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Original Paper

The impact of the addition of natural materials on the composting of animal manure

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In this study we investigated the microbiological and chemical parameters during the composting of different substrates. Composting of two types of substrates amended with natural materials, manure mixed with zeolite (S1) and manure mixed with zeolite and lime (S2), was investigated and compared with that in the amendment-free substrate (C). During the composting the counts of coliform and faecal coliform bacteria in S2 and C differed significantly (P <0.001). There were also significant differences in coliform and faecal coliform bacterial counts between substrates S1 and S2 (P >0.01 and P >0.05, resp.). The total bacterial counts in C, S1 and S2 showed no significant differences throughout the composting (P >0.05). Degradation of organic matter was significantly increased in S2 compared to C (P <0.001) due to relatively rapid decomposition of organic matter by microorganisms in this substrate. Determination of chemical parameters also showed significant differences between individual substrates. The pH level in S2 was higher and varied from 9.16 to 7.99. Release of N-NH_4^+ from S2 substrate was significantly reduced. The total nitrogen (N_t) content in S2 substrate was increased by 45.01% compared to the other two substrates and resulted in a decreased C/N ratio towards the end of composting. Our results indicated that composting of manure amended with natural material provided promising results and has a potential for implementation in practice.

Keywords: composting, chemical parameters, microorganism, zeolite, lime

1 Introduction

Composting is considered to be the most effective management of animal manure on farms as it reduces the risk of contamination of environmental compartments by pollutants and microorganisms (Li et al., 2012). Under controlled conditions a stabilized, mature, deodorized hygienic material is produced, free of pathogens and plant seeds (Alavi et al., 2017).

Composting is a complex process of bio-transformation of organic substrates accompanied by physical and biological changes resulting from the action of various microorganisms (Wagas et al., 2019). The removal and recovery of nutrients from livestock manure involves chemical, physical, and biological processes. The most commonly used method is the biological treatment utilizing microorganisms (Szogi et al., (2015). In a composting system, the composition and activity of microbial communities is affected by constant variation of physicochemical parameters (Chandna et al., 2013).

The bacterial communities play an important role in the degradation of organic matter, proteins, lipids, cellulose and lignin (Ren et al., 2016). Study by Meng et al. (2019) showed, that N-NO_3, N-NH_4^+, total nitrogen, C/N ratio, temperature and moisture content significantly influence composition of the relevant bacterial community. Natural materials are often used to modify the structure of compost and its relevant properties. Addition of these materials in the process of

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storage and composting of organic substrates results in better utilization of nutrients, reduction of risk of leakage of pollutants, especially nitrogen and phosphorus, into soil and water as well as reduction of contamination of individual environmental compartments by microorganisms (Sasáková, 2015).

Bougnom et al. (2020) reported, that the co-composting of cow manure with wood ash (<15%) allowed the authors to obtain a good organic fertilizer with higher liming potential and nutrient content.

The aim of this study was to evaluate the effect of natural materials on changes in microbiological and chemical parameters during composting of animal manure.

2 Material and methods

2.1 Materials and building of piles

The composting experiment was conducted at the experimental facility of the University of Veterinary Medicine and Pharmacy (UVMP) in Košice, Slovakia. The experimental period lasted 90 days, from June to August 2019. Cow manure from cattle farm PD Paňovce was used for composting. It was mixed with chopped straw (length 2–5 cm) at a ratio of 5.6 : 1 (76 kg manure: 14 kg straw; w:w fresh weight basis). Natural zeolite (clinoptilolite) was supplied by Zeocem, a.s., quarry in Nižný Hrabovec, Slovakia. The hydrated lime used in this experiment was purchased at a store. Treatment involved creating composting piles. Three piles were built on a concrete floor (0.8 × 0.8 × 0.8 m) and were protected from rain in an effort to imitate conditions on the farms: S1 – manure mixed with zeolite (2.5% by weight of zeolite); S2 – manure mixed with zeolite and lime (2.5% of each zeolite and lime); C – unamended manure (control).

Table 1 Basic chemical properties of the composting materials

	TOC (%)	TN (%)	C/N (%)
Manure	20.51 ±0.51	2.45 ±0.67	8.3 ±0.76
Straw	45.05 ±0.56	0.52 ±0.68	86.6 ±0.62

Values are means ±standard deviation (*n* = 3); TOC – total organic carbon; TN – total nitrogen, C/N – carbon/nitrogen ratio

2.2 Sampling and chemical examination

The changes in bacteriological and chemical properties were monitored by collection of three samples from the core of each pile after 1st, 3rd, 5th, 8th, 13th, 19th, 26th, 40th, 62nd and 90th day of composting. Examination of all parameters was carried out in duplicate. The level of pH (in 1 : 10 water extract) was determined after shaking the homogenized samples with distilled water for 15 minutes, using a pH-meter HQ440d multi of fy. HACH with a glass electrode. Dry matter was determined by drying samples at 105°C to a constant weight. Ash was determined as a residuum after incineration at 550 °C/4h. Ammonium ions (NH_4^+) were analyzed by steam distillation and titration. Samples for determination of total nitrogen were digested using a HACH-Digesdahl apparatus (P/N 44336-21, Hach company Loveland Colo, USA) and processed by steam distillation after addition of 40% NaOH. Organic nitrogen was computed as N_t-(N-NH_4^+ + N-NO_3^-).

