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EFFECT OF THE COMPOSTING PROCESS ON PHYSICAL AND ENERGETIC CHANGES IN COMPOST*

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A b s t r a c t. Composting is one of the most common methods of treating biodegradable waste, and application of the process' final product into the soil is, due to the high carbon content, one of the most rational ways of its management. If the compost is not in line with legal requirements, it is necessary to search for alternative ways of its use, such as application for energy purposes. The aim of this study was to estimate differences in the physical, including energetic, properties of composts prepared from plant feedstock with additions of such materials as biochar, sewage sludge, coffee grounds and yeast effluent. The composting process was carried out for 140 days. The basic chemical and physical properties as well as heat of combustion were determined in the analysed feedstocks and mixtures derived from them. It was found that 10% addition of biochar had no significant effect on the composting process rate; however, biochar-amended treatments showed a smaller loss of dry matter and higher C:N ratio compared to other combinations. The use of biochar or coffee grounds as additives in the composting process reduced volumetric density of the composted biomass. Maize straw amended with sewage sludge and coffee grounds reduced air-filled porosity of composts. The share of biochar in the compost limited this tendency. The heat of combustion determined in composts was lower than the parameter determined in material mixtures before the composting process. The results show that sewage sludge reduced the heat of combustion of composts, which was closely related to ash content.

K e y w o r d s: biochar, compost, porosity, density, heat of combustion

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INTRODUCTION

As in the case of soil, the physical properties of compost result from volumetric ratio of solid, liquid and gas phases, and from the particle size of composted material. Composting results in the formation of volumetric density, total porosity and structure, consistency, viscosity and compactness of compost. By analogy, secondary properties, which depend on the basic physical properties of compost, can be distinguished. Consequently, the basic physical properties of compost have a direct impact on its thermal and chemical properties.

Determination of the basic properties of compost is practical both at the stage of selecting a feedstock, and of product quality assessment (Malińska 2013). Particular attention is paid to the water content, bulk density, particle size and mechanical strength. These properties affect the porosity of composted biomass, and thus the processes of gas and heat diffusion and draining of excess water from the heap. This, in turn, conditions the composting process and, consequently, the quality of the final product (Khan *et al*. 2016, Lim *et al*. 2016).

Compost properties are of great importance not only in the context of product with high fertiliser value, but also for product as a low-temperature heat source. Thus, in order to assess the product quality, it is necessary to carry out standard compost analyses at the end of the biological transformation processes, which will determine the potential methods of its management. Should it be established that the compost is not in line with legal requirements for natural environment management, it is necessary to search for alternative ways of its use, such as application for energy purposes. The use of compost for energy purposes is justified when it is of insufficient quality or contains harmful substances, preventing it from being used for agricultural or reclamation purposes (Zajonc *et al.* 2011, Zajonc *et al*. 2014, Karcz and Kantorek 2014). The need to seek energy feedstock among resources which have not been considered in terms of energy biomass so far stems not only from the environmental protection standards, but also from the growth in energy demand and changes in the biomass access structure (Karcz Kantorek 2014). Another problem that arises in relation to organic recycling of materials, such as sewage sludge, is the development of low-cost forms of waste treatment – e.g. by the constructed wetland method (Boruszko *et al*. 2014). Also, distributed systems of economic waste management (household sewage treatment facilities) may not meet the environmental criteria and result in the need for thermal conversion of such products.

Most of available literature refers to the effect of composts on physicochemical properties of soil (Głąb and Gondek 2008, Lim *et al*. 2016). Due to the diversity of feedstocks, their morphology, particle size fraction, chemical composition and, in particular, high carbon content in various compounds and at different levels of maturity and stability, determination of the physical properties of composts is not easy. It requires either specific equipment or adaptation of methods used in determining the properties of organic soils. Considering analytical difficulties, Jakubek *et al.* (2011) proposed, for instance, the analysis of digital images and the use of neural networks, for identifying compost quality.

