Volume 10, Issue 1, 2020
DOI: 10.31924/nrsd.v10i1.040

MATURITY AND STABILITY EVALUATION OF COMPOSTED POULTRY MANURE

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Abstract

Composting is one of the most popular recycling processes for organic waste. Compost is an inherently variable product produced from a wide variety of organic source materials known as feedstocks.

The aim of our research was to examine the process of composting with maturity and stability parameters. The windrow composting experiments were set up in the composting area of the University of Debrecen, Institute for Water and Environmental Management and a mixture of broiler and hen manure was composted by adding zeolite (0, 1, 2, 5, 7 w/w %). The time for composting experiments was 62 days. We continuously measured the main parameters describing the composting processes: moisture content (w/w %), temperature (°C), pH, electrical conductivity (mS/cm), organic matter content (w/ w%).

Based on our results, it can be concluded that the 50 w/w % moisture content is sufficient for composting in the case of the mixtures of substances tested by us. The four stages of composting can be separated by temperature, and the thermophilic phase is longer with increasing zeolite mixing. The value of pH ranged from pH 6.63 to 8.0, with lower pH values at the beginning and neutral at the end of the composting process. Electrical conductivity values decreased at the end of the composting process. Adding a higher percentage of zeolite reduced the content of organic matter, thereby increasing the mineral content.

Overall, the parameters studied by us are suitable for determining the maturity of compost and for describing the composting process.

Key words: composting, manure, maturity, stability, poultry manure

INTRODUCTION

Intensive animal husbandry generates large amounts of waste and by-products that can sometimes harm the environment. Solid manure or slurry is produced in significant quantities from by-products, but in some animal species and housing technology solutions, large amounts of wastewater should be counted. The manure can’t used directly, stored and stored before application and matured.

Composting is an environmentally friendly biological process of aerobic thermophilic microbial degradation of wastes and by-products by populations of the various microorganism which leads to a stabilised, mature, deodorised, hygienic product, rich in humic substances, free of pathogens and marketable as organic amendment or fertiliser (Haug, 1993). Composting is an appealing solution for sustainable management of manure

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and it is importance to solve the problem of waste management. The compost quality for land application depends on its maturity and stability (Albrecht et al., 2008). A great number of physical, physico-chemical, chemical and biological methods were used to study the properties of compost (Bernai et al., 1998; Itavaara et al., 2002; Wang et al., 2004; Kovács, Füleky, 2016), such as: C/N ratio, humified organic carbon, cation exchange capacity, microbial respiration, enzyme activities (Chen, 2005; Castaldi et al., 2005; Tang et al., 2006; Tiquia, 2005), gas concentration tests, reflectance tests (Juhász, Hunyadi, 2014).

MATERIAL AND METHOD

The experiments set-ups and the laboratory tests were carried out at the University of Debrecen, Faculty of Agricultural and Food Sciences and Environmental Management, Institute of Water and Environmental Management. The broiler and hen manure source was the deep litter husbandry units of the Baromfi-Coop Ltd. located in Nyírjákó, Hungary. The bulking agent used was zeolite, which was derived from Mád. Main characteristics of initial materials are shown in Table 1.

Table 1

Main characteristics of raw materials

Parameter	Broiler manure	Hen manure	Zeolite
pH_{H2O}	6.91	6.59	8.49
OM (w/w%)[1]	58.81	66.18	1.16
EC (mS/cm)[2]	11.10	12.78	0.65
TN (w/w%)[3]	2.75	2.14	0.08

[1]OM: Organic matter; [2]EC: Electrical conductivity; [3]TN: Total nitrogen.

The windrow composting experiment was 62 days. It was composed of broiler manure (2/3 volume) and hen manure (1/3 volume) (Table 2). Samples were taken from several points of the compost prisms and taken every three days, and the average sample was used to test them.

