Co-composting as an oxygen stabilization of an organic fraction of municipal solid waste and industrial sewage sludge

M. Milczarek, E. Neczaj and K. Parkitna

ABSTRACT

The purpose of this work is to study the characteristics of the co-composting of municipal solid waste (MSW), sewage sludge, grass and sawdust. Differing proportions of biodegradable waste were investigated through changes of temperature, oxygen consumption, organic matters, moisture content, carbon, nitrogen, C/N ratio as well as heavy metals and pathogen microorganisms content. The present study has shown that addition of MSW above 10% had a negative impact on the composting process. The initial C/N of the mixtures with a higher MSW content was below 18. Lower losses of organic matter occurred during composting for the mixture with the highest addition of MSW. Although studies have shown that composting is a good method for the disposal of organic waste additional research is required in order to optimize the organic and nitrogen compounds degradation during the co-composting process. In conclusion, a 1:4:4:1 mixture of MSW:sewage sludge:grass:sawdust is recommended because it can achieve high temperature as well as the highest organic matter degradation and highest N content in the final composting product. The concentration of heavy and light metals in all composts was within the limits of regulation of the Polish Minister of Agriculture and Rural Development.

Key words | compost, meat industry, organic wastes, sewage sludge

INTRODUCTION

The meat industry in Poland is currently made up of about 3,500 businesses but in comparison with the countries of Western Europe is highly fragmented. The businesses vary in size (from large conglomerates producing more than 10,000 Mg/year to small family companies) as well as activity profile (slaughter houses from processing and slaughter houses only) (Olszewski 2002; Bartkiewicz 2007). Meat industry plants are seen as a place where it is difficult to purify industrial wastewater with high organic load, nutrients and high concentration slurry and inorganic salts. This leads to the formation of sludge of a similar nature. The presence of phosphorus in the sludges is due to its content in the faeces of animals. Another source is detergent used for washing equipment and work surfaces. These sludges are also dangerous in terms of epidemiology, because they contain pathogenic microorganisms from the digestive systems of animals for slaughter (Konieczny & Szymański 2007). Land application of sewage sludge is of great interest in view of its fertilizer and soil amendment, unless it contains toxic compounds. The heterogeneous nature of biosolids produced in different wastewater treatment plants necessitates knowledge of the chemical and biological properties of sewage sludge prior to the land application (Sikorski & Bauman-Kaszubska 2008). Although the meat-packing wastewater sludge (as well as other food industries) does not contain toxic substances, it does include enormous amounts of organic substances, which can be successfully composted (Mizgajski & Andrzejewska 2006). Sludge composting and using them in agriculture should be a priority for their development. The properties of fertilizer are the main criteria for its use in soil. (Tomczak-Wandzel et al. 2004; Konieczny & Szymański 2007). The need for alternative methods of managing industrial sewage sludge has revived interest in composting. Composting is a method of solid waste management whereby the organic component of the solid waste stream is biologically decomposed under
controlled conditions to a state in which it can be handled, stored, and applied to the land without adversely affecting the environment. It is a preferred treatment method for industrial sewage sludge and municipal waste from both an ecological and economical standpoint, as it not only reduces the volume of the material in the waste stream but also converts it into a valuable resource. Most modern composting operations consist of three basic steps: (1) processing of the municipal solid waste (MSW); (2) decomposition of the organic fraction of the MSW (OFMSW); and (3) preparation and marketing of the final compost product. The success of these operations depends, to a large extent, on proper accomplishment of the decomposition step. During this step, the biodegradable portion of the organic fraction of MSW is decomposed by a variety of microorganisms that utilizes the organic matter as a carbon source. In general, the chemical and physical characteristics of compost vary according to the nature of the starting material, the condition under which the composting operation was carried out, and the extent of the decomposition. The rate of organic matter biodegradation is influenced by several variables which can fall into two general categories: (1) those that determine the availability and concentration of the compound to be degraded or that affect the microbial population size and activity; and (2) those that directly control the reaction kinetics itself, such as population size, temperature and moisture content (Kuleu & Yaldiz 2004; Saludes et al. 2007; Sikorski & Bauman-Kaszubska 2008). The composting process occurs more efficiently when the carbon-to-nitrogen (C/N) ratio is between 30 and 40 and the moisture content is between 50 and 65% (Agnew & Leonard 2003; Janowska & Siebielska 2008). MSW usually has the characteristics of an incompact structure and high C/N ratio, whereas sewage sludge usually has a dense structure, due to its high moisture content, and low C/N. Sewage sludge is a good candidate for composting since its organic matter content can vary from 45 to 80% of the total solid content. The high moisture content of sludge means that it cannot be composted alone and requires a large amount of bulking agent (such as sawdust, vegetal remains, straw) to absorb moisture and increase the C/N ratio (Iranzo et al. 2004; Tremier et al. 2009). MSW could act as a bulking agent for sewage sludge due to its loose structure and high C/N ratio. Therefore, mixing MSW and sewage sludge can improve the structure and C/N ratio and increase the nitrogen content of MSW for the compost product. Marek et al. (2003) have shown that only a small part of sewage sludge could be composted because of inadequate properties of the raw mixture (moisture, porosity and C/N ratio) with higher volumetric ratio between sewage sludge and other organic wastes. However, several studies (Huang et al. 2004; Zhu 2007; Kumar et al. 2010) found that composting can also be effective at C/N ratios lower than 20.