The aim of this study was to explain differences in the physical, including energetic, properties of composts prepared from plant feedstock with additions of such materials as biochar, sewage sludge, coffee grounds and yeast effluent. Biochar added in the composting process was treated as an agent improving physical and chemical properties of composted matter, while studies of the compost energetic properties were carried out due to the identified impossibility of introducing compost to the environment and need for its disposal.

MATERIAL AND METHODS

Conditions and scheme of the experiment

Waste was composted for 140 days, from mid-May to the end of September 2015. The process was carried out in 1.2 x 1.0 x 0.8 m bioreactors with perforated bottom to allow active aeration. Laboratory bioreactors were sheltered against precipitation, but exposed to the outside temperature and sunlight. This ensured heat exchange between the composted material and the surrounding environment. The basic feedstock used in the composting process was shredded maize straw (29.3 kg D.M.) (Tab. 1). Biomass prepared in this way was amended with sewage sludge, food waste (coffee grounds) and willow-derived biochar or effluent formed during the production of yeast (industrial waste).

Table 1. Substrate weight combinations

Treatment	M	MSS municipal sewage sludge	BC biochar	CG coffee grounds	E effluent
		kg DM			dm^3
M	29.3				
M+MSS	29.3	4.4			
M+MSS+BC	29.3	4.4	3		
M+CG	29.3			26.1	
M+CG+BC	29.3		3	26.1	
M+CG+E	29.3			26.1	100

The scheme of the experiment included 6 treatments: 1. control – maize straw (M), 2. maize straw + municipal sewage sludge (M+MSS), 3. maize straw + municipal sewage sludge + willow-derived biochar (M+MSS+BC), 4. maize straw + coffee grounds (M+CG), 5. maize straw + coffee grounds + willow-derived biochar

(M+CG+BC), 6. maize straw + coffee grounds + yeast effluent (M+CG+E). The weight ratios of feedstocks used in the experiment are shown in Table 1.

Maize straw may become a substrate for industrial composting if its parameters do not meet the requirements for obtaining energy, e.g. in the case of high moisture content. Due to the relatively high protein content and, above all, significantly higher content of digestible carbohydrates compared to other types of waste biomass, maize straw has a natural property of self-heating during the composting process (Skonecki *et al.* 2011).

The amounts of waste materials introduced into the composted maize biomass were limited not only due to their physical parameters, but also because of the humidity of the feedstock. The proportions of feedstocks used in individual treatments were, by weight of dry matter: M:MSS – 1:0.15; M:MSS:BC – 1:0.15:0.1; M:CG – 1:0.89; M:CG:BC – 1:0.89:0.1; M:CG:E – 1:0.89:0.07. After mixing the materials, moisture of the mixture was equilibrated to 60% by weight. Aeration of the biomass was performed in cycles, 6 times a day; air was flowing through the bioreactor at the rate of 15 dm^3 per minute for 60 minutes; the biomass was manually shifted every 10 days. In the course of the composting process, the outside temperature in the shadow and the temperature of the composed biomass (at half height of the composted matter) were recorded every 30 minutes using DT-171 data logger.

Chemical and physical analyses

In order to identify the properties of matter composted by aeration, dry materials were ground in a laboratory mill (1 mm sieve mesh diameter), then dried at 105°C for 12 hours (Jindo *et al*. 2012) and analysed. The pH of materials (material : water = 1 : 2.5) was determined electrochemically using a pH meter (pH–meter CP-505), electrical conductivity (material : water = 1 : 2.5) using a conductivity meter (Conductivity/Oxygen meter CCO-501) (Meier *et al*. 2015), and the contents of total nitrogen, carbon, oxygen and sulphur were determined using an elementary analyser (Vario MAX Cube, Elementar Analysensysteme 2013).

The physical properties of the composted biomass were analysed in samples collected in three replicates from the compost biomass, directly from the bioreactor, to 100 cm^3 cylinders. The following were determined in the analysed samples: field capacity (FC, pF 2.0) by pressure plate method, and bulk density. Solid phase density (GO) was determined by pycnometry. Total porosity (TP) was calculated basic on particle and bulk density. Air fIeld capacity (AC) was calculated as a difference between total porosity and water field capacity.

