOWANIA

Abstract: The changes of fertilizer components and heavy metal contents were analyzed in selected municipal wastes during composting process while the quality of produced compost was assessed in view of its impact on the environment. The material for analyses was provided by a mixture of selected wastes from green areas subjected to composting process using MUT-Kyberferm technology. Contents of organic carbon, potassium, phosphorus, heavy metals and total nitrogen were assessed in the collected samples.

Contents of organic carbon diminished with composing time, opposite to changes of nitrogen content, which were increasing. Composting proceeded showing a considerable dynamics of organic carbon content changes. Heavy metal contents did not exceed the values permissible for organic fertilizers. Results of organic carbon and heavy metal contents analysis in the tested compost indicate its potential application in agriculture, which is a rational way of organic waste material management.

Keywords: compost, fertilizer components, heavy metals

Municipal wastes pose an increasingly serious problem for developing city agglomerations. Their storage usually involves setting aside large areas of agricultural land, degradation of the environment due to water, soil and atmosphere pollution with chemical or microbiological factors [1]. Selective collection of green wastes led to development of various composting technologies and in consequence to setting up separate objects in which this process is carried on [2].

Organic recycling of wastes, including composting, should be treated as an important method of their recovery. In result of the intensification of changes which occur during composting the wastes may be fully disposed of a commercial product, *eg* organic fertilizer may be obtained. Processes occurring during composting favour the matter

¹ Department of Agricultural and Environmental Chemistry, University of Agriculture in Krakow, al. A. Mickiewicza 21, 31-120 Kraków, Poland, phone: +48 12 662 4346, fax: +48 12 662 4341, email aozimek@o2.pl

transformation whereas nutrients became better available to plants in compost than in the initial material.

The aim of the paper was an analysis of changes of fertilizer components and heavy metal contents occurring during composting process conducted on a technological scale on organic material obtained from green areas in Krakow. The results will be compared with the results obtained in the analysis of the process conducted in a laboratory scale.

Material and methods

Initial material was prepared in a composting plant of green wastes in Krakow-Plaszow; it was a mixture of selected fractions of wastes, mainly from green areas, subjected to composting process. The following wastes were used for initial material preparation: grass 29.89 %; fine cuttings 26.77 %, fresh cuttings 23.2 %; leaves 9.06 %; cereal wastes 6.91 % and kitchen wastes 4.11 %. The cereal wastes consisted of cereal chaff originating from cereal processing plant in Krakow, whereas kitchen wastes came from restaurants and canteens in Krakow. Each time the samples of materials for analysis were collected from one, determined windrow, in pursuance of branch standard PN-R-04006:2000 at monthly intervals during the period from October 2008 to March 2009. Five individual samplings from various windrow sites constituted a collective sample. A sample collected in October was the initial material after leaving the reactor chamber, *ie* after completing the phase of intensive composting. The following samples were taken from ripening material. Initially it was ripening compost in intermediate ripening hall (sample collected in November), subsequently compost which was ripening on the composting plant yard.

The composting was carried out using MUT-Kyberferm technology, which is a chamber composting technology. The first – thermophilous phase comprises intensive composting in a reactor for 14 days. The bioreactor is a closed installation of concrete placed in a hall. The wastes in the bioreactors are vacuum aerated through a system of pipes with a condensate trap. Fresh air supplied to the bioreactors is heated and watered. Condensate, or the effluents are used for material moistening, which allows to use the installation without using tap water. The second phase is intermediate ripening in the composting plant hall for 3 weeks, whereas the third phase involves final ripening for three weeks in windrows on the square.

Collected material was subjected to chemical analysis which determined dry mass content in samples with natural moisture after their drying at the temperature of 70 °C in a dryer with hot air flow. Laboratory analyses were conducted in two replications.

The following assessments were conducted in dried and crushed compost samples:

- total nitrogen by means of Kjeldahl method, after sample mineralization in concentrated sulphuric(VI) acid,
- potassium, phosphorus, calcium, sodium and heavy metals using ICP-AES method after sample mineralization in a muffle furnace (450 °C for 5 hours) and dissolving the remains in nitric(V) and chloric(VII) (perchloric) acids,
- organic carbon in a mixture of potassium dichromate(VI) and concentrated sulphuric(VI) acid using oxidative-titrating method,

- organic matter as losses after sample mineralization in a muffle furnace (450 °C for 5 hours),
- pH by potentiometer in a suspension of organic material and water, maintaining dry matter to water ratio 1:10,
- electrolytic conductivity – by conductometer.

