EFFECT OF THE ADDITION OF VARIOUS EXOGENOUS SUBSTANCES ON THE PHYSICO-CHEMICAL PROPERTIES OF THE AEROBIC COMPOSTING OF LIVESTOCK MANURE

by

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The utilization of aerobic composting to produce organic fertilizer represents a significant method of resource utilization of livestock and poultry manure. In this study, two substances were selected for analysis. The study included two substances: tillage soil and corn bracts and corncobs. Each substance was co-composted with livestock manure at a ratio of 5% and 15%, respectively. The results demonstrated that the temperature ranking for each treatment group was as follows: corn bracts, corncobs 15% > corn Bracts, corncobs 5% > control group > tillage soil 15% > tillage soil 5%. The maximum temperature of the treatment group with 15% corn bracts and corncobs reached 60.2 °C, which was higher than the 37.2 °C of the tillage soil group and the 46.7 °C of the control group. The corn bracts and corncobs 15% group was maintained at a temperature above 50 °C for a period of 19 days, with a final carbon-to-nitrogen ratio of 16:9. The pH fluctuation of the corn bracts and corncobs treatment group was significant, and the moisture content decreased relatively slowly, indicating a vigorous microbial response and a strong water retention capacity. The difference in electrical conductivity between the treatments was not statistically significant, and there was no evidence of toxicity to plants at the end of the composting process. Pearson correlation analysis revealed a strong correlation between the difference in compost temperature and the addition of exogenous additives.

Key words: *livestock manure, aerobic composting, resource utilization*

Introduction

Livestock farming is one of the most traditional and oldest industries in the world. While providing humans with meat, eggs, and dairy products, livestock and poultry animals also produce large amounts of manure through digestion and metabolism [1]. The improper disposal of livestock and poultry manure can have a significant impact on the environment and ecology. To mitigate the environmental impact of livestock and poultry manure, there are three effective resource utilization methods: fertilizer, feed, and energy are three key re-

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sources that can be derived from livestock and poultry manure [2]. In comparison to the extraction of nutrients from livestock and poultry manure and the preparation of solid biofuels, aerobic composting exhibits low energy consumption, minimal odor production, and the capacity to generate organic fertilizer products with specific added value and negligible toxicity [3]. Although the content of nutrients in organic fertilizers is significantly lower than that of conventional mineral fertilizers, organic fertilizers can enhance soil properties and microbial activity, which cannot be replaced by conventional mineral fertilizers [4]. However, traditional aerobic composting is distinguished by a gradual increase in temperature, extended treatment periods, and variable outcomes. Consequently, the current focus of research is on the incorporation of auxiliary materials or microbial agents into the compost to enhance the composting process. However, the procurement of these materials will inevitably result in an increase in the cost of composting. Moreover, it is challenging to select microbial preparations that are optimal for a given environmental context, given the variability in conditions across regions and seasons. Therefore, it is crucial to identify exogenous additives with efficacious treatment outcomes.

Tillage soil (TS) is a common substance employed in agricultural production. Long-term TS are rich in microorganisms, which may contribute to the temperature enhancement of livestock and poultry manure compost. Furthermore, the mineral content of the TS enhances water retention and accelerates the decomposition process of the compost, thereby producing a more fertile organic fertilizer [5]. Corn bracts and corncobs (CBC) represent the primary byproducts of corn processing and have historically been regarded as waste, resulting in significant resource wastage and environmental contamination. The CBC contains organic matter-degrading microorganisms, which can be added to the compost to increase the abundance of microbial communities [6]. Furthermore, CBC adjusts the carbon-to-nitrogen (C/N) ratio, provides fluffiness to the compost, and promotes aerobic respiration efficiency of the microorganisms, thereby achieving the goal of treating agricultural waste while increasing the quality of the compost product [7].