Table 2

Applied settings of windrow composting

Name of treatments	Mixed raw materials
Control	26.66 kg broiler manure + 13.33 kg hen manure + 0 kg zeolite
1 w/w% zeolite	26.66 kg broiler manure + 13.33 kg hen manure + 0.4 kg zeolite
2 w/w% zeolite	26.66 kg broiler manure + 13.33 kg hen manure + 0.8 kg zeolite
5 w/w% zeolite	26.66 kg broiler manure + 13.33 kg hen manure + 2.0 kg zeolite
7 w/w% zeolite	26.66 kg broiler manure + 13.33 kg hen manure + 2.8 kg zeolite

For the assessment of compost maturity, important parameters including moisture content, temperature, pH, electrical conductivity, total nitrogen (TN) content, organic matter (OM) content were measured during the composting process (62 days).

The temperature measurements of compost prisms were done in situ, with PT 100 temperature meter. Temperature measurements were made at 12 cm depths of the windrow. The "front" point in the windrow longitudinal section corresponds to the 15 cm section, the "center" point corresponds to the windrow's 35 cm section, and the "end" point corresponds to the windrow's 55 cm section.

The moisture content of the fresh samples was determined as weight loss upon drying at 105 ºC in an oven for 24 hours (MSZ-08-0221-1:1979). The pH and electrical conductivity (EC) of the sample were measured using a 1:10 (w/w, compost/water ratio) sample to deionized water extract. Then, the mixture was stirring 24 hours. After this solution was filtered and the pH and electrical conductivity was measured using Hanna Instruments 2550. The organic matter (OM) content was measured to ashing the sample at 550°C (MSZ-08-0012-6:1981, chapter 3.2).

Statistical analysis was performed using R software in an R Studio user environment R Core Team, 2017. Based on the given parameter, ANOVA was used to verify the statistical differences between the samples at a significance level of 5 %. In order to quantify the statistical differences evidenced by one-way ANOVA, we used the LSD mean value comparison test (Mendiburu, 2019).

RESULTS AND DISCUSSION

The main parameters of composting and compost maturity were examined: moisture content, pH, electrical conductivity, temperature.

Moisture content during composting also influences microbial activity, rate of degradation and composition of microbial population. the optimum moisture content of composting is between 40-60 w/w % (Alexa, Dér, 2001).

The moisture content of the experiment is developed steadily over the 9 weeks (~50 w/w %). Moisture content of the 0 week means the moisture content determined when mixed the windrows, because of this time we measured only the broiler manure, hen manure and zeolite moisture content, without added water.

The 7 w/w % zeolite blend follows the same trend as the other smaller zeolite blends, but with a lower moisture content of -5 w/w % and even -10 w/w % for each measurement. Statistical analysis we proved ($p < 0,05$) the significant differences of the compost windrows.

This can be explained by the fact that the zeolite is capable of absorbing large amounts of water, since the small particles have a relatively high specific surface area. It was concluded that the 50 w/w % moisture content of this mixture was sufficient to complete the composting process.

The pH is highly influenced by biodegradation by acting on the activity of the microorganisms involved in the composting process, thereby increasing and decreasing the biodegradation.

The optimum pH during the composting process is between 6 and 8 (Chang, Chen, 2010; Gea et al., 2007; Alburquerque et al., 2006), since the strongly alkaline or acidic pH affects the degradation negatively. For example, composting of manure results in a high amount of ammonia being released at elevated pH (alkaline medium pH > 8) with high nitrogen loss and odor. However, the additive mixture of organic matter also affects the pH of the medium, e.g. the wood chips are acidifying, even the zeolite is alkalizing.

There is no chemical difference between the weeks and the mixes (whether the control prism or additive treated prisms) (Table 3). The pH values are within the range where the fermentation takes place (pH values 6.8 -7.5).