The ash content was analysed in feedstocks used in the process and in the material after composting. For this purpose, the above materials were annealed at 600°C, and their heat of combustion was determined using KL-12Mn calorimeter.

The heat of combustion was determined automatically taking into account the balance characteristic temperature (±0.001 K) and duration of cycles on the basis of PN-81/G-04513, PN-71/C-0462, PN-93/Z15008/04 and PN-ISO 1928 standards, as well as the following formula:

$$Qs = \frac{C(Dt - k) - c}{\mathrm{m}} \; [\mathrm{J\ g^{-1}}] \tag{1}$$

where: Qs – heat of combustion (J g^{-1}); C – thermal capacity of the calorimeter (J °C^{-1}); Dt – total temperature rise in the main period (°C); k – correction for heat exchange between the calorimeter and the surrounding environment (°C); c – total corrections for additional thermal effects (J); m – weight of solid fuel sample (g).

Analysis quality control and statistical analyses

Determinations in all the analysed samples were performed in three replicates. The accuracy of analytical methods was verified based on the certified reference materials and standard solutions: CRM IAEA/V – 10 Hay (International Atomic Energy Agency). The obtained data were compiled with the use of STATISTICA 12 (StatSoft Inc.). Variations in the properties were determined by calculating the standard deviation (± SD).

RESULTS AND DISCUSSION

Selected chemical and physiochemical properties of composts

The greatest dry matter losses during the composting process were determined in maize straw (M) (Tab. 2). In this treatment, 64% of dry matter was dispersed in the gaseous form. Dry matter loss was reduced in M+MSS and M+MSS+BC treatments amended with sewage sludge, which was due to, inter alia, increased content of minerals. In turn, the addition of biochar reduced dry matter loss during the process compared to the compost of M+MSS and M+CG treatments. Undoubtedly, biochar and coffee grounds are stable materials, less prone to changes during biological decomposition. An accumulation of the effects was observed after introducing yeast effluent into the composted matter: changes in the chemistry of the environment, reduced decomposition through narrowed diversity of microbiological decomposition, and reduced decomposition of stable carbon from coffee grounds. Together with the effluent, a fungi load was introduced, which dominated and reduced the process of organic matter decomposition.

The resulting composts had different values of electrical conductivity and pH (Tab. 2). The lowest electrical conductivity was observed for composts produced with coffee grounds. This is justified, since in this case a stable organic material (coffee grounds) had been previously extracted, which reduced the number of cations constituting carriers of electric charge. On the other hand, the highest electrical conductivity was found in M+CG+E treatment amended with yeast effluent and characterised by high salinity. In the case of maize straw (M), there was a decomposition of plant tissue, releasing mineral components. The addition of stable materials, such as biochar and coffee grounds, could have reduced the compost salinity. In practice, there is no need for significant "dilution" of composts with a large number of monovalent cations. However, situations may arise in which high salinity of composts, particularly from municipal waste, can cause an osmotic effect in crop plants. This necessitates the use of a lower dose of compost, and certainly, makes it necessary to mix it with substrate or introduce it into the soil relatively early to enable determination of ion balance of the soil solution. The study results revealed that coffee grounds acidified the composted biomass; however, the lowest pH value was determined in M+CG+E treatment, amended not only with coffee grounds, but also with yeast effluent (Tab. 2).

The data presented in Table 2 also indicate a very far-reaching composting process. In all treatments, an indirect indicator of compost stability – the C:N ratio – decreased about 3 times in relation to its value determined before composting. After the composting process, the C:N ratio ranged from 10.3 to 13.5, which indicated completion of the composting process. It was also concluded that the addition of biochar increased the C:N ratio after the composting process, compared to other treatments not amended with this material.