Despite many previous studies on MSW or sewage sludge composting, little information on the characteristic of the co-composting of MSW and sewage sludge is available. The objective of this work was to develop quantitative relationships between physical properties of the composting material and the performance of the composting process. Industrial and municipal wastes were used as raw materials for the preparation of compost mixtures.

MATERIALS AND METHODS

Materials

Raw materials used for this study were collected from a regional municipal landfill, and a Silesian region meat plant. Sawdust and green waste in the form of grass were used as a co-substrate for composting experiments. The mixtures for the co-composting process were prepared by adding different quantities by weight of co-substrates:

- Sample I – 10% MSW, 40% sewage sludge, 40% grass, 10% sawdust.
- Sample II – 10% MSW, 30% sewage sludge, 50% grass, 10% sawdust.
- Sample III – 40% MSW, 10% sewage sludge, 40% grass, 10% sawdust.
- Sample IV – 50% MSW, 10% sewage sludge, 30% grass, 10% sawdust.

Characteristics of the raw materials are detailed in Table 1.

Analytical methods

A laboratory-scale composting system as shown in Figure 1 was used for this study. The experiment lasted over the period of 30 d using an insulated closed batch reactor with the volume of 45 dm³. For insulation purposes, the sides of the reactor were wrapped with 5-cm thick layers of foam. The experimental work was conducted at room temperature. Atmospheric air was pumped into the reactor using a valve and a rotameter to control the airflow. The exhaust gas was cooled down to ambient temperature by passing it through a condensation arrangement. The air outlet was analysed with...
a gas analyser GA2000 (Geotechnical Instruments, UK), which enabled the measurements of O₂, CO₂ and NH₃ emission.

The pH was measured potentiometrically in the supernatant suspension of a 1:10 compost:water mixture. For moisture content determination, a given sample was weighed in a crucible and put into an oven heated at a temperature of 105°C overnight and reweighed. The difference in weight was expressed at the amount of water in the sample and was used to determine the moisture fraction of the material. The oven-dried sample was further heated at 550°C for 4 h for the determination of volatile solids. Organic carbon in each sample was measured using a total organic carbon (TOC) analyser (Analytik Jena Multi N/C 2100). Total soluble N was extracted by the Kjeldahl digestion method using BüchiDistillation Unit K-335 equipment, followed by distillation and determination of NH₄-N using titrimetric procedures. Total P was extracted by the ammonium vanadate–molybdate method and the concentration in the sample was read on a spectrophotometer at 470 nm (Hermanowicz et al. 2013). All compost digestates were analysed for the total content of heavy metals by inductively coupled plasma mass spectrometry (Optima 200 DV), after digesting the samples with a mixture of concentrated HNO₃ and HCl (1:3 v/v) in a microwave digester. The population sizes of Salmonella spp. were determined on selective media specific for each microbial group. The number of helminth eggs was determined following Schwartzbrod (2003). Data collected were analysed using SAS software. The results have been presented as average and standard deviation.

