CHANGE OF NUTRIENTS AND HUMUS IN THE COMPOSTING PROCESS USING DIFFERENT LIVESTOCK MANURES

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Abstract. Aerobic manure composting was carried out using raw materials of like fresh manure of cattle, pig and chicken, and 10% corn stalk as a raising agent. The changing trend of the composting parameters in the composting process of different livestock manures including temperature, pH, water content, nutrients and humus were studied mainly. The results showed that the organic carbon content continued to decrease during composting. At the end of the composting, the total carbon content of the composting R2 (pig manure) was highest with a value of 294.7 ± 19.15 $g \cdot kg^{-1}$, whereas the total carbon content of the R3 (chicken manure) was the lowest with the value of 284.57 ± 11.78 $g \cdot kg^{-1}$. The contents of the total nitrogen, phosphorus and potassium showed an increasing trend during livestock manure composting process. The total nitrogen and total phosphorus were found to be highest in the R2, while total potassium was the highest in R3 with values of 2.25 ± 0.18%, 2.41 ± 0.15% and 0.78 ± 0.19%, respectively. The contents of total humic acid and free humic acid demonstrated an initial decreasing trend, and later showed an increasing trend. The contents of the total and free humic acid were found to be highest R3, with values of 29.84 ± 1.98 and 25.84 ± 1.25%.
Keywords: *fecal treatment, humic acid, organic carbon, composting system, resource utilization*

Introduction

The gradual increase in the number of extensive and intensive livestock and poultry farms satisfied the human needs for the livestock and poultry products. However, the casual stacking and inefficient treatment of the large amounts of livestock manure makes a significant burden on the environment (Liang et al., 2013). Nowadays, the livestock manure, industrial waste water and domestic waste water have been considered as the three paralleling pollution sources. Livestock manure has been an important factor that impedes the healthy development of the breeding industry. Besides, it also wastes the precious nutrient resources in large amounts (Xi et al., 2016). Currently, the livestock manure is increasing in its production with a speed of 10% each year. In 2014, the total amount of livestock manure was 6 billion t, which contained 60 million t of the nutrient resource, and equaled the quantity of the main fertilizer used in China in that year (Wang et al., 2013; Finstein et al., 2016; Guo et al., 2016). On one hand, these solid wastes contribute a certain extent of pollution to

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the environment. On the other hand, these wastes contain high quantities of organic matter and essential nutrient such as nitrogen, phosphorus, potassium and the biomass which is vital for the plants (Zhou et al., 2014). Thus, the application of the organic fertilizers prepared from the livestock manures on farmlands can not only effectively decrease the quantity of fertilizers and decrease the input cost of fertilizers, but also increase the organic matter content of soil and the soil fertility, thus promoting the sustainable utilization of farmland (Warker, 2001). In 2015, the Chinese government proposed "the activity of zero increase of the pesticide application quantity", thereby providing an unprecedented opportunity for development of organic fertilizers.

The humus produced in the composting process is a lignan derivative produced by the oxidation of the side chain of the lignan by microorganisms, which forms the key core and the skeleton of humus. This is one of the most important formation pathways of the humus (Ktilcia et al., 2014; Smars et al., 2002). In the composting process, the index of humification is related to the water-soluble carbohydrate and phenolic structure. It demonstrates the inverse relationship between the phenolic compounds and the humification index in the composting process, which confirms that the phenolic compounds are the principle materials of humus. The generation of humus with smaller molecular weight, less hydroxyl groups and minimal functional group occurs very rapidly in composting than in soil. There are many enzymes involved in the composting process, mainly including the hydrolase and redoxase. The mineralization extent of composting is mainly affected by the change in the enzyme activity of the hydrolase, while the extent and intensity of humification are affected by the change in the enzyme activity of the redoxase (Gao et al., 2010; Bernal et al., 2010). The species of the inducible enzyme dominates the composing process. Thus, the enzyme activity can demonstrate the change in the organic matter in different stages of the composting reaction (Bolta et al., 2003). Abdennaceur et al. (2011) showed that the transformation in the aromatic organic compounds in composting humus could be characterized by the enzyme activity of polyphenol oxidase, with an inverse relationship to the maturity of composting. Currently, many studies have been conducted on the microflora in aerobic composting with materials of single livestock manure; however, there are scarce reports on the comparison of the change of humus and nutrients in the composting process with raw materials of different livestock manures. In this study, the changes of material composition of heap in the composting with different livestock manures were studied using the raw materials of three livestock manure of cattle, pig and chicken, focus on change rule of TN, TP, TK, humus and free humus content in the composting process, which could provide a theoretical evidence and technical support for local enterprises.