Table 3

Average pH values of the compost treatments

Name of treatments	pH value
Control (week 1)	6,90
Control (week 8)	7,48
Difference between week 1 and week 8	+0,58
1 w/w% zeolite (week 1)	7,00
1 w/w% zeolite (week 8)	7,55
Difference between week 1 and week 8	+0,55
2 w/w% zeolite (week 1)	6,90
2 w/w% zeolite (week 8)	7,31
Difference between week 1 and week 8	+0,41
5 w/w% zeolite (week 1)	6,80
5 w/w% zeolite (week 8)	7,59
Difference between week 1 and week 8	+0,79
7 w/w% zeolite (week 1)	6,80
7 w/w% zeolite (week 8)	7,40
Difference between week 1 and week 8	+0,60

Conductivity also plays an important role in the composting process by indicating the salt content of the compost.

The conductivity value should decrease as the composting process progresses. The increasing tendency of conductivity reduces the suitability of compost for nutrient supply, as it can cause phytotoxicity and inhibit germination. The conductivity and thus the soluble salt content do not influence the degradation processes, but may limit the use of compost (Tamás, 1990).

In addition, if aerobic dominance is not achieved in the composting process, conductivity increases due to the release of mineral salts and ammonium ions released from the decomposition of organic matter (Gao et al., 2010). The conductivity values decreased with increasing mixing of the zeolite (Table 4).

Table 4

Average electrical conductivity values of the compost treatments

Name of treatments	Electrical conductivity (EC) [mS/cm]
Control (week 1)	6,33
Control (week 8)	7,19
Difference between week 1 and week 8	+0,86
1 w/w% zeolite (week 1)	5,93
1 w/w% zeolite (week 8)	6,04
Difference between week 1 and week 8	+0,11
2 w/w% zeolite (week 1)	5,62
2 w/w% zeolite (week 8)	5,81
Difference between week 1 and week 8	+0,19
5 w/w% zeolite (week 1)	5,08
5 w/w% zeolite (week 8)	5,35
Difference between week 1 and week 8	+0,27
7 w/w% zeolite (week 1)	4,15
7 w/w% zeolite (week 8)	5,53
Difference between week 1 and week 8	+1,38

One of the most common ways to determine compost maturity is to monitor the temperature during the composting process. The temperature of the compost is important not only for its degradation but also for pathogenic microorganisms and parasites. High temperatures (55 °C) kill pathogenic microorganisms and parasites, but if the prism temperature does not reach the correct value, its infectivity can be maintained (De Bertoldi, Vallini Pera, 1983). As a result of prolonged high temperatures, bacterial populations are transformed and various thermophilic microorganisms become more prominent, and bacterial density and activity decrease at temperatures above 60 °C (Miyatake, Iwabuchi, 2005).

The temperature of the control prism is shown in Fig. 1 and temperature of the 7 w/w % zeolite prism shown in Fig. 2.

In the case of the control prism, it can be clearly seen that the temperatures were measured in different parts of the prism different. The highest temperature was measured in the center of the prism. After mixing, the prisms were wetted and heat production was started. Based on these, a primary phase of composting can be observed on day 1, which is accompanied by a rapid increase in temperature. By day 12, a very intense heat-producing phase was present in the prism, with the highest temperature measured on day 2 (52.8 °C).

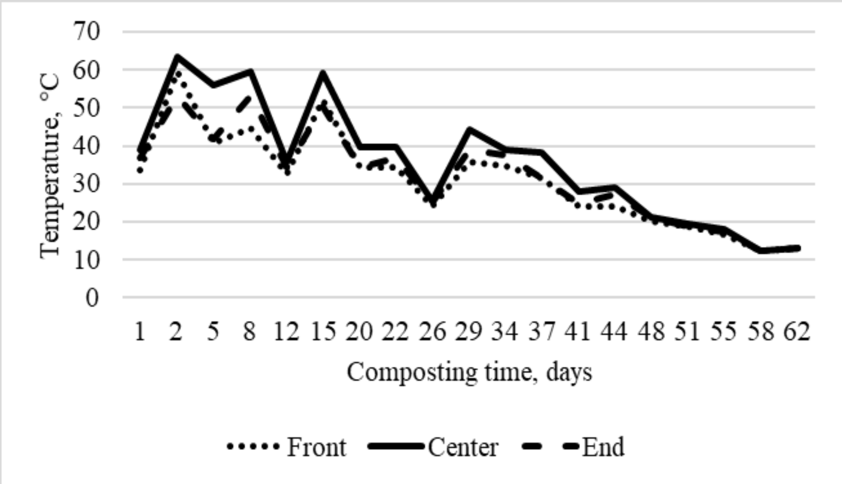

Fig. 1. Measurements of temperature with control compost prism longitudinal section and composting time