Temperature in the substrates was monitored by thermometers testo 175 T3 (Testo Ltd, United Kingdom) using probes (type K) in depth 10 cm below the surface of the pile and in the core of the pile. The ambient temperature was monitored by temperature and humidity data logger testo 175 H1 (Testo Ltd, United Kingdom).

2.3 Bacteriological examination

Samples collected for chemical examination were analysed also bacteriologically. This consisted of determination of the total counts of mesophilic, coliform, and faecal coliform bacteria and faecal streptococci as indicators of hygiene level changes during composting. The count of selected micro-organisms was expressed as the mean of $\log_{10}$ CFU/ ml ±standard deviation. Plate counts of total coliforms and *E. coli* (CFU/ml) were determined on Endo agar (HiMedia, India) with incubation for 24 h at 37 or 43 °C, respectively. Plate counts of faecal enterococci (CFU/ml) were determined on a solid selective medium containing sodium azide and colourless 2,3,5-trifenyltetrazolium chloride. Plate counts of the tested bacteria (CFU/ml) were determined in the same intervals as the physicochemical parameters.

2.4 Statistical analyses

The results of chemicals parameters: pH, dry matter (DM), organic matter (OM), ammonia nitrogen (N-NH_4^+) and total nitrogen (N_t) are presented as means of three samples ±standard deviation (*SD*) for each substrate. Individual results between groups were statistically analysed using analysis of variance (ANOVA). The level of $p \leq 0.05$ was considered statistically significant.

3 Results and discussion

The temperature is one of the most important factors that affect the processes of composting. In the core of the substrates S1 and S2 were reached maximum temperature 38.6 and 52.5 °C, respectively. In the control pile the temperature course copied the course of ambient temperature and reached maximum 38.2 °C. The temperature achieved in the substrates S1 and S2 affected the survival od selected microorganisms in comparison to control substrate (C).

Mesophilic bacteria dominate during the initial decomposition and heat is released by breakdown of the easily degraded organic matter (Meng et al., 2019). The total counts of mesophilic bacteria (Figure 1a) during the composting were approximately the same in C and S1 with a rise at the start followed by a gradual decrease. In contrast, in the S2 substrate they increased after a small decline at the start and later slowly decreases as in the other two substrates. This increase might be related to the availability of easily useable organic compounds (Meng et al., 2019). The total bacterial counts in C, S1 and S2 showed no significant differences throughout the composting ($P > 0.05$). The variations in the abundance of faecal streptococci (Figure 1b) were similar in all substrates and showed slow decline over time throughout the composting.

Determination of the abundance of faecal coliform bacteria (Figure 1c) showed significant differences between C and S2 ($P < 0.001$) and S1 and S2 ($P < 0.05$).

The variations in the abundance of coliform bacteria are illustrated in Figure 1d. Significant differences were observed between the counts in C and S2 ($P < 0.001$) and S1 and S2 ($P < 0.01$) substrates. There were not significant differences between C and S1 throughout composting ($P > 0.05$). Many authors reported an increase in the abundance and diversity in different compost types as composting progressed through its diverse phases (Ren et al., 2016).