Materials and methods

Experiment materials

Cattle manure, pig manure and chicken manure used in the composting process with livestock manures were procured from the breeding farm near Shenyang Aerospace University in Shenbei New District, Shenyang, Liaoning. Corn stalks were also provided by the same breeding farm. Corn stalks were cut into pieces of 2-4 cm by the knife mill before use. The physicochemical properties of composting materials are shown in *Table 1*.

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***Table 1.** Agrochemical characters of different compost materials*

Raw materials	Water content (%)	pH	Total carbon (%)	Total nitrogen (%)	Total potassium (K_2O%)	Total phosphorus (P_2O_5%)	C/N
Cattle manure	68.9	7.64	38.32	1.78	1.48	1.45	21.53
Pig manure	73.4	7.35	39.41	1.80	1.58	1.78	21.89
Chicken manure	70.8	7.28	41.15	2.99	1.52	2.98	13.76
Corn stalk	21.5	7.19	54.82	1.04	0.98	0.46	52.71

Experimental method

An aerobic static composting was conducted using the composting materials of three livestock manures, including cattle manure (R1), pig manure (R2) and chicken manure (R3). The 21 d composting reaction was conducted with 6 self-designed aerobic composting boxes among which 2 composing boxes were considered as a group to contain single type of livestock manure.

The results of every parameter data in the experiments were taken as an average. The porosity and organic matter content of the livestock manure were adjusted by additives of 10% corn stalk. In the whole composting process, different parameters like temperature, oxygen concentration, carbon dioxide concentration, density, etc. was monitored. Besides, the stink gas produced during the composting process was treated using a bio-filter (as shown in *Fig. 1*). The changes in the aforementioned parameters in the composting process were compared and the pile nutrients (the content of C-N-P-K) in the composing process in different livestock manure, humus and free humus were mainly analyzed.

Experiment apparatus

The self-designed composting box was used in the composting experiment. The experiment apparatus of the composting is shown in *Figure 1*.

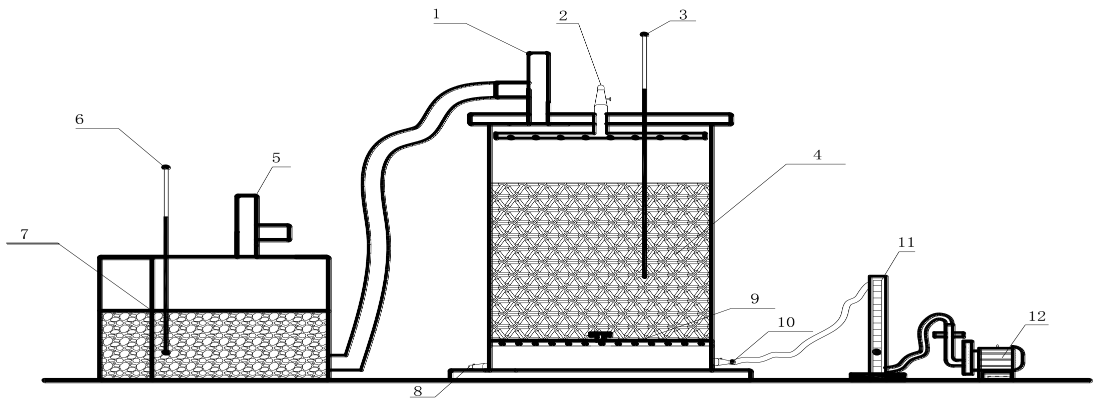

***Figure 1.** Experimental apparatus used in the aerobic composting with livestock manures. 1. Vent of the composting box 2. Back-ejecta nozzle of leachate 3. Thermometer 4. Composting box 5. Gas outlet of bio-filter 6. Thermometer 7. Bio-filter 8. Discharge pipe of leachate 9. Grid plate 10. Inlet pipe 11. Flow meter 12. Fan*