The minimum points in the temperature curves represent the points where no moisture content of about 50 w/w % was available, which resulted in a decrease in microbial activity which resulted in a decrease in temperature. By day 62, the temperature of the prism had dropped and raised its external (environment) temperature. This indicated to us that the material had reached the curing stage. Based on the temperature profile of the prism, the composting stages were completed within 62 days.

In the 7 w/w % zeolite treated prism the thermophilic phase lasted longer (up to 22 days) than in the control prism (Fig. 2).

There was no significant difference between the temperature measured in the longitudinal sections in either the control or the 7 w/w % zeolite treated prisms at the 5 % significance level.

This additive can be explained by a favorable impact on the compost raw materials, since the zeolite has improved air supply to the prism, and thus had a positive effect on the development of the temperature. The highest temperature was 58.73 °C and the internal temperature of the prism (58.73-37.10 °C) was well above the outside temperature during the first 22 days.

From these results it can be concluded that by increasing the proportion of additive the length of the thermophilic phase can be increased and a higher initial temperature can be achieved after adjusting the appropriate (in our case 50 w/w %) humidity level.

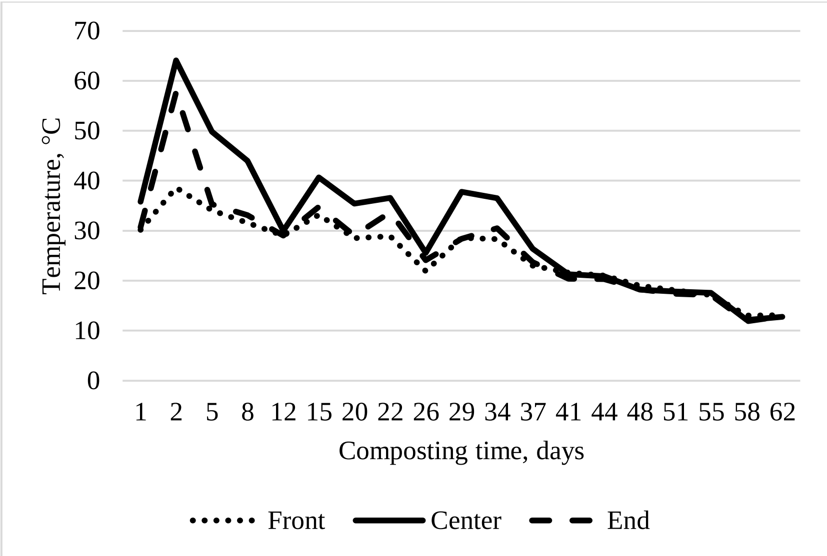

Fig. 2. Measurements of temperature with control compost prism longitudinal section and composting time

About 50 w/w % of the organic matter is completely mineralized during composting. Protein, cellulose and hemicellulose are readily degraded during aerobic fermentation. Many of these compounds produce organic residues called humic substances (Chefetz et al., 1998). There is no ideal organic matter content for raw materials or ready compost. The organic matter content decreases during composting. Typical feedstocks and starter blends contain more than 60 w/w % organic matter and 30-70 w/w % finished compost.

It can be observed that the higher the proportion of zeolite was added to the fertilizer mixture, the smaller was the organic content (Fig. 3).

Both the first and the eighth weeks had the highest organic matter content (over 68 w/w %) in the control. This high organic matter content can be explained by the high organic matter content of the starting materials. The difference in organic matter content between the control and the 7 w/w % zeolite blend is approximately 7 w/w %.