Table 2. Dry matter loss, electrical conductivity and pH of the produced composts

Treatment	Dry matter %	Process residue %	Ash g kg^{-1}	EC m S^{-1}	pH	C:N before the process	C:N after the process
M	35.1	36.0	188.9±9.4	6.78±0.20	7.89±0.20	37.3±0.9	12.6±0.2
M+MSS	32.4	39.7	272.6±10.3	4.86±0.18	7.96±0.18	28.3±0.8	10.3±0.2
M+MSS+BC	34.6	43.7	263.7±8.8	4.64±0.18	7.60±0.21	30.7±1.1	13.5±0.3
M+CG	40.2	45.8	136.3±5.4	2.78±0.08	7.01±0.19	27.9±1.2	10.9±0.4
M+CG+BC	42.1	52.3	125.1±4.9	2.70±0.11	7.33±0.12	29.2±1.3	12.2±0.3
M+CG+E	42.8	57.3	161.8±5.7	7.15±0.22	6.65±0.24	27.5±0.9	11.8±0.3

Changes in temperature during composting

The outside temperature reflected the meteorological conditions in the months in which the composting process was conducted. In the initial period, the ambient temperature of bioreactors (Fig. 1) was below 20°C, but between the 20th and

110th day of the process, the ambient temperature exceeded 20°C. During the summer months, maximum temperatures in the decade were above 30°C.

In maize straw treatments amended with sewage sludge (M, M+MSS, M+MSS+BC), in the first 10 days, the temperature increased to over 50°C and remained at a similar level for 30 days, indicating intensive microbiological processes present in the composted material during that period. Based on the temperature, it can be stated that the intensity of microbiological processes in these treatments was rapidly reduced after 30 days, and after 40 days the temperature inside the composted matter did not differ from the ambient temperature (Fig. 1).

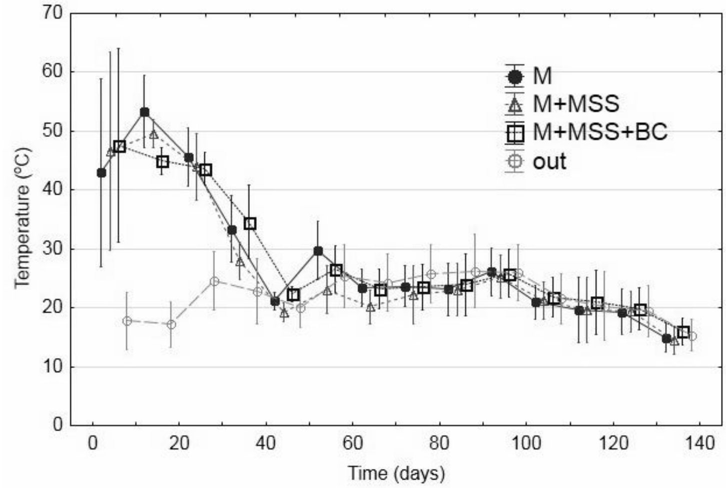

Fig. 1. Average (±SD) ambient temperatures in the decade and temperatures of the composted matter amended with sewage sludge

The composted materials amended with coffee grounds (Fig. 2) had significantly different temperature changes during the process that those amended with sewage sludge (Fig. 1). Mixtures with coffee grounds entered the phase of intense microbiological decomposition much slower, with the highest temperatures inside the composted material after 20 days, and only in the case of biomass with effluent (M+CG+E) an average temperature of over 50°C was reached. The microbiological processes in these treatments were much longer, as evidenced by temperatures of the composted materials. The temperatures measured in treatments amended with coffee grounds were similar to the ambient temperature only after 100 days of the process. Although the temperature in M+CG+E treatment was higher at the beginning, after 50 days of the process it was lower than in M+CG and M+CG+BC treatments. However, the effect of biochar addition to the composted material with sewage sludge or coffee grounds on the temperature inside the composted matter was not clear. Undoubtedly, the process dynamics is largely affected by the amount of available carbon in various substrate combinations (Ozimek and Kopeć 2012).

