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

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Introduction

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.

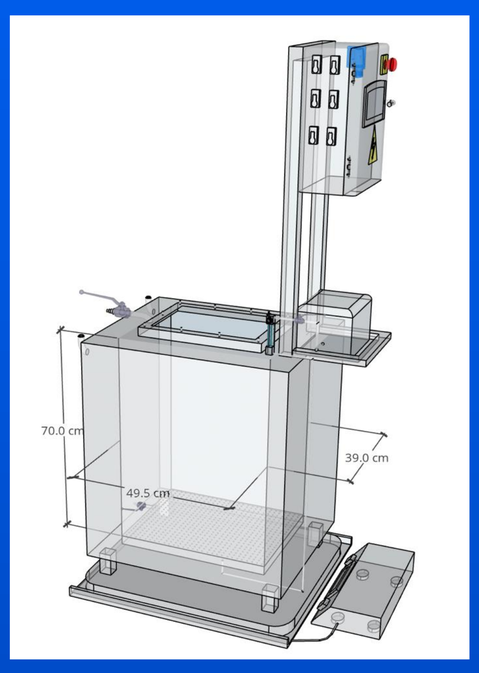

Fig. 1. Bioreactor for composting

Table 1. Characteristics of feedstock, composting proces and compost

Feedstock	RS	RS+BS	RS+G
Moisture (%)	72.2±1.8	71.3±2.4	74.2±1.3
OM (g/kg d.m.)	710±24	694±19	605±21
HA (g/kg d.m.)	59.2±2.4	61.3±3.1	57.4±3.2
HA/OM (%)	8.3±0.8	8.8±0.3	9.4±0.9
N (g/kg d.m.)	22.4±1.3	21.7±0.9	21.1±1.8
In composting process			
OM loss in the bioreactor (g/kg d.m.)	146.4±4.5	140.1±3.2	54.7±4.1
OM loss during the whole process (g/kg d.m.)	241±8.7	232±7.6	131±4.9
HA increase (g/kg d.m.)	90.3±4.1	94.5±3.2	36.4±2.7
Cumulative N loss (%)	45±2	46±3	32±3
Compost			
Moisture (%)	48.2±2.8	46.3±3.4	46.3±1.9
OM (g/kg d.m.)	467±23	464±39	482±23
HA (g/kg d.m.)	149.4±7.1	155.1±6.2	95.3±4.6
HA/OM (%)	31.7±2.4	33.5±2.6	20.1±3.2
N (g/kg d.m.)	13.4±0.9	14.2±0.8	15.1±1.4
$N\text{-}NH_4$ (mg/kg d.m.)	132±16	148±12	161±21

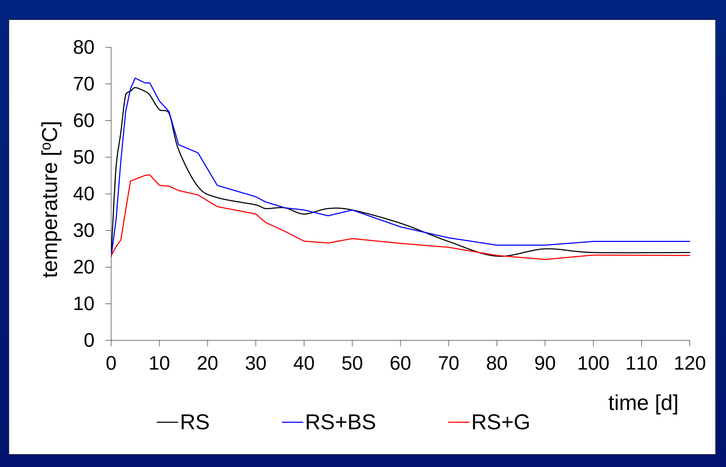

Fig. 2. Temperature profiles

Materials and methods

Sewage sludge was composted with lignocellulosic waste in a two-stage system (1° aerated bioreactor (Fig. 1), 2° turned 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 (series named RS), 15% of rapeseed straw and 8% of barley straw (RS+BS). In series RS+G, in addition to rapeseed straw (8%), grass (15%) was introduced.

Results & Discussion

During composting in the bioreactor, in RS and RS+BS thermophilic conditions and temperature up to 68-70°C were already noted after 3 days. In series RS+G, the maximum temperature did not exceed 43°C (Fig. 2). This means that thermophilic conditions necessary for sludge hygienization were not obtained with grass. The use of grass could limit the free flow of air in the bioreactor which limits the range and rate of mineralization, and, as a result, the amount of heat obtained.

The highest content of organic matter (OM) (ca. 710 g/kg d.m.) was recorded in the feedstock with rapeseed straw (RS) and the lowest (605 g/kg d.m.) in RS+G. The concentration of humic acids (HA) in all feedstocks was ca. 60 mg C/g OM.

During composting in the bioreactor, the highest loss of OM (146.4 g/kg d.m.) was reported for RS. A slightly lower OM loss was noted for RS+BS, while in series with grass (RS+G), OM loss was only 54.7 g/kg d.m. After 120 days of composting, the largest loss of OM (232-241 g/kg d.m.) was obtained for RS, and the lowest for RS+G. In RS and RS+BS the highest increase in HA content (90-94 mg C/g OM) was also noted. In series RS+G, OM losses were lower (131 g/kg d.m.) as well as an increase in HA content (36.4 mg C/g OM). Low temperature disturbs the proper succession of microorganisms in the compost and limit the production of HA. Thermophilic conditions are necessary to initiate the degradation 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. In this study composting increased the share of HA in OM form ca. 10% in the feedstock to over 30% in RS and RS+BS and 20% in RS+G.

Ammonia losses were estimated on the basis of nitrogen balance. Intense ammonia blowing was noted during the first day of mineralization: thermophilic conditions and alkaline reaction (> 8.5 pH) caused the balance to shift towards the formation of the free form of ammonia, which was released from the compost. The largest cumulative loss of nitrogen (up to 46%) was recorded in RS and the lowest (ca. 32%) in RS+G. In the mature compost nitrate nitrogen dominated, and the concentration of ammonium nitrogen did not exceed 200 mg/kg d.m.

Conclusions

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 mineralization range and rate and, in turn, temperature profiles. As a result, the feedstock composition affects the content of OM, N and HA in mature compost. Importantly, straw as amendment favors the formation of HA, the most stable form of organic carbon.

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