By week 8, a minimal increase in organic matter content was observed, with the exception of 2 w/w % zeolite and 7 w/w % zeolite mixing, with minimal decrease (-0,34 w/w %). The organic matter content should decrease as composting progresses, as Bazrafshan et al., 2016. According to their studies, the organic matter content of the mixture they composted was 66.25 w/w % at the start of composting and decreased to

34.38 w/w % at the end of the process (31.87 w/w % decrease) (after 80 days). During the first 40 days of composting, a maximum reduction in organic matter (24.03 w/w %) was observed, which may be due to high microbial activity and high temperature.

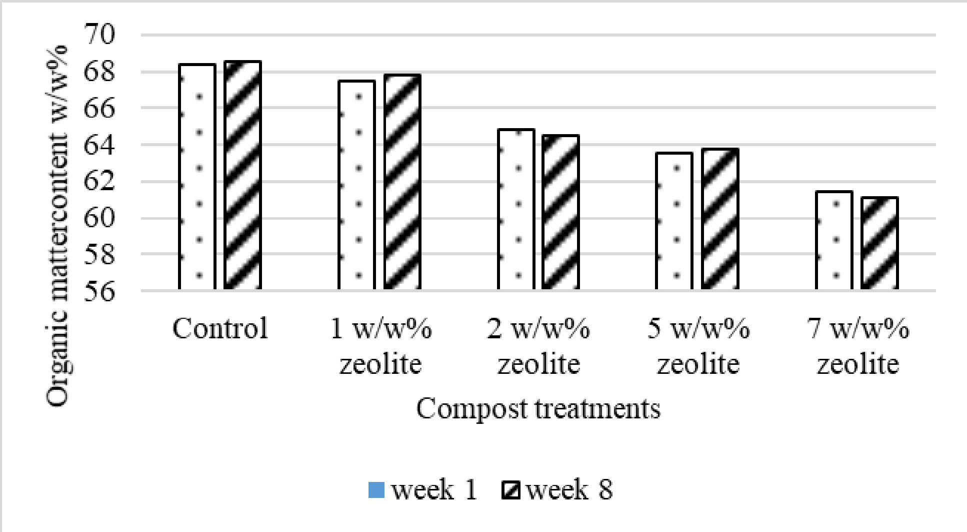

Fig. 3. Organic matter content of compost treatments

Organic degradation did not occur between the first and the eighth week, according to the literature (Bazrafshan et al., 2016), it should have been reduced, which is explained by the fact that the core temperature was very high compared to the small prism size, and therefore the thermophilic organisms had to be replaced by extreme thermophiles. For extreme thermophiles, degradable organic matter was not sufficient, while thermophiles were not available. However, as the proportion of zeolite increased, the rate of organic matter decomposition increased.

CONCLUSIONS

As for the moisture content, the 50 w/w % moisture content of the poultry manure and chicken manure mixture is sufficient to allow the fermentation to take place.

Based on temperature, the four stages of composting can be separated. By increasing the proportion of the additive, the length of the thermophilic phase can be increased, since in the case of the control the intensive heat-producing phase lasted until 12 days, while in the 7 w/w % zeolite treated prism it lasted until 22 days.

The pH values ranged from those in the literature. The conductivity values can be said to be favorable, because when the fermentation is complete, the electrical conductivity values decrease, which is accompanied by the evaporation of the ammonia and the precipitation of the mineral salts.

Overall, the zeolite does not play a major role, as the fertilizer used has the greatest effect on the organic matter content.

Acknowledgment

I would like to say thanks to Sándor Kun for his dedicated work, and I would like to thank the Baromfi-Coop Ltd. for providing us with the raw materials and for the professional support.

This research was supported by EU grant to Hungary; GINOP 2.2.1.-15-2017-00043.

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Received: October 31, 2019
Revised: January 17, 2020
Accepted and published online: May 31, 2020