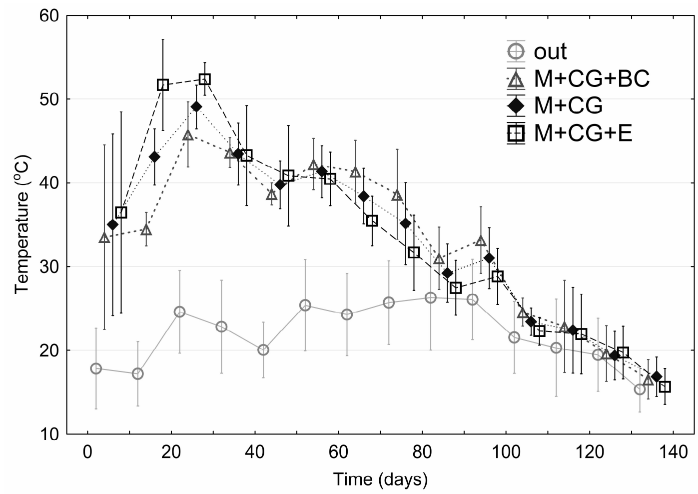

Fig. 2. Average (±SD) ambient temperatures in the decade and temperatures of the composted matter amended with coffee grounds

Physical parameters of composts

The physical properties of compost are of practical importance when it comes to their storage, transport and use. Based on the properties of compost, one can predict the properties of substrates for plant cultivation after the application of the compost. Certainly, the conclusions are indirect in nature, but have a sufficient degree of probability.

Compost derived from maize plant matter (M) had lower bulk density than composts produced with an addition of sewage sludge (M+MSS and M+MSS+BC) (Tab. 3). A small addition of willow-derived biochar in M+MSS+BC treatment slightly reduced the bulk density compared to the parameter value determined in M+MSS with no biochar added. Maize straw amended with coffee grounds confirmed the tendency of changes in this parameter. In practice, this means that the weight unit of compost amended with biochar has smaller volume than the weight unit of compost without biochar. The addition of yeast effluent introduced "a slime" as in the case of sewage sludge, which increased its bulk density.

Total porosity in the studied composts ranged from 83.02 to 88.37% (Tab. 3). Although the range of difference in this parameter was only 5.35%, it was found that the addition of sewage sludge reduced the total porosity, similarly to yeast effluent.

The air-filled and water porosity were largely dependent on the type of mixture subjected to the composting process (Tab. 3). The addition of biochar increased the air-filled porosity at the expense of field water capacity. Combinations with sewage sludge and yeast effluent were also characterised by higher air-filled porosity compared to combinations with coffee grounds. The addition of coffee grounds significantly increased the possibility of water retention by composts, similar as adittions of hydrogel (Baran *et al*. 2015). This parameter appears to be important in the context of the substrate retention properties for plants. The possibility of increasing water retention in the soil through the use of composts is of great practical importance.

Table 3. Water and air properties of composts

Treatment	BD	AP	FC	TP
	g cm^{-3}	%	%	%
M	0.194±0.001	42.04±0.09	45.05±2.06	87.09±2.39
M+MSS	0.255±0.003	39.67±1.88	43.35±4.95	83.02±3.61
M+MSS+BC	0.245±0.008	49.12±0.56	34.56±2.15	83.68±1.75
M+CG	0.188±0.003	25.44±0.20	62.00±0.14	87.44±0.31
M+CG+BC	0.174±0.007	29.29±0.46	59.09±0.27	88.37±0.16
M+CG+E	0.250±0.010	39.71±0.71	43.60±1.22	83.31±1.43

Each value represents the mean of three replicates ± standard deviation; BD – particle density, AP – air-filled porosity, FC – field water capacity, TP – total porosity

Some parameters relating to the porosity may result from blocking of the active surface of biochars during composting. Khan *et al.* (2016) observed that this results from the concentration of readily available elements invoked from the process feedstocks.

Elemental composition and heat of combustion

During the composting process, organic substances were converted and the number of inorganic components was increased. Materials used in the composting process and composts derived therefrom were characterised by very diverse elemental composition (Tab. 4). This was probably the result of not only the material itself, but also technological processes used during its treatment. Thermally converted materials, such as coffee grounds and biochar, had high heat of combustion and content of total carbon. In turn, composted materials amended with effluent contained significant amounts of sulphur, which may be problematic in thermal conversion of biomass. The elemental composition of composts was less diverse.