It is imperative to conduct studies on the selection of appropriate exogenous additives and the determination of the addition ratio in order to guarantee the quality of compost. In this study, aerobic co-composting experiments were conducted on livestock and poultry manure by adding total solids (TS) and volatile solids (VS) in proportion to the manure's composition. The objective of this study was twofold: firstly, to investigate the effects of the two additives on the physicochemical properties and the extent of decomposition of the compost; and secondly, to analyze the correlation between exogenous additives and environmental factors.

Materials and methods

Composting materials and experimental methods

The raw materials of compost were fresh cow dung, corn stalks, TS, CBC, sourced from Dalate Banner, Ordos City, Inner Mongolia. The physical and chemical properties of compost materials are shown in tab. 1. The composting experiment was conducted in Dalate Banner, Ordos City, Inner Mongolia, it was divided into five treatment groups. Treatment 1 (S5): 5% TS + cow dung, Treatment 2 (S15): 15% TS + cow dung, Treatment 3 (C5): 5% CBC + cow dung, Treatment 4 (C15): 15% CBC + cow dung, and Treatment 5 (CK): cow dung. Before the beginning of the experiment, the compost material C/N ratio was adjusted to 30:1 with corn stover, mixed well by mechanical and manual mixing, and placed in an outdoor composting reaction pond, with each pile being 2 m long, 2 m wide, and 1.2 m high. Each treatment was stacked for 30d, and the piles were turned once on the 15 d to ensure good ventilation.

Table 1. Physical and chemical properties of compost raw materials

Raw materials	C/N ratio	pH	Moisture content
Fresh cow manure	28.34	7.34	72.5%
Corn stover, bracts and corncobs	51.53	6.23	8.27%
Tillage soil	5.47	9.11	2.01%

Sample collection and preservation

Sampling was conducted at 1, 7, 14, 21, and 30 days of the composting process. Three samples were collected from the top, middle, and bottom positions of each pile and thoroughly mixed to create a representative composite sample. Sampling was conducted in triplicate for each pile. Each set of compost samples was divided into two portions: one portion was maintained at 4 °C for the measurement of moisture content (MC) and electrical conductivity (EC), while the other portion was air-dried and sieved for the measurement of total nitrogen (TN), total carbon (TC), and pH.

Measurement methods for physical and chemical indicators

During the composting cycle, a probe digital thermometer (LCD-105, Shentuo Instrumentation Co., Ltd., HengShui, China) was inserted into the top, middle, and bottom of the heap at 14:00 every day to measure the compost temperature. Concurrently, the daily ambient temperature was recorded. Fresh compost samples were collected and added to ultrapure water at a ratio of 1:10 (w/v), and the pH and EC were determined by a pH meter (PHS-3C, Shanghai Yidian Scientific Instrument Co., Ltd.) and a conductivity meter (DDS-307A, Shanghai Yidian Scientific Instrument Co., Ltd.) after being shaken at 25 °C for 20 minutes in a thermostatic shaker. The MC was determined by drying the samples in a drying oven (101-1DB Tianjin Tester Instrument Co., Ltd.) at 105 °C until a constant weight was achieved. The TC content of the samples was determined by the volumetric method, employing potassium dichromate. The TN content was determined by the Kjeldahl method, as described in reference Technical specification for livestock and poultry manure composting (NY/T 3442-2019).

Statistical analysis

The impact of variations in physicochemical parameters was analyzed using Origin 2022. Pearson correlation coefficient analysis was conducted using SPSS 22.0 to assess the statistical significance of the observed differences between the samples at the 0.05 level of significance [8, 9].

Results and discussion

Temperature variations during composting

Temperature is a crucial parameter for the progression and maturation of the reactor composting process. The microbial degradation of organic matter within the pile releases heat,