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Results and discussion

Changes in C-N-P-K content in the composting with different livestock manures

Change in total carbon content in the composting with different livestock manures

Figure 2 shows the changes in the total carbon content in the composting process with different livestock manures. It was seen that the total carbon contents in the pile were in the following order at the initial stage of the composting process: R3 (chicken manure) > R1 (cattle manure) > R2 (pig manure), with corresponding values of 378.45 ± 25.45 g·kg^{-1}, 366.28 ± 18.18 g·kg^{-1} and 358.24 ± 24.18 g·kg^{-1}, respectively. With the process of the composting of the livestock manures, the organic carbon source was transformed to carbon dioxide due to the decomposition of the organic carbon by microorganisms. Thus, the organic carbon content in the pile exhibited a decreasing trend. At the end of the composting, total carbon content was in the following order: R2 (pig manure) > R1 (cattle manure) > R3 (chicken manure), with corresponding values of 294.7 ± 19.15 g·kg^{-1}, 290.45 ± 13.14 g·kg^{-1} and 284.57 ± 11.78 g·kg^{-1}, respectively. The decreasing amplitude of the total organic carbon in the composting piles with different livestock manures of R1, R2 and R3 were different with a degradation rate of the organic carbon of 20.7%, 17.7% and 24.8%, respectively. The decreasing amplitude of R3 (chicken manure) was the largest, whereas the decreasing amplitude of R2 (pig manure) was the smallest. In the whole composting process, the change of the total carbon content showed a decreasing trend due to the transformation of the carbon, which was the main component of energy material of microorganisms and cells to yield carbon dioxide and humus by the decomposition and utilization of microorganisms in the composting process. The loss of carbon due to the emission of the carbon dioxide resulted in the gradual decrease of the organic carbon during the composting process. At the end of the composting, the total carbon content of R2 (pig manure) was the highest, whereas the total carbon content of R3 (chicken manure) was the lowest (Khalil, et al., 2011; Guo et al., 2016).

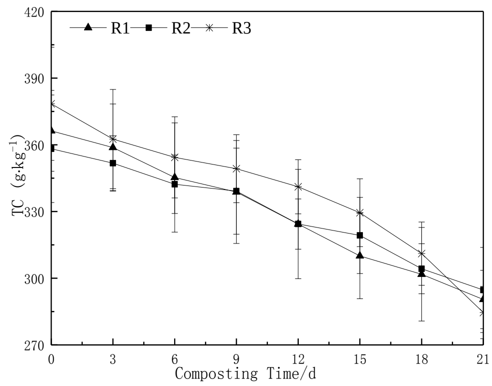

Figure 2. *Change of TC in three kinds of livestock dung composting*

Change in total nitrogen content in the composting with different livestock manure

Figure 3 shows the change in the total nitrogen content in the composting process with different livestock manures. It was seen that the total nitrogen content in the initial composting process was in the order of: R2 (pig manure) > R3 (chicken manure) > R1 (cattle manure), with corresponding values of 1.57 ± 0.11, 1.41 ± 0.08 and

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1.28 ± 0.18%, respectively. With the process of the composting reaction, the total nitrogen percent content in all the composting piles with livestock manures showed an increasing trend, mainly because both the organic carbon and the organic nitrogen were assimilated and catabolized by microorganisms in the composting process. The need of organic carbon in the microorganisms was higher than the need of organic nitrogen, with the general need ratio of carbon to nitrogen as 25:1. The degradation velocity of organic carbon was higher than that of organic nitrogen in the composting degradation process, resulting in the lower attrition rate of organic nitrogen than that of organic carbon in the composting process. Thus, the percent content of total nitrogen in all the composting piles with livestock manures demonstrated an increasing trend. At the end of the composting, the total nitrogen content in R1, R2 and R3 composting increased, with the corresponding increasing amplitude of 50.78%, 43.33% and 51.77%, respectively, among which the increasing amplitude of R3 (chicken manure) was the largest, while the increasing amplitude of R2 (pig manure) was the smallest.