In the case of composts, reduced heat of combustion in treatments with sewage sludge was characteristic. This feedstock has the highest ash content (Tab. 2) and, in consequence, the value of the parameter was reduced in the derived products. The heat of combustion of composts also resulted from changes present during composting and the quality of the resulting organic compounds. The last factor could be of great importance for heat of combustion determined in M+MSS+BC treatment in which higher level of process residue (Tab. 2) was determined in relation to treatment M, at a similar carbon content (Tab. 4).

Table 4. Heat of combustion and elemental composition of feedstocks and composts

Material	Calorific value	N	C	H	S	O
	$kJ\ g^{-1}$	$g\ kg^{-1}$				
Maize straw (M)	13.63±0.51	10.6±0.2	393.4±15.1	6.2±0.5	0.20±0.01	41.6±0.2
Sewage sludge (MSS)	9.28±0.38	33.1±0.3	240.5±10.3	4.2±0.2	1.16±0.01	21.4±0.1
Biochar – willow (BC)	20.68±0.62	9.7±0.1	639.1±18.6	2.4±0.1	0.08±0.01	19.0±0.1
Coffee grounds (CG)	18.33±0.59	23.8±0.2	507.7±15.4	7.3±0.6	0.14±0.01	37.7±0.2
Yeast effluent	not analysed					
biomass before composting						
M	13.63±0.50	10.6±0.8	393.4±10.6	6.15±0.61	0.20±0.02	41.6±2.1
M+MSS	13.06±0.89	13.5±0.9	373.4±17.9	5.89±0.43	0.31±0.02	39.0±2.9
M+MSS+BC	13.68±0.80	13.2±0.9	393.6±18.3	5.62±0.46	0.32±0.03	37.5±3.6
M+CG	15.84±0.49	16.8±0.6	447.2±17.5	6.69±0.51	0.22±0.02	25.4±2.1
M+CG+BC	16.09±0.53	16.4±0.7	456.4±18.6	6.48±0.54	0.23±0.03	38.8±3.3
M+CG+E	15.31±0.51	17.1±0.7	449.0±19.8	6.71±0.55	0.43±0.04	30.6±3.2
biomass after composting						
M	12.41±0.41	31.6±0.6	365.6±14.1	5.21±0.41	0.34±0.02	35.8±0.8
M+MSS	11.16±0.38	34.6±0.5	332.4±12.4	4.90±0.46	0.63±0.03	30.5±0.9
M+MSS+BC	10.94±0.34	29.0±0.2	361.1±13.7	4.38±0.37	0.57±0.03	29.6±0.9
M+CG	12.73±0.35	41.0±0.7	417.8±16.7	5.50±0.54	0.29±0.02	34.7±0.8
M+CG+BC	14.49±0.38	37.5±0.7	442.2±15.3	5.47±0.61	0.27±0.02	33.7±0.7
M+CG+E	13.24±0.41	39.7±0.6	423.3±14.8	5.14±0.40	1.33±0.05	31.0±0.7

Coffee grounds added to the compost as a feedstock increased the heat of combustion of the compost. This was probably due to the lower ash content and higher carbon content in composts containing this material. Figure 3 shows regression analysis of the heat of combustion in relation to the ash content in composted materials. The relationship between the heat of combustion and organic dry matter content and total carbon and nitrogen in sewage sludge was also demonstrated by Iżewska *et al.* (2013).

The heat of combustion determined in composts was lower than the parameter determined in mixtures before the composting process (Tab. 4). During 140 days of the composting process, the heat of combustion was reduced, especially in the following treatments: M – 9%, M+MSS – 15%, M+MSS+BC – 20%, M+CG – 20%, M+CG+BC – 10% and M+CG+E – 17%. These changes are significantly lower than dry matter losses observed in this period (Tab. 2). The indication of compost management is relative. Compost is produced mainly because of its fertiliser value. This production requires energy expenditure, for instance, to introduce air into the composted mass. Therefore, the energetic use of such a product is unjustified. Studies confirmed that composts which do not meet the fertilising or sanitary requirements can still be combusted. The heat of combustion of the resulting composts was similar to the values determined for waste paper or certain municipal waste. On the other hand, Dominczyk-Kuderko *et al.* (2015) highlighted the importance of biological drying of waste in order to obtain biofuels which will be possible to store and have a satisfactory energy value.