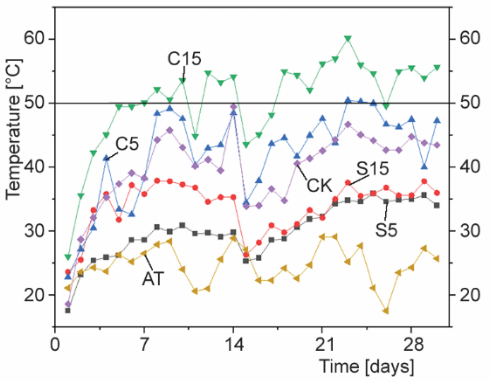

Figure 1. Compost temperature variation

resulting in an elevation of the pile temperature [10]. As illustrated in fig. 1, the temperature of all treatments began to rise following the commencement of aerobic composting. The temperature of the CBC treatment exhibited a notable increase, with the temperatures of the C5 and C15 treatments approaching 50 °C on days 5 and 8, respectively. This may be attributed to the presence of microorganisms that can facilitate rapid heap explosion. The CBC can enhance the porosity of the heap, thereby facilitating the utilization of microorganisms of oxygen, accelerating the degradation of organic matter, and promoting a corresponding increase in temperature. Among the samples, the highest temperature recorded for C15 was 60.2 °C. The treatment TS exhibited a slower rate of warming and a lower temperature than the control throughout the experiment, with the maximum temperature not exceeding 40 °C. The temperature of S15 was higher than S5, likely due to the TS, despite the presence of microorganisms, containing minimal organic matter and being unsuitable for fermentation. Furthermore, TS is unable to create the necessary pores for the pile, as those formed by CBC, and ventilation is inefficient, making it challenging to raise the temperature.

The temperature of the piles decreased rapidly in each treatment group at 15 days. At the outset of this composting experiment, the heap warmed up slowly, with a maximum temperature that was lower than that reported in the relevant literature. The following potential explanations are offered.

– The experiment was conducted in the spring in northern China, where the ambient temperature was low and the temperature varied greatly. As illustrated in fig. 1, the temperature of the experiment fluctuated in response to the ambient temperature. Therefore, the ambient temperature was a significant factor influencing the composting process.
– This experiment employed natural composting without the addition of exogenous bacterial agents, resulting in a slow start-up. The C5 maintained a temperature above 50 °C for a period of three days, C15 for 19 days, and C15 achieved the requisite level of harmless treatment of livestock manure.

Changes in moisture content during composting

It is of paramount importance to maintain an adequate moisture content in the composting process, as this is essential for the growth and reproduction of microorganisms. The microorganisms will cease metabolizing when the MC is below 15.0% and above 60.0%. This reduces the aeration of the compost. The optimal initial MC of the compost is 50% to 60% [11].

As illustrated in fig. 2(a), the initial MC of each treatment group was approximately 60%. This value gradually decreased as composting proceeded. In the initial seven days, the MC of C5 and C15 exhibited a notable decline. During this period, the two treatments were in a rapid warming state, which resulted in the evaporation of water due to microbial activity and heat generation. The MC of S5 and S15 decreased at a relatively slow rate, which may be attributed to the gradual warming of the heap. In the 7-14 days period, the MC of the S5 and S15 decreased more significantly than that of the C5 and C15 treatments. This was attributed to the weaker water retention performance of the TS than that of the CBC. At the conclusion of the composting process, the MC of all treatments exhibited a notable decline, reaching approximately 40%. The C15 treatment exhibited the lowest MC, at 36.38%. The MC exhibited a gradual decline throughout the experiment, with the MC of the final compost product being higher than that of the initial material. The primary reason for this is that composting is typically conducted during the winter months, when the ambient temperature is lower and water evaporation from the pile is slower. This finding is consistent with the results of a previous study by [12], which used cow dung and rice straw for aerobic composting at low temperatures.