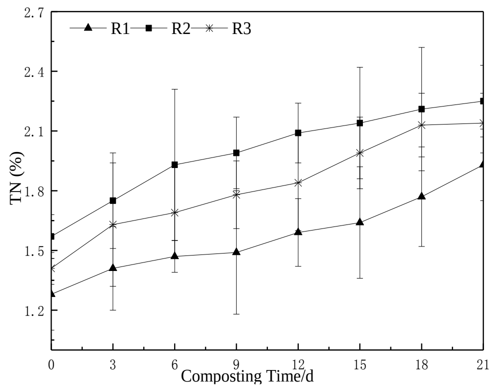

Figure 3. *Change of TN in three kinds of livestock dung composting*

Change in total phosphorus content in the composting with different livestock manure

Figure 4 shows the change of the total phosphorus content in the composting process with different livestock manures. It was observed that the total nitrogen content in the initial composting process in different piles was in the following order: R2 (pig manure) > R3 (chicken manure) > R1 (cattle manure), with corresponding values of 1.80 ± 0.12, 1.64 ± 0.17 and 1.25 ± 0.15%, respectively. The percentage content of total phosphorus in all the composting pile with livestock manures demonstrated an increasing trend with the process of the composting reaction. This was mainly due to the assimilation and catabolism of organic carbon, organic nitrogen and organic phosphorus by microorganisms in the composting process with livestock manures. The need of organic carbon for microorganisms was higher than that of the organic nitrogen and organic phosphorus. And the general need ratio of C:N:P was 100:5:1. The degradation velocity of the organic carbon in the composting degradation process was higher than that of organic phosphorus, resulting in the lower attrition rate of organic phosphorus than that of the organic carbon and organic nitrogen in the composting process. Thus, the percent content of total phosphorus in the composting piles with livestock manures demonstrated an increasing trend. At the end of the composting, the total phosphorus contents of R1, R2 and R3 composting increased by 25.61%, 33.38% and 11.58%, respectively, among which the increasing amplitude of R2 (pig manure) was largest,

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whereas the increasing amplitude of R3 (chicken manure) was smallest. There was neither any production of leachate nor any loss of phosphorus. Thus, the evaporation loss of the total phosphorus in the composting was relatively small.

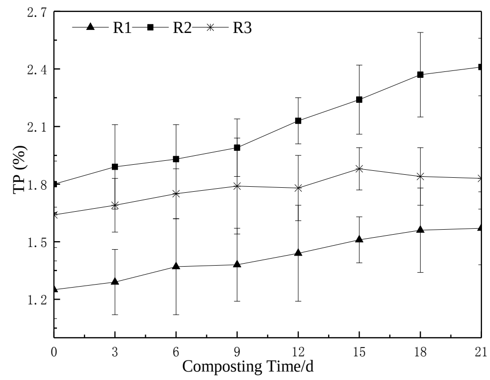

***Figure 4.** Change of TP in three kinds of livestock dung composting*

Change in total potassium content in the composting with different livestock manures

Figure 5 shows the change in the total potassium content in composting process with different livestock manures. It was seen that the total potassium content in the initial composting process in the piles was in the following order: R3 (chicken manure) > R1 (cattle manure) > R2 (pig manure), with corresponding vales of 1.21 ± 0.12, 1.14 ± 0.12 and 1.03 ± 0.22%, respectively. The total potassium percentage content in all the composting piles with livestock manures demonstrated an increasing trend with the process of composting reaction due to the low adsorption and utilization rate of potassium. In the composting process with livestock manures, the organic carbon, organic nitrogen and organic phosphorus were all assimilated and catabolized by microorganisms. The need of organic carbon, organic nitrogen and organic phosphorus of microorganisms were higher than that of organic potassium. There was almost no loss of potassium in the composting process. Thus, the total potassium percentage content in the composting pile with all different livestock manures demonstrated an increasing trend. At the end of the composting, the total potassium content of R1, R2 and R3 composting increased by 35.88%, 62.13% and 47.07%, respectively, among which the increasing amplitude of R2 (pig manure) was largest, whereas the increasing amplitude of R1 (cattle manure) was smallest.