Mean values for analytical replications for each date presented in Tables were interpreted in the paper. Statistical analysis was conducted using Statistica 9 programme.

Results

Analysis of collected material chemical composition revealed (Table 1) a diversification of dry mass content (33.8–47.6 %), due to the character of the technological process. Compost was ripening in windrows on the composting plant yard, irrespective of weather conditions, from November to March. Snowfall and rainfall might have caused its periodical excessive moistening.

Table 1

Selected properties of compost during composting process

Month of composting	Dry matter [%]	Electrolytic conductivity [mS · cm ⁻¹]	pH	Organic matter	C _{tot}	N _{tot}	C:N
				[g · kg ⁻¹ d.m.]			
October	47.5 ± 1.56	6.3 ± 0.35	6.3	697 ± 0.71	294.2 ± 2.34	16.4 ± 0.08	18
November	36.0 ± 0.85	4.16 ± 0.19	7.0	579 ± 8.99	253.5 ± 5.80	18.5 ± 0.02	14
December	51.9 ± 2.83	3.88 ± 0.09	7.2	557 ± 15.53	208.6 ± 8.08	16.6 ± 0.09	13
January	42.1 ± 1.06	2.93 ± 0.12	7.2	547 ± 0.82	203.7 ± 17.66	19.2 ± 0.01	11
February	38.6 ± 0.64	3.75 ± 0.04	7.5	511 ± 18.80	207.0 ± 5.62	16.1 ± 0.12	13
March	41.1 ± 0.14	2.82 ± 0.04	7.7	522 ± 13.08	198.5 ± 3.16	19.0 ± 0.04	10

± SD (standard deviation), n = 2.

The reaction of the initial material on pH scale was 6.3 (Table 1). After a month of composting the analyzed materials revealed a neutral reaction, which was growing with the time of the process duration. Value of electrolytic conductivity in the final product was 3.82 mS · cm⁻¹ and decreased by half in comparison with the initial material (6.30 mS · cm⁻¹) (Table 1).

Content of organic matter was decreasing with duration of composting time and ranged from 697 g · kg⁻¹ d.m. in October to 522 g · kg⁻¹ d.m. in March. Parallel with losses of organic matter, total carbon content was also diminishing (Table 1).

Total nitrogen content showed an opposite relationship. It fluctuated on the level from 16.4 gN · kg⁻¹ d.m. in the material taken out from the bioreactor chamber to 19.2 gN · kg⁻¹ d.m. in the subsequent phases of composting. The amount of ash in the composted mass was also increasing (Table 1).

Because of the total carbon to total nitrogen ratio, compost may be regarded as stable at each phase of the process after intensive composting. C:N ratio was decreasing with composting time reaching 18 in the compost leaving bioreactor chamber and 10 in the final product (Table 1).

The contents of phosphorus, potassium and sodium in the compost revealed slight diversification. Increase in calcium content occurred mainly after the first month of composting. Content of each of the macroelements in the final product increased in comparison with the initial material (Table 2).

Table 2

Fertilized components content during composting process

Months of composting	P	K	Ca	Na
	[g · kg ⁻¹ d.m.]			
October	2.2 ± 0.27	6.8 ± 3.36	20.7 ± 0.85	0.7 ± 0.05
November	2.5 ± 0.22	9.8 ± 0.80	26.8 ± 0.08	0.9 ± 0.03
December	2.7 ± 0.30	10.0 ± 0.17	29.3 ± 0.20	1.0 ± 0.01
January	3.1 ± 0.34	10.1 ± 0.67	30.7 ± 1.02	1.0 ± 0.01
February	2.7 ± 0.17	9.8 ± 0.94	30.7 ± 0.20	1.1 ± 0.01
March	2.7 ± 0.49	8.4 ± 0.38	30.7 ± 0.16	1.0 ± 0.01

± SD (standard deviation), n = 2.

An important criterion of compost assessment in view of its environmental application (mainly in agriculture) is determining its heavy metal contents. Analysis of the total contents of selected metals (Cd, Cu, Zn) (Table 3) allowed to classify the final product – ripe compost to I quality class (according to limits suggested by the European Commission) [4].