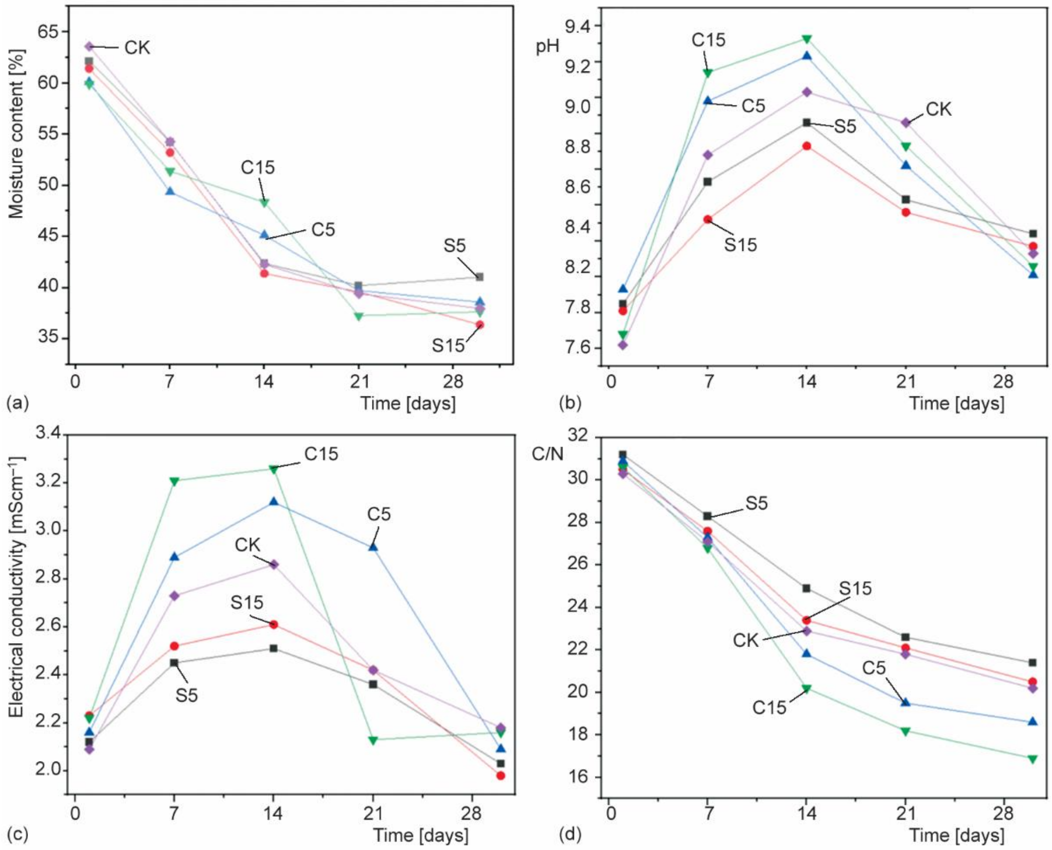

Figure 2 Changes in physical and chemical properties of composting

Changes in pH during composting

The pH of the composting process not only represents the acidity and alkalinity of the compost, but also serves as an important index for regulating the growth and metabolism of microorganisms. The overall trend of pH change in both the experimental and control groups is illustrated in fig. 2(b), which depicts a pattern of increasing and then decreasing. All the treatments reached their maximum value at 14^{th} day, with S5 (8.86), S15 (8.73), C5 (9.23), and C15 (9.33) exhibiting a decline and stabilization from that point onwards. During the precomposting period, the pH of the heap exhibited a rapid increase, likely due to the decomposition of a substantial quantity of organic matter, resulting in the production of NH_4^+-N. The decline in pH observed during the mid-composting stage was attributed to the volatilization of a significant quantity of the produced NH_3, as well as to the microbial fermentation that produced organic acids [13]. The pH of C15 was the highest at 14 days, indicating that it had the most intense composting reaction, while the pH of S5 and S15 were lower than that of CK, suggesting that the TS had a lesser effect on promoting composting.

Changes in electrical conductivity during composting

Inorganic salts and soluble organic acids produced during composting can be toxic to crops. The EC indicator can be used to indicate the total concentration of ions in the heap leachate, thus indirectly reflecting the content of soluble inorganic salts in the experimental samples. It is commonly accepted that when the EC is below 4 mS/cm, there is no evidence of toxicity to seed germination [14]. There were no discernible regular fluctuations in EC throughout the composting process for all groups depicted in fig. 2(c). However, a general trend emerged, with an initial increase followed by a subsequent decline. The C15 reached a maximum of 3.26 mS/cm at the 14^{th} day, S5 was 3.12 mS/cm, and the EC of CK exhibited greater fluctuations relative to the treatment TS. At the conclusion of the composting process, the EC of all treatment groups was observed to be within the range of 2.2 to 2.5, which was not found to be toxic to seed germination.