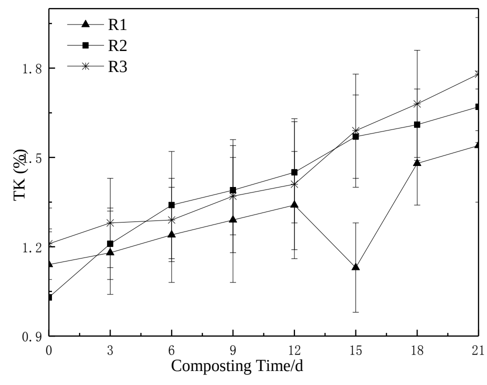

***Figure 5.** Change of TK in three kinds of livestock dung composting*

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Change of humus content in the composting process with livestock manures

The humus content is the key index describing the quality of organic fertilizer, which can enhance the soil fertility, change the formation of aggregate structure, adjust the soil porosity, and increase the ability of ventilation and water-retaining of soil. Furthermore, the growth of crops can be promoted by the changing of metabolism in plants influenced by the changing of enzyme activity.

Change in total humic acid content in the composting process with livestock manures

Figure 6 shows the change in the total humic acid content in the composting process with livestock manures. It was seen that the total humic acid content in the initial composting process in the piles was in following order: R3 (chicken manure) > R1 (cattle manure) > R2 (pig manure), with corresponding values of 37.82 ± 2.45, 36.84 ± 1.25 and 32.18 ± 1.58%, respectively. With the process of the composting reaction, the total humic acid content in the pile demonstrated an initial decrease, followed by an increase in all the piles. In the 0-15 d period of the reaction, the total humic acid in the initial period of R1, R2 and R3 was 36.84 ± 1.25, 32.18 ± 1.58 and 37.82 ± 2.45%, respectively, that decreased after 15 d to 14.87 ± 1.98, 13.64 ± 1.78 and 18.45 ± 2.40, respectively, with a corresponding decreasing amplitude of 59.63, 57.61 and 51.21%, respectively. This was due to the decomposition of the unstable humic acid generated in the degradation of the susceptible organic matters by the thermophilic bacteria in the high temperature period. The content of total humic acid reached the minimum at 15 d, and then increased. At the end of the reaction, the total humic acid content of R1, R2 and R3 were 25.12 ± 1.77, 24.21 ± 1.89 and 29.84 ± 1.98%, respectively. The increase of the total humic acid content in the late stage of the reaction was due to the decrease of the temperature and the enhancement of the microorganism activities, which was beneficial for the stability of humus structure and properties. The organic matter that was difficult to degrade was transformed to humic acid by the microorganisms. Thus, the total humic acid content in the product was found to be increased, thereby enhancing the quality of the composting product.

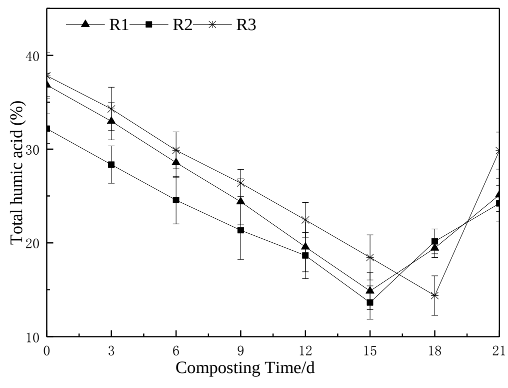

Figure 6. *Change of total humic acid in three kinds of livestock dung composting*

Change in free humic acid content in the composting with different livestock manures

Figure 7 shows the change in the free humic acid content in the composting process with different livestock manures. It was seen that the changing trends of the free and