**RESULT AND DISCUSSION**

**Carbon dioxide, oxygen, and temperature**

Carbon dioxide production and oxygen consumption are very useful parameters for monitoring of the composting process (Treimer et al. 2009). The temperature must be positively correlated with CO₂ production and negatively with O₂. A negative correlation between O₂ and CO₂ has been observed for all the mixtures (Figure 2). Oxygen concentration in the exhaust should be maintained between 10 and 18% (v/v) to optimize biological composting (Megalhes et al. 1993). The period in which the consumption of oxygen decreased and then increased corresponded to the period in which the temperature was high and the thermophilic condition was observed, which is consistent with the results.
obtained by Yamada & Kawase (2006). The oxygen concentration in the outlet air during composting decreased sharply during the first day, from ca 20% to ca 14% for Samples I, III, IV respectively, and from 19.5 to 16.5% for Sample II; a slowly fluctuating increasing trend was observed thereafter. However, in an experiment conducted by Lashermes et al. (2012) where digested sewage sludge mixed with branches, grass clippings, privet hedge trimmings and leaves were composted, the O₂ concentration in the outlet gas slightly diminished over the first 2 weeks and remained constant thereafter providing evidence of aerobic conditions. A significant decrease in O₂ concentration during the first day of pig faeces and corn stalks composting, from 21% to 2–6.3%, was also observed by Guo et al. (2012). This was probably associated with increases in free air space along the process, which facilitates aeration and, thus, oxygen supply (Baptista et al. 2010). Nevertheless, the oxygen content was over 10% during the whole experiment, indicating that 0.3 dm³ d.m. (dry matter) kg⁻¹ min⁻¹ does provide sufficient oxygen for the microorganism’s requirement.

Carbon dioxide was mainly emitted during the thermophilic period because of biodegradation of easily degradable carbon (Petric et al. 2012). The carbon dioxide concentration in the outlet air during composting was significantly correlated to its temperature; hence it might be used as another indicator for monitoring the composting process. The mass of the produced CO₂ significantly increased in all reactors during the first 3 d (Figure 2). After the third day, easily degradable organic matter was degraded and the amount of produced carbon dioxide was reduced. The carbon dioxide profile in the outlet from Sample III was different from the other samples during days 3 to 20, where the CO₂ concentration decreased sharply from day 7, increased to day 16, and again decreased thereafter.

The temperature regimes of the composting reactors containing different mixtures are illustrated in Figure 3. Three typical phases of composting were observed during the process for all mixtures: (I) a short initial mesophilic phase (T < 55°C) lasting approximately 2 d; (II) a thermophilic phase during which the temperature increased (T > 55°C) from days 2 to 7. During phase II, temperature of Sample I reached a maximum value of 69.9°C at day 4; for Sample II, the higher temperature of 71.7°C was observed at day 3. The temperature of Samples III and IV was the highest on days 4 (70.1°C) and 3 (71.4°C) respectively. After the easily degradable compounds were depleted, the composting...
entered the curing phase (III) where the temperature slowly dropped.

It is well documented that the duration of the thermophilic phase depends on the chemical composition and adjustment of the parameters used to the optimal values (Huang et al. 2004). Bié et al. (2011) optimized the thermophilic phase of the composting process. The best results were obtained in mixtures with the highest share of green waste, also confirming the possibility of adjusting the phase by changing the proportion by weight of waste in the mixture. In our experiment, after 30 d of composting, the temperature maintained a stable level in all the mixtures. The temperature profile for Samples I and II was similar and achieved a value of 21°C. For samples with higher addition of MSW (Samples III and IV), the temperature was six degrees higher. There are many factors that have an impact on the course of temperature evolution during composting. One of them is a suitable C/N ratio (Li et al. 2011). A C/N ratio between 25 and 30 is usually considered as an optimum ratio for composting; however, it is possible to carry out the process at lower C/N (Kumar et al. 2010). The C/N ratio in Sample I (28.2) and II (23.68) was significantly higher than in Sample III (17.78) and IV (15.1), probably due to a higher sewage sludge concentration and lower MSW content as well as grass addition in the mixtures.

The TOC contents of all treatments decreased during the composting process (Figure 4). The TOC evolution in Samples I, II and III indicated that mineralization was incomplete: only a total of 10–13% of the initial TOC was lost during composting. A very low TOC reduction was observed for Sample IV with a higher MSW addition, around 2%. Different results were obtained by Lu et al. (2009). These authors have shown that with higher addition of MSW (90%) it is possible to achieve TOC reduction of around 28%. For the optimal MSW and sewage sludge mixture composition they obtained TOC reduction of 29%.