Table 3

Trace elements content during composting process

Months of composting	Cd	Cu	Zn
	[mg · kg ⁻¹ d.m.]		
October	0.41 ± 0.06	19.2 ± 2.64	112.3 ± 13.62
November	0.56 ± 0.01	26.0 ± 1.65	127.8 ± 5.93
December	0.62 ± 0.12	20.4 ± 1.54	141.4 ± 7.25
January	0.90 ± 0.07	33.9 ± 0.04	210.5 ± 9.64
February	0.71 ± 0.02	36.9 ± 4.23	162.4 ± 4.51
March	0.68 ± 0.04	48.2 ± 1.55	212.8 ± 2.31

± SD (standard deviation), n = 2.

Compost sampled in October contained 0.41 mgCd · kg⁻¹ d.m., in January the content increased to 0.90 mgCd · kg⁻¹ d.m. and subsequently it stabilized on the level of

0.68 mg · kg⁻¹ d.m. in March. Differences in cadmium concentrations were statistically non-significant (Table 3).

Copper and zinc contents were increasing with the composting time. The amount of copper grew from the level of 19.2 to 48.2 mgCu · kg⁻¹ d.m., while zinc amount at the beginning of the process was 112.3 mgZn · kg⁻¹ d.m. and increased to 212.8 mgZn · kg⁻¹ d.m. in the ripe product (Table 3).

Homogenization of material and its stabilization were progressing with the time of composting. It has been indicated by diminishing values of standard deviation in a majority of analyzed parameters (Tables 1–3).

Discussion

Application of some waste materials for fertilization purposes is difficult or sometimes impossible because of their contents of excessive amounts of harmful elements. The elements which most seriously limit the use of some waste materials are heavy metals and pathogenic organisms. Another limitation may be poor physical parameters of the materials. Therefore, a technology is sought which could improve physical, chemical and sanitary properties of such wastes and in result upgrade them [5]. Priorities of waste management policy make composting one of the most common methods of utilisation of dispensable organic mass. Baran et al [1, 7] think that composts of some fractions of selected wastes and mixed wastes is a fertilizer generally characterized by a high contents of nitrogen, phosphorus and potassium, whereas the contents of heavy metals usually do not exceed limit values.

On the basis of chemical analysis conducted on the tested compost it may be stated that mineralization of organic matter was particularly apparent during the thermophilous phase, as evidenced by decreasing content of total carbon content and considerable increase in ashes amount in the composted biomass. The content of organic compounds was diminishing along with various changes intensity during composting [3, 6].

Nitrogen transformations were occurring parallel with organic matter transformation process. Various intensity of ammonification, nitrification and denitrification processes at individual composting phases shaped the total N content. The amount of total N was growing in the ripening compost, which has been confirmed also in papers by other authors [2, 3].

At the final phases of composting a stabilization of organic matter mineralization occurred and the degree of its humification was increasing, which favoured stabilization of C:N ratio. The index assumes the value of 10 at the final phase of composting, which may evidence a high value of produced compost. The fact has been corroborated among others by Siuta [8], Jedrczak [2] and Jimenez and Garcia [9]. Value of electrolytic conductivity was decreasing, which testifies a decreased salinity and improves fertilizer value of the compost [2].

The ripening processes occurring in the discussed compost affected the total content of macroelements. Compost revealed macroelement contents on the level reported by a majority of authors [1, 5, 7, 10, 11].

Potassium content in the analyzed compost increased slightly during composting process and considering the results obtained by Gondek [5] it may evidence this element deficiency in composts. Also Kalembsa et al [12] indicate considerable deficiencies of potassium in the compost manufactured using "GWDA" technology. A decrease in potassium content may be caused by its losses with water leaching from the windrow. Changes in this element content confirm a tendency for changes in electrolytic conductivity. Phosphorus content changed slightly during composting process. Eventually, it assumed the value of $3.16 \text{ gP} \cdot \text{kg}^{-1} \text{ d.m.}$, approximate for most composts [10]. Densification of the content which in this case occurred was caused by carbon losses.

Also heavy metal contents were densified. Unlike the organic components of compost, heavy metals do not undergo biological breakdown, therefore ripe material becomes enriched in metals in comparison with the fresh material [13].