From the perspective of microbial activity, microorganisms in CBC facilitate the decomposition of organic matter, resulting in the production of large quantities of organic acids and other metabolites, which in turn elevate the conductivity. As the compost enters the maturation stage, some small molecules are converted into larger humus molecules, resulting in a slight decrease in the EC of the compost and eventual stabilization.

Changes in carbon-to-nitrogen ratio during composting

The C/N ratio is the primary chemical index utilized to assess the maturation of compost. It is commonly accepted that the optimal initial C/N ratio for aerobic composting is 20-30:1. At the outset of the composting process, the C/N ratios for C5, C15, S5, S15, and CK were 30.9, 30.6, 31.2, 30.5, and 30.3, respectively. As the composting process entered the high temperature phase, the C/N ratio of each group began to decline, as illustrated in fig. 2(d). The most pronounced decline was observed for C15, which decreased from 26.8 to 20.2 within 7-14 days, and then further to 16.9 at the conclusion of the experiment. The C5 group exhibited a more pronounced decline in C/N ratio relative to TS and CK, suggesting that CBC facilitated the composting reaction. Furthermore, the addition ratio of CBC exhibited a positive correlation with the composting effect.

Correlation analysis

Pearson correlation analysis was conducted for each group using IBM SPSS Statistics 27 software to examine the relationship between temperature, MC, pH, EC, and the C/N ratio. A strong correlation between the treatment group and temperature can be observed in tab. 2, indicating that the addition of exogenous materials to the compost pile significantly affects the temperature of the pile under the same experimental conditions. The effect of temperature on MC was not significant, indicating that the variation of MC depends on the water retention properties of the compost and the additives. The significant correlation between pH and EC indicates that the microbial decomposition of organic matter into small molecule organic acids during the composting process results in fluctuations in pH while affecting the EC [9]. A significant correlation was observed between C/N ratio and MC. It was found that a suitable C/N ratio can accelerate the decomposition rate of organic matter by microorganisms. Moisture is a crucial factor in enabling the normal life activities of microorganisms, and thus the decomposition rate of microorganisms is related to the MC of compost.

Table 2. Pearson correlation coefficient

	Processing group	Temperature	Moisture content	pH	EC	C/N ratio
Processing group	1	0.595**	–0.007	0.137	0.212	–0.152
Temperature	0.595**	1	–0.262	0.364	0.482*	–0.350
Moisture content	–0.007	–0.262	1	–0.379	–0.012	0.928**
pH	0.137	0.364	–0.379	1	0.837**	–0.351
EC	0.212	0.482*	–0.012	0.837**	1	–0.056
C/N	–0.152	–0.350	0.928**	–0.351	–0.056	1

* Significant correlation at the 0.05 level. ** Correlation is significant at the 0.01 level.

Conclusion

In this study, we investigated the effects of co-composting TS and CBC with livestock manure. We were excited to see that the composting efficacy of the treatment group with TS was inferior to that of the control group. However, we were even more thrilled to see that the fermentation-promoting effect on the heap was not discernible. The treatment group with added CBC exhibited a superior effect, with elevated temperature, moisture content, pH, electrical conductivity, and C/N ratio indicators compared to the control group. Of these, C15 reached the standard for short-term composting decomposition, which is great news! Correlation analysis of environmental factors revealed a significant effect of exogenous additives on composting temperature, which is very promising. This indicates that the addition of CBC had a promotional effect on the composting effect, with the size of the effect positively correlated with the proportion of the addition. This study provides a theoretical framework for the safe and effective treatment of livestock and poultry waste and agricultural waste, which is a fantastic achievement.

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