The changes in concentrations of NH₄-N followed the typical trends for this form of nitrogen during aerobic composting (Figure 5). During the first 7 d of composting, NH₄-N contents of all samples increased significantly and reached peak values due to ammonification with an increase in temperature and pH, as well as the mineralization of organic-N compound (Mahimairaja et al. 1994; Fang et al. 1999). After an initial increase, NH₄-N contents decreased by volatilization loss and immobilization by microorganisms. The final NH₄-N contents of Sample I was 1.78 g/kg d.m., Sample II was 1.49 g/kg d.m., Sample III was 1.87 g/kg d.m. and Sample IV was 2.2 g/kg d.m. This was mainly due to the higher N content in Sample IV with a lower C/N. It has been noted that the absence of or decrease in NH₄-N is an indicator of a good composting and maturation process (Huang et al. 2004). High NH₄-N concentrations in compost indicate instability (Sánchez-Mondero et al. 2001). The maximum NH₄-N content in mature compost should be less than 0.4 g/kg d.m. (Zucconi & de Bertoldi 1987).

The changes in nitrate nitrogen through the study period are shown in Figure 5. The concentration of nitrate nitrogen continued to increase throughout the composting time. The nitrate nitrogen content was about zero initially, which kept on increasing as the reaction proceeded until the end of the experiment. Only little nitrification was observed under the thermophilic conditions. An NH₄-N/NO₃-N ratio of less than 0.16 has been established as a maturity index for composts of various origins, including pig slurry, poultry manure, municipal refuse and sewage sludge (Bernal et al. 2009). In this study, the NH₄-N contents were clearly higher than the NO₃-N contents and the NH₄-N/NO₃-N ratios ranged from 2.98 to 3.66. After 56 d of composting swine manure with corncob, Zhu (2006) measured final NH₄-N/NO₃-N ratios of 9.13–48.33, while after 63 d of composting swine manure with rice straw the ratios were about 5.47–6.93 (Zhu 2007), although both composts were mature. Therefore, the NH₄-N/NO₃-N ratio may not be suitable as a maturity index for pig manure composts, and this should be further studied.

**Effect of waste mixing ratios on co-compost quality**

During the composting process, organic matter is decomposed and transformed to stable humic compounds. Humic substances have a capacity to interact with metal ions and the ability to buffer pH and to act as a potential...
source of nutrients for plants. The changes in main chemical parameters during the composting are shown in Table 2. The moisture content affects the microbial activity directly, the compost temperature, and hence the rate of decomposition. The optimal moisture content for composting is at high C/N ratio of around 55–60% (Liang et al. 2003). At the beginning of the composting process the moisture content was about 64.7% for Sample I and 66.6% for Sample II, while it was higher for Sample III and Sample IV at 69.2 and 68% respectively. The moisture content decreased continuously to the end of the observation period. It can be noted that the initial moisture content was too high in all samples as well as in the final product.

The contents of organic matter decreased by translating into carbon dioxide and water in all treatments after composting for 30 d. The organic matter evolution showed the same low level of 10% in Samples I, II, and III. A lower loss of organic matter was observed for the mixture with