Compost manufactured from mixed municipal wastes often contains relatively high amounts of lead, cadmium, copper and zinc. Because most of these elements is present also in some waste materials, they become unsuitable for composting [2]. The guidelines limiting heavy metal contents aim at differentiation of products suitable for use from those unsuitable as raw materials for composting [13]. In the presented investigations the composted material consisted of selectively gathered wastes from green areas. Obtained compost was characterized with heavy metal contents not exceeding the permissible limits, which indicates suitability of these wastes for composting and lack of pollution in the areas where they were acquired.

Conclusions

1. Composting time significantly affected improvement of some parameters evidencing the ripeness and quality of compost.
2. Changes of fertilizer components and heavy metal contents occurred mainly after completion of the first composting phase.
3. Composting of selected fractions of wastes, mainly from green areas in Krakow, allows to obtain a product abundant in organic substance and basic biogens with considerable fertilizer value and indicates potential use of the compost in agriculture.
4. Heavy metal contents were much lower than the amounts permissible by regulations suggested by the EU and allowed to classify the compost to I class.

References

- [1] Baran S, Wójcikowska-Kapusta A, Żukowska G, Strzałka A. *Zesz Probl Post Nauk Roln.* 2009;537:33-39.
- [2] Jędrzak A. *Biologiczne przetwarzanie odpadów.* Warszawa: Wyd Nauk PWN; 2008.
- [3] Drozd J, Licznar M, Bekier J. *Roczn Glebozn.* 2009;3:67-74.
- [4] Hogg D, Barth J, Favoino E, Centemero M, Caimi V, Amlinger F, Devliegher W, Brinton W, Antler S. Comparison of compost standards within the EU, North America and Australasia. The Waste and Resources Action Programme 2002 [online] <http://www.wrap.org.uk>
- [5] Gondek K, Filipek-Mazur B. *Acta Agrophys.* 2005;5(2):271-282.
- [6] Wu L, Ma LQ. *J Environ Qual.* 2002;31:1323-1328.
- [7] Baran S, Wójcikowska-Kapusta A, Żukowska G, Bik M.: *Zesz Probl Post Nauk Roln.* 2009;537:25-31.

- [8] Siuta J. Ekoinżynieria, Puławy, Warszawa: 1999.
- [9] Jimenez E, Garcia V. Agr Environ. 1992;38:331-343.
- [10] Faithfull NT. Methods In Agricultural Chemical Analysis: A Practical Handbook. 1st edition. Wallingford: CABI Publishing; 2002.
- [11] Rosik-Dulewska Cz. Zesz Probl Post Nauk Roln. 2001;477:467-477.
- [12] Kalembsa D, Symanowicz B, Kuziemska B. Acta Agrophys. 2002;73:123-129.
- [13] Bilitewski B, Hardtle G, Marek K. Podręcznik gospodarki odpadami. Warszawa: Seidel-Przywecki; 2003.

ZMIANY ZAWARTOŚCI SKŁADNIKÓW NAWOZOWYCH ORAZ METALI CIĘŻKICH W TRAKCIE PROCESU KOMPOSTOWANIA

Katedra Chemii Rolnej i Środowiskowej
Uniwersytet Rolniczy im. Hugona Kołłątaja w Krakowie

Abstrakt: Podjęto badania, których celem było określenie zmian zawartości składników nawozowych oraz metali ciężkich, zachodzących w czasie kompostowania wybranych odpadów komunalnych. Materiał do badań stanowiła mieszanina wyselekcjonowanych odpadów z utrzymania terenów zielonych, poddana procesowi kompostowania według technologii MUT-Kyberferm. Próbki pobrano w odstępach miesięcznych z kompostowni w Krakowie-Płaszowie. W pobranych próbkach materiałów organicznych oznaczono zawartość węgla organicznego, zawartość potasu i fosforu, metali ciężkich oraz azot ogólny.

Zawartość węgla organicznego zmniejszała się wraz z upływem czasu kompostowania, przeciwnie do zmian zawartości azotu, która zwiększała się. Kompostowanie przebiegało z dość dużą dynamiką zmian zawartości węgla organicznego. Zawartości metali ciężkich nie przekroczyły wartości dopuszczalnych dla nawozów organicznych. Wyniki badań zawartości węgla organicznego, pozostałych składników nawozowych i metali ciężkich w badanym kompoście wskazują na możliwość wykorzystania tych wyników w rolnictwie. Jest to racjonalny sposób zagospodarowania odpadowych materiałów organicznych.

Słowa kluczowe: kompost, składniki nawozowe, metale ciężkie