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total humic acid were similar. The free humic acid content was in a descending order: R3 (chicken manure) > R1 (cattle manure) > R2 (pig manure) in the initial stage of composting reaction with livestock manures with corresponding values of 26.84 ± 1.87, 19.87 ± 1.23 and 18.53 ± 1.29%, respectively. With the process of the composting reaction, the free humic acid content in the pile demonstrated a trend of initial decrease, with a subsequent increase. In the 0-15 d period of the reaction, the free humic acid content in the initial stage of R1, R2 and R3 piles was 19.87 ± 1.23, 18.53 ± 1.29 and 26.84 ± 1.87, respectively, which decreased to 16.88 ± 1.99, 15.98 ± 1.98 and 20.18 ± 1.27, respectively, at 15 d, with corresponding decreasing amplitudes of 15.04, 13.76 and 24.81%, respectively. This was due to the decomposition of the unstable humic acid and the even more unstable free humic acid by the thermophilic bacteria. The content of free humic acid reached the minimum at 15 d and then increased. At the end of the reaction, the free humic acid content of R1, R2 and R3 was 24.84 ± 1.87, 23.45 ± 1.56 and 25.84 ± 1.25, respectively. The increase of the free humic acid content in the late stage of reaction was due to the decrease in the temperature and the enhancement of microorganism activities, which were beneficial for the stability of humus structure and properties. The organic matter which was difficult to degrade was transformed to total humic acid by the microorganisms. Thus, the total humic acid content in the product was increased, thereby enhancing the quality of the composting product.

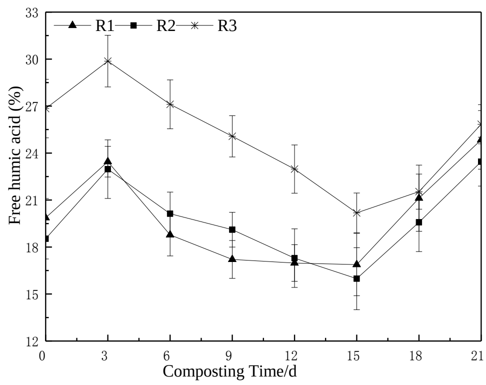

Figure 7. *Change of free humic acid in three kinds of livestock dung composting*

The results of the variance analysis showed that the discrimination of free humic acid content in the composting piles with R1, R2 and R3 livestock manures was not significant with a descending order of R3 (chicken manure) > R1 (cattle manure) > R2 (pig manure).

Humic acid in the composting was transformed from newborn and original humic acid in the materials. The composting time, raw materials, composting technologies, and the environment conditions can be factors limiting the formation of humic acid in composting (Xiao et al., 2011). Besides, microorganisms are also known to greatly influence the formation of humic acid, e.g. mesophilic microorganisms in the composting process can promote the formation of humic acid (Kinney et al., 2012; He et al., 2004; Malifiska et al., 2014).

The experimental results showed that the contents of total and free humic acid in all the composting piles with livestock manures increased dramatically in the late stage of the composting, accompanied by a decrease in temperature. The decrease of

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temperature and maturity could promote the increase of the content of total humic acid and thus enhance the composting quality. At the end of the composting, the contents of total and free humic acid in the composting with chicken manure were highest.

Conclusions

1) The organic carbon content in the composting with livestock manures gradually decreased. At the end of the composting, the total carbon content of R2 (pig manure) composting was highest with the value of 294.7 ± 19.15 $g \cdot kg^{-1}$, whereas the total carbon content of R3 (chicken manure) composting was lowest with the value of 284.57 ± 11.78 $g \cdot kg^{-1}$.

2) Total nitrogen, total phosphorus and total potassium in all the composing process with livestock manures demonstrated an increasing trend. At the end of the composting, the contents of total nitrogen, total phosphorus and total potassium were highest in R2 (pig manure), R2 (pig manure) and R3 (chicken manure), respectively, with corresponding values of 2.25 ± 0.18, 2.41 ± 0.15 and 1.78 ± 0.19%, respectively.

3) The contents of total and free humic acid in all the composting process with livestock manures demonstrated a trend of an initial decrease, followed by an increasing trend. At the end of the composting, the contents of total and free humic acid in R3 (chicken manure) were highest with corresponding values of 29.84 ± 1.98 and 25.84 ± 1.25%, respectively.

This article mainly writes the use of pig manure, chicken manure and cow dung for composting, to explore the trend of physical and chemical indicators such as temperature and humus during composting. In this experiment, only a single livestock manure is used for composting. Next, I will choose different livestock manures mixed compost, or livestock manure and straw mixed compost will be selected for scientific guidance of agricultural and livestock waste composting quality control.

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