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sample I Initial</th>
<th>Sample I Final</th>
<th>Sample II Initial</th>
<th>Sample II Final</th>
<th>Sample III Initial</th>
<th>Sample III Final</th>
<th>Sample IV Initial</th>
<th>Sample IV Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content [%]</td>
<td>64.7 ± 1.2</td>
<td>45.9 ± 1.4</td>
<td>66.6 ± 1.0</td>
<td>47.2 ± 1.0</td>
<td>69.2 ± 1.5</td>
<td>50.3 ± 1.3</td>
<td>68.0 ± 1.7</td>
<td>49.8 ± 1.3</td>
</tr>
<tr>
<td>Dry matter [%]</td>
<td>35.3 ± 2.0</td>
<td>54.1 ± 3.6</td>
<td>33.4 ± 2.1</td>
<td>52.8 ± 1.7</td>
<td>30.8 ± 1.1</td>
<td>49.7 ± 1.9</td>
<td>32.0 ± 2.2</td>
<td>50.2 ± 3.2</td>
</tr>
<tr>
<td>Organic matter [%]</td>
<td>73.18 ± 2.0</td>
<td>65.7 ± 2.3</td>
<td>80.7 ± 3.1</td>
<td>72.63 ± 2.3</td>
<td>83.27 ± 3.1</td>
<td>74.9 ± 2.9</td>
<td>79.0 ± 3.6</td>
<td>71.1 ± 2.7</td>
</tr>
<tr>
<td>pH</td>
<td>6.6 ± 0.0</td>
<td>6.5 ± 0.1</td>
<td>6.7 ± 0.0</td>
<td>6.8 ± 0.1</td>
<td>6.6 ± 0.0</td>
<td>6.7 ± 0.1</td>
<td>6.5 ± 0.1</td>
<td>6.6 ± 0.0</td>
</tr>
<tr>
<td>C [% d.m.]</td>
<td>36.7 ± 0.6</td>
<td>31.1 ± 0.8</td>
<td>37.89 ± 0.7</td>
<td>33.3 ± 0.6</td>
<td>33.78 ± 0.9</td>
<td>30.1 ± 0.9</td>
<td>27.16 ± 1.0</td>
<td>26.7 ± 0.8</td>
</tr>
<tr>
<td>Kjeldahl N [% d.m.]</td>
<td>1.3 ± 0.7</td>
<td>1.4 ± 0.6</td>
<td>1.6 ± 0.3</td>
<td>1.7 ± 0.0</td>
<td>1.9 ± 0.2</td>
<td>2.1 ± 0.1</td>
<td>1.8 ± 0.3</td>
<td>1.9 ± 0.5</td>
</tr>
<tr>
<td>P [% d.m.]</td>
<td>2.6 ± 0.2</td>
<td>2.21 ± 0.0</td>
<td>2.79 ± 0.1</td>
<td>2.43 ± 0.0</td>
<td>2.0 ± 0.2</td>
<td>1.8 ± 0.0</td>
<td>1.7 ± 0.1</td>
<td>1.65 ± 0.0</td>
</tr>
<tr>
<td>K [% d.m.]</td>
<td>6.7 ± 0.6</td>
<td>5.24 ± 0.4</td>
<td>5.9 ± 0.5</td>
<td>5.71 ± 0.5</td>
<td>6.35 ± 0.63</td>
<td>7.39 ± 0.7</td>
<td>5.3 ± 0.5</td>
<td>4.99 ± 0.4</td>
</tr>
<tr>
<td>C/N ratio</td>
<td>28.2 ± 0.1</td>
<td>22.2 ± 0.8</td>
<td>23.68 ± 0.9</td>
<td>19.6 ± 0.9</td>
<td>17.78 ± 1.4</td>
<td>14.3 ± 0.8</td>
<td>15.1 ± 0.7</td>
<td>14.05 ± 0.5</td>
</tr>
</tbody>
</table>

Figure 5 | Changes in N-NH4 and N-NO3 during composting process.

Table 2 | Initial material mixture and co-compost quality for various options tested
the highest addition of MSW (Sample IV). Lu et al. (2009) also observed that the organic matter evolution showed higher losses and higher biodegradability in mixtures with smaller amounts of MSW. The C/N ratio was used by many authors as one of the most important indicators of compost maturity. However, it cannot be used as an absolute indicator of compost maturity due to its large variation depending on composted materials (Mathava et al. 2010). The C/N of all mixtures decreased during the composting process although it did not reach low enough values typical for mature compost. The final C/N of the mixture I with a sewage sludge content of 40% was the highest of the four ratios, because the initially higher C/N resulted in a final higher C/N during the composting process (Woo-Jung & Scott 2005). The yieldahl N concentration in the composting mass remained constant during composting or even increased in all composts by the end of the process. The increase measured in all of the samples was due to loss of weight in the mass being composted as a result of organic matter degradation (Huang et al. 2004; Banegas et al. 2007; Vlyssides & Barampouti 2010). A decrease of total P content was observed at the end of the process; the loss of organic P is likely due to the mineralization of organic phosphorus and the consumption by microorganisms (Jedrczak 2007; Janowska & Siebielska 2008; Bien et al. 2010).

The changes in chemical parameters of the different MSW:sewage sludge:grass:sawdust ratios indicate that 1:4:4:1 could achieve the highest organic matter degradation and highest N content in the final composting product. The heavy metal concentration in the final product deserves consideration since heavy metals may enter the food chain when the digested products are applied on land. The initial and final metal concentrations compared with the maximum recommended values in the Polish regulations are shown in Table 3.

The concentration of cadmium was low in all samples and decrease of Cd content was observed in all the final products. The maximum reduction in the Cd content (from initial 3.2 to final 2.0 mg/kg d.m.) was observed in the sample with the highest content of sewage sludge. The decrease in total concentration of cadmium was probably due to losses caused by leaching during the process. Cadmium is one of the most bioavailable and soluble metals. The highest content of sewage sludge in the mixture (Sample I) had an effect on the concentration of other metals in the compost. There was observed a decrease in the concentration of Cr, Ni, and Pb in composts, which indicates the likely presence of leachable forms and their passage to the leachate. In other attempts the concentration of lead was reduced only in the case of a mixture containing the highest proportion of MSW from 30.2 to 25.1% (Bien et al. 2010, 2011). As shown in the research of Singh & Kalamdhad (2013), the mobility of metals and their bioavailability depend strongly on their specific chemical forms or ways of binding, rather than total concentration. In other cases (Sample I, II and III) an increase in the concentration of metals in composts was observed. Sample III with a high proportion of grass (40%) and OFMSW (40%) had the highest percentage increase of concentrations of Cr, Ni and Pb, of 23.9, 18.4 and 31.9% respectively. The heavy metals were concentrated during the composting process due to weight loss in the course of composting following organic matter decomposition, release of CO2 and water, and the mineralization process (Zorpas et al. 2000; Singh & Kalamhad 2012). Generally in the samples with the highest content of sewage sludge, metals probably occurred as leachable forms. The obtained results during the experiment show that the concentrations of heavy metals in all composts were within the limits of the regulation of the Polish Minister of Agriculture and Rural Development.