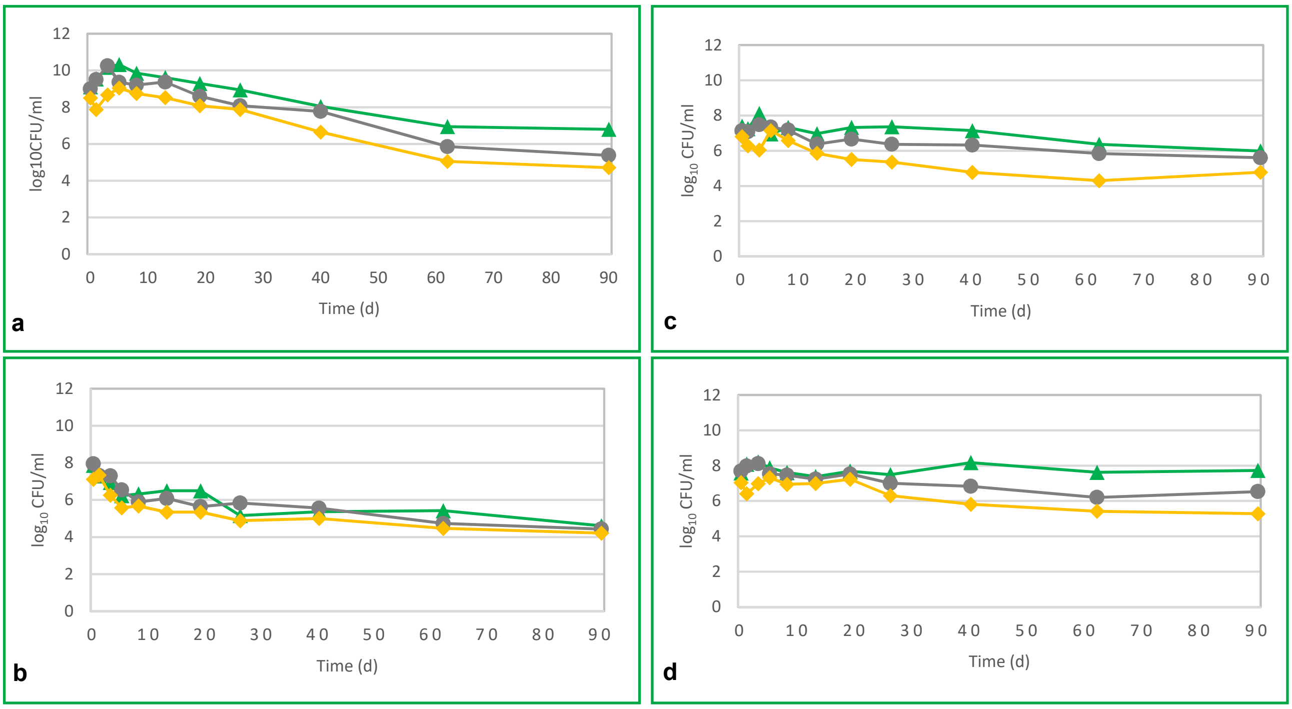

Figure 1 Counts of bacteria during composting: a) total counts of mesophilic bacteria; b) counts of faecal streptococci; c) counts of faecal coliform bacteria; d) counts of coliform bacteria
C – amendment-free substrate (C); S1 – manure mixed with zeolite (S1); S2 – manure mixed with zeolite and lime (S2)

Chemical parameters in individual substrates showed considerable differences during composting. The initial stage of composting was characterized by a decrease in pH in each substrate, associated with formation of organic acids in the substrates without lime. The pH in the C, S1 and S2 throughout the composting was in the alkaline range and fluctuated from 7.18 to 9.16. The pH in C was significantly lower than that in S2 (P <0.05) but no significant difference was found between C and S1. Substrates S1 and S2 amended with zeolites showed significant difference in pH (P <0.0001). In the latter stage of composting pH tends to decrease due to nitrification that produces H^+ (Lim et al., 2017).

The lower C/N ratio indicates a higher N content of the compost. The $N\text{-}NH_4^+$ concentrations in S1 and S2 decreased at a higher rate in the first stage of composting in comparison with the control. This maybe due to the action of zeolite and higher pH levels in the initial stage. Compared with C, the addition of zeolite and lime in S2 significantly reduced $N\text{-}NH_4^+$ release from this substrate (P <0.05). The final levels of $N\text{-}NH_4^+$ at the end of our study indicated that a mature compost was obtained.

The loss of N_t at the beginning of the composting may be due to the loss of ammonia by volatilization at high temperatures. Variance analysis showed significant differences in N_t content of C and S2 (P <0.0001) and between S1 and S2 (P <0.05). Generally, the continuous increase in N_t during composting is due to the mineralisation of organic compounds that reduces dry matter in the substrates (Awasthi et al., 2016).

It is well known, that additives could affect composting differently, depending on mixture proportion, oxygen consumption rate, moisture content, pH, C/N ratio, etc. (Li et al., 2012). Due to rapid degradation of organic matter we observed increase in temperature in the core of all substrates. Chan et al. (2016) reported, that persistence of the thermophilic temperature phase for at least 1 week was critical for the efficient devitalisation of pathogens and obtaining hygienic compost.

According to Villaseñor et al. (2011), addition of zeolites can improve degradation of organic matter during composting by increasing porosity of the substrate. The ash content increased in relation to the reduction of organic matter. Lower OM degradation in the control substrate corresponded to lower pH and high moisture content which resulted in anaerobic conditions and lower rate of decomposition processes. Gradual decrease in the C/N ratio in all substrates during composting was observed as a result of higher rate of C decomposition and lower N losses (Chang et al., 2019).

4 Conclusions

To evaluate the improvement of composting of animal manure by amendment of composted substrates with natural materials basic experiments with different combination of amendmens were performed. Compost temperature, pH, organic matter, C/N, ammonia nitrogen and total nitrogen and count of microbial comunities were used as the indicators of properties of the final compost. The results showed that the amendment with natural material resulted in the following:

1. decreased volatilization losses of $N\text{-}NH_3$ due to retention of NH_4 at the ion-exchange sites;
2. changes in the counts of microorganisms;
3. the most effective decrease in NH_3 volatilization;
4. reduced losses of nitrogen compounds from the compost;
5. more effective inactivation of pathogens.

The results of our study indicate that co-composting of animal manure with natural material is a promising approach which has the potential for implementation in practice. This treatment is also eco-friendly and due to the quality improvement of the composted material could offer cost reduction and better utilization of the final product.

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