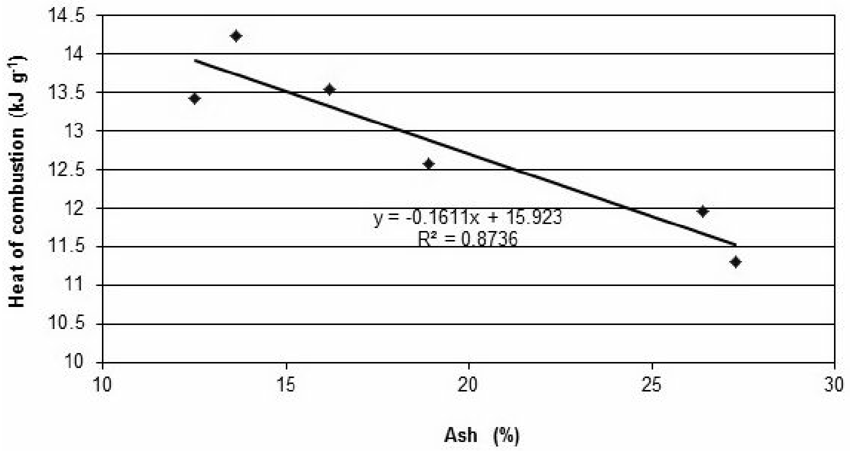

Fig. 3. Correlation between the gross heat of combustion of composts and ash content

CONCLUSIONS

The addition of biochar had no significant effect on the rate of maize straw composting; however, biochar-amended treatments showed a smaller loss of dry matter and higher C:N ratio. The use of biochar or coffee grounds in the composting process reduced bulk density of the compost. Maize straw amended with sewage sludge and, in particular, coffee grounds reduced air-filled porosity of composts. Sewage sludge reduced the heat of combustion of composts, which was closely related to the ash content.

REFERENCES

Baran A., Zaleski T., Kulikowski E., Wieczorek J., 2015. Hydrophysical and Biological Properties of Sandy Substrata Enriched with Hydrogel. Pol. J. Environ. Stud., 24(6), 2355-2362.

Boruszko D., Dąbrowski W., Grygorczuk-Petersons E., Magrel L., Wiater J., 2014. Low-cost methods of wastewater treatment and sewage sludge utilization. Civil and Environmental Engineering, 5(4), 135-142.

Dominczyk-Kuderko A., Krzystek L., Ledakowicz S., Pogoda M., 2015. Biologiczne suszenie mieszaniny masy pofermentacyjnej z biogazowni i organicznej frakcji stałych odpadów komunalnych. Inż. Ap. Chem., 54, 4, 150-151.

Elementar Analysensysteme GmbH., 2013. Operating instructions vario MAX cube pp. 407.

Głąb T., Gondek K., 2008. Effect of organic amendments on morphometric properties of macropores in stagnic gleysol soil. Polish J. of Environ. Stud., 17, 2, 209-214.

Iżewska A., Wołoszyk C., Sienkiewicz S., 2013. Assessment of physical, chemical and energetic properties of sludge in industrial and municipal sewage treatment plant. Scientific Papers of the University of Zielona Góra, ser. Environ. Eng., 152(32), 94-104.

Jakubek A., Piotr Boniecki P., Jacek Dach J., 2011. Research methodology and preparation of learning datasets for neural networks identifying compost quality. Agric. Eng., 1(126), 85-90.

Jindo K., Suto K., Matsumoto K., Garcia C., Sonoki T., Sanchez-Monedero M.A., 2012. Chemical and biochemical characterisation of biochar-blended composts prepared from poultry manure. Biores. Technol., 110, 396-404.