One of the problems posed by the direct use of composted sewage sludge and an organic fraction of MSW in agriculture is the risk of plant and human contamination by pathogens. During the composting process, Salmonella and a number of live helminth eggs were determined in samples taken at the initial and final stage of the composting process (Table 4). Salmonella is considered as the most

<table>
<thead>
<tr>
<th>Table 3</th>
<th>The heavy metals concentration in the final compost</th>
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<tbody>
<tr>
<td>Metal [mg/kg d.m.]</td>
<td>Limits imposed by Polish regulations (Dz.U. 2008, No.119, poz.765)</td>
</tr>
<tr>
<td>Cd</td>
<td>5</td>
</tr>
<tr>
<td>Cr</td>
<td>100</td>
</tr>
<tr>
<td>Ni</td>
<td>60</td>
</tr>
<tr>
<td>Pb</td>
<td>140</td>
</tr>
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specific and problematic microorganism from a hygienic point of view, since it is a universal bacterium with a high growth capacity. Although the presence of *Salmonella* was detected initially in all samples, it was not detected in the final samples of all experiments.

The results show that all initial samples are infected with helminth eggs but there is a large variation in the degree of infection for the different sludge samples (143–53 eggs/kg d.m.). In our research the inactivation of the helminth eggs in the compost can be accomplished, if the temperature inside the reactor is sufficient as in the case of Sample III and Sample IV. The high concentration of helminth eggs contained in Samples I and II could not be inactivated by the high level of temperature. Literature data showed that helminth eggs could survive with such moisture content as in biosolids stored in the environment (Gallizzi 2003; Kone 2007; Bień 2010). As shown in Table 4, it can be concluded that the inactivation of the helminth eggs will take place if the amount of sewage sludge is low, as with Samples III and IV. Gallizzi (2003) composted faecal sludge mixed with sawdust. The results of that research showed that the inactivation of all eggs is possible when the temperature of the compost heaps exceeds 45 °C for at least 5 d. Kone *et al.* (2007) observed excellent removal efficiency of *Ascaris* eggs in their study, which can be attributed to the good temperature pattern. They composted faecal sludge mixed with organic wastes; the viability of *Ascaris* eggs was reduced from 58% to less than 20 and 10% within 40 and 60 d, respectively. However, our results have shown that composting cannot be regarded as a method of waste hygienization. The resulting compost should be subjected to chemical treatment (for example, liming) to remove hazardous organisms.

**CONCLUSIONS**

In this experiment four different mixtures were composted containing sewage sludge from the meat industry, organic fraction of MSW, grass and sawdust. The obtained products were characterized by a low content of heavy metals; attempts III and IV were characterized by total hygienization and nutrient content falling within the requirements of the Minister of Agriculture in Poland. However, our results have shown that composting cannot be regarded as a method of waste hygienization. The present study has shown that addition of MSW above 10% had a negative impact on the composting process. The initial C/N of the mixtures with a higher MSW content was below 18. Lower losses of organic matter during composting were observed for the mixture with the highest addition of MSW (Sample IV). Although studies have shown that composting is a good method for the disposal of organic waste, additional research is required in order to optimize the organic and nitrogen compounds’ degradation during the co-composting process. In conclusion, a 1:4:4:1 mixture of MSW:sewage sludge:grass:sawdust is recommended because it can achieve high temperature as well as the highest organic matter degradation and highest N content in the final composting product.

It should be noted that each batch of waste has a different composition, and physico-chemical analysis is required before each preparation and introduction of the mixture into the bioreactor. An extremely important aspect of the management of organic waste is installation costs. The method that is described in this paper is one of the cheapest. This allows for a complete waste disposal problem by creating the possibility of there use in nature.

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