The impact of different bulking agents and amendments on organic matter and nitrogen transformations during sewage sludge composting

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Composting of organic waste materials, including sewage sludge, is a form of organic recycling and has a great application importance. However, because of low porosity, high moisture and low C/N ratio, unfavorable for composting, sewage sludge cannot be composted alone. In order to improve the structure and porosity, moisture and the C/N of the feedstock, sewage sludge is mixed with bulking agents and amendments. Usually, these are lignocellulosic waste in the form of bark, sawdust, green waste, cereal straw and wood chips. The addition of these materials into sewage sludge affects the chemical composition of the feedstock and the rate of organics mineralization and then humification, which is related to the availability of precursors for humus synthesis.

In this study, sewage sludge was composted with lignocellulosic waste in a two-stage system (1^o aerated bioreactor, 2^o windrow). The aeration intensity was maintained at 0.5-1.5 l/(kg d.m.·min) in such way as to prevent overheating of the compost. The research was conducted with a constant share of sewage sludge (65%) and bulking agents in the form of wood chips (12%). As amendments, rapeseed/barley straw was added, which, compared to wood chips, contains much more cellulose and less lignin, and grass. In particular series, the share of amendments were as follows: 23% rapeseed straw (RS, series 1), 15% rapeseed straw and 8% barley straw (RS+BS, series 2). In series 3, in addition to rapeseed straw (8%), grass (15%) was introduced (RS+G).

During composting in the bioreactor, in series with a high share of straw (RS; RS+BS) thermophilic conditions were already noted after 3 days from the start of the experiment, with a maximum temperature of 68-70ºC. In series with grass (RS+G), the maximum temperature in the bioreactor did not exceeded 43ºC. This means that thermophilic conditions necessary for sludge hygienization were obtained with wood chips as bulking agents and straw as amendments. Replacing part of the straw with grass turned out to be unfavorable: thermophilic conditions were not obtained. The different course of the temperature profiles resulted in differences in the activity of microorganisms in the mineralization phase as a result of the different C/N ratio in the feedstock (the C/N ratio in straw is higher than in grass) and differences in porosity caused by the addition of straw. Rapeseed straw, which is an amendment, due to its high carbon and low nitrogen content, also acts as a bulking agents because it improves porosity. The use of grass instead of straw could limit the free flow of air in the reactor and, as a result, the amount of heat obtained during mineralization.

In the feedstock, the highest content of organic matter (ca. 710 g/kg d.m.) was recorded with 23% share of rapeseed straw, and the lowest (605 g/kg d.m.) with 8% share of rapeseed straw and 15% share of grass. The concentration of humic acids in all feedstocks was approx. 60 mg C/g OM.

During composting in a bioreactor, the highest losses of organic matter (OM) (146.4 g/kg d.m.) reported for feedstock containing 23% rapeseed straw. A slightly lower OM loss was noted for RS+BS, while in series with grass (RS+G), losses were only 54.7 g/kg d.m. After 120 days of composting (bioreactor and windrow), the largest losses of OM (232-241 g/kg d.m.) were obtained during composting of sewage sludge with 23% of straw. These experiments also showed the highest increase in humic acids (90-94 mg C/g OM). After replacing part of the straw with grass (RS+G), organic matter losses was lower (131 g/kg d.m.) as well as increase in humic acids (36.4 mg C/g OM). The reason for the low increase in humic acids in this series was lower mineralization rate of organics in the bioreactor. At a low rate of mineralization, thermophilic conditions were not obtained. This disturbed the proper succession of microorganisms in the compost and reduced the production of humic acids. Thermophilic conditions are necessary to initiate the degradation processes of cellulose and lignin with the participation of fungi and actinomycetes, which are then continued in the cooling phase, leading to the formation of humus. The addition of bulking agents and amendments to sewage sludge changes the chemical composition and the proportions between readily and hardly biodegradable compounds in the feedstock. The consequence of this is a change in the availability of organic compounds, which affects the temperature profiles and the succession of microorganisms. As a result, the composition of composted waste affects the content of humic acids.

During composting, the greatest increase in the concentration of ammonium nitrogen is noted in the mineralization phase, when the decomposition of organics is the most intensive. Along with the decrease in the rate of organic matter decomposition, the concentration of ammonium nitrogen decreases, mainly as a result of the release of ammonia from the compost or its oxidation to nitrate nitrogen. Ammonia release processes take place intensively in thermophilic conditions and at high pH (pH>8.0). Nitrification, leading to an increase in the concentration of oxidized nitrogen forms, begins after the temperature is lowered to approx. 40°C. In the mature compost, the concentration of nitrate nitrogen is higher than the concentration of ammonium nitrogen. In this research, ammonia losses were estimated on the basis of nitrogen balance. Intense ammonia blowing was noted during the first day of mineralization: high temperature (thermophilic conditions) and alkaline reaction (> 8.5 pH) caused the balance to shift towards the formation of free form of ammonia, which was released from the compost. The largest cumulative loss of nitrogen (up to 46%) was recorded with 23% share of straw in the feedstock and the lowest (ca. 32%) during composting of sewage sludge containing rapeseed straw (7%) and grass (15%), where the maximum temperature was 43.5ºC. In all series, an increase in the concentration of nitrate nitrogen was noted. At the beginning of composting, the concentration of nitrate nitrogen was low, and a significant increase in the concentration of nitrate nitrogen took place in the cooling phase. In the water extract, apart from nitrate nitrogen, there was also nitrite nitrogen, and its maximum concentration ranged from 127.7 mg/kg d.m. to 246 mg/kg d.m., which indicates that hypoxic conditions could have occurred, or there was an inhibition of bacteria that oxidized nitrite nitrogen to nitrate nitrogen. Next, complete oxidation of nitrite nitrogen took place and in the mature compost, among the mineral forms of nitrogen, nitrate nitrogen dominated, and the concentration of ammonium nitrogen did not exceed 200 mg/kg d.m.

To conclude, composting of sewage sludge is in line with the assumptions of the National Waste Management Plan in Poland (2014 along with subsequent updates), according to which the most important goals in municipal sewage sludge management are: reducing the amount of sewage sludge that are landfilled; increasing the amount of municipal sewage sludge that are processed before introducing into the environment; maximizing the degree of use of nutrients contained in sludge while meeting the requirements for sanitary, chemical and environmental safety.

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