Karcz H., Kantorek M., 2014. Fluidized bed pyrolysis in thermal treatment of wastes. Industrial Furances & Boilers, 1, 26-37.

Khan N., Clark I., Sánchez-Monedero M.A., Shea S., Meier S., Qi F., Kookana R.S., Bolan N., 2016. Physical and chemical properties of biochars co-composted with biowastes and incubated with a chicken litter compost. Chemosphere, 142, 14-23.

Lim T.J., Spokas K.A., Feyereisen G., Novak J.M., 2016. Predicting the impact of biochar additions on soil hydraulic properties. Chemosphere, 142, 136-144.

Malińska K., 2013. Changes in Physical Properties of Materials During Laboratory Composting. Eng. Environ. Prot., 16(4), 523-536.

Meier S., Curaqueo G., Khan N., Bolan N., Rilling J., Vidal C., Fernández N., Acuna J., González M.E., Cornejo P., Borie F., 2015. Effect of biochar on copper immobilization and soil microbial communities in a metal-contaminated soil. J. Soils Sediments, 1-14.

Ozimek A., Kopeć M., 2012. Assessment of biological activity of biomass at different stages of composting process with use of the oxitop control measurement system. Acta Agroph., 19(2), 379-390.

Skonecki S., Potręć M., Laskowski J. 2011. Physical and chemical properties of agricultural wastes. Acta Agroph., 18(2), 443-455.

Zajonc O., Frydrych J., Jezerska L. 2014. Pelletization of Compost for Energy Utilization. IERI Procedia, 8, 2-10.

Zajonc O., Raclavská H., Juchelková D.,Volfová M. 2011. Energetyczne właściwości kompostu. Energetic properties of Compost. Journal of the Polish Mineral Engineering Society, 77-88.

WPŁYW PRZEBIEGU PROCESU KOMPOSTOWANIA NA ZMIANY FIZYCZNE I ENERGETYCZNE KOMPOSTU

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Streszczenie. Kompostowanie jest jedną z najpopularniejszych metod przetwarzania odpadów biodegradowalnych, a jego aplikacja do gleby ze względu na dużą zawartość węgla stanowi jeden z najracjonalniejszych sposób jego zagospodarowania. W przypadku, gdy kompost nie spełnia wymogów prawnych konieczne jest poszukiwanie alternatywnych sposobów jego wykorzystania, takich jak zastosowanie do celów energetycznych. Celem przeprowadzonych badań było wyjaśnienie zróżnicowania właściwości fizycznych, w tym energetycznych kompostów przygotowanych na bazie surowca roślinnego z dodatkami materiałów takich jak biowęgiel, osad ściekowy, fusy z kawy lub odciek z drożdży. Proces kompostowania prowadzono 140 dni. W analizowanych substratach i otrzymanych z nich mieszaninach oznaczono podstawowe właściwości chemiczne i fizyczne oraz ciepło spalania. Stwierdzono, że 10% dodatek biowęgla nie wpływał znacząco na tempo procesu kompostowania, jednak w obiektach z jego dodatkiem straty suchej masy były mniejsze, a stosunek C:N większy w porównaniu do pozostałych kombinacji. Zastosowanie biowęgla lub fusów z kawy jako dodatków w procesie kompostowania przyczyniło się do zmniejszenia gęstości objętościowej kompostowanej biomasy. Dodatek osadu ściekowego oraz fusów z kawy do słomy z kukurydzy zmniejszał porowatość powietrzną kompostów. Udział biowęgla w kompoście ograniczał tę tendencję. Oznaczone w kompostach ciepło spalania było mniejsze w stosunku do wartości tego parametru oznaczonego w mieszaninach przed rozpoczęciem procesu kompostowania. Stwierdzono, że osady ściekowe wpływały na zmniejszenie wartości ciepła spalania kompostów, które pozostawało w ścisłej zależności z zawartością popiołu.

Słowa kluczowe: biowęgiel, kompost, porowatość, gęstość, ciepło spalania