ISSN 2616-5880 Vol. 4, Issue 7: 60-68, DOI: 10.25236/AJMC.2023.040710

Effect of C/N regulation on garden waste composting

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Abstract: *By adding additional urea to regulate the C/N of different piles, a non regulated C/N experimental group and a urea regulated C/N experimental group were set up. During the composting process, multiple indicators such as temperature, pH value, EC value, organic matter content, total nitrogen content, and C/N value of different piles were measured to evaluate the progress of the composting process of garden and forest green waste and its degree of maturity. The aim is to explore the feasibility of directly composting landscaping waste and the role of regulating C/N in the composting process of landscaping waste.*

Keywords: *C/N regulation; garden waste; composting*

1. Introduction

With the deepening of ecological civilization construction and the rapid development of urban landscaping, the area of urban greening has rapidly expanded, and the amount of garden waste has been increasing year by year. Garden waste has affected the healthy development of urban greening, and its comprehensive management and utilization are urgent. However, so far, most cities in China still mainly adopt the methods of landfill and incineration to treat traditional urban solid waste, that is, the vast majority of garden and green waste is transported to landfill sites in the suburbs or far away from the city for landfill treatment together with other waste, A small portion of landscaping waste is mixed with other urban solid waste for incineration treatment. From the perspective of environmental protection and resource utilization, currently using landfilling and incineration as the main treatment methods to treat garden and green waste not only causes a large amount of waste of urban land resources but also poses certain harm to the urban ecological environment. Moreover, this goes against our original intention of striving to establish a resource-saving, environmentally friendly society and ecological civilization construction. Using garden waste as the main composting raw material for composting treatment, new urban soil amendments, organic fertilizers, and nursery greenhouse cultivation substrates are produced to transform garden waste from urban pollutants into available resources in the city and make reasonable use of so as to minimize the negative impact of the development process of urban landscaping on the natural environment. Using garden waste as the main raw material for composting as urban soil amendment, nursery greenhouse cultivation substrate, and organic fertilizer for land use can not only significantly reduce the amount of urban organic waste, but also improve the physical and chemical properties of urban soil, increase the fertility of urban soil, promote urban soil improvement, and plant as well to indicate significant improvement of urban ecological environment.

This study aims to conduct composting experiments using landscaping waste as the main raw material for composting. Research has shown that most microorganisms typically require a nitrogen to carbon ratio of around 1:30 to maintain their own life activities and reproduction, among which, approximately two-thirds of the carbon will be oxidized to CO_2, and the remaining will be used by microorganisms to synthesize protoplasm. If the initial C/N of the pile is too high, that is, the carbon content is higher than the nitrogen content, which will reduce biological activity. When the C/N is higher than 35, the life activities of microorganisms will be severely affected, and it will require microorganisms to spend a lot of time first using and decomposing excess carbon until the C/N of the pile reaches a suitable C/N for microbial growth and reproduction, in order to promote the acceleration of the composting process, which will lead to a decrease in the degradation rate of the raw materials in the pile, and the compost maturity cycle will be significantly prolonged. Due to the fact that the composting raw material selected in this study is garden green waste, which contains a large amount of difficult to degrade substances such as lignocellulose. In response to the high C/N content of garden green waste itself, the experiment adjusted the C/N of different piles by adding additional urea. A non regulated C/N experimental group and a urea regulated C/N experimental group were set up, and the temperature, pH value, EC value, organic matter

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content of different piles were measured during the composting process Multiple indicators such as total nitrogen content and C/N are used to evaluate the progress of the composting process of landscaping waste and its degree of maturity. The aim is to explore the feasibility of directly composting landscaping waste and the role of regulating C/N in the composting process of landscaping waste.

2. Materials and Methods

2.1 Raw materials in composting

This study selected the winter pruned branches and leaves of camphor trees, which are widely planted in road greening as the main raw material in Nanjing, Jiangsu Province for composting. The pruned branches and leaves of camphor trees in winter were transported back to the laboratory, and the larger trunk parts were removed. The smaller branches and leaves were crushed to less than 5 cm using a grinder as the composting material, while rice husk powder was selected as the auxiliary material for composting. The raw materials for composting and their initial basic physicochemical properties are shown in Figure 1 and Table 1.

Figure 1: Raw material of compost

Table 1: Basic physical and chemical properties of raw material of compost

Composting raw materials	moisture content/%	Total nitrogen/%	Total organic carbon/%	C/N
garden waste	60	1.62	72.5	44.6

This study uses a static aerobic composting device as the reaction device for the study of composting of landscaping waste. The main body of the static aerobic composting device is a cylindrical plastic tank, which is divided into two parts by a perforated air distribution partition filled with small holes. The upper part is a compost fermentation bin, and the lower part is equipped with an air distribution chamber. The air pump passes the air through the rotary flow meter to the humidification bottle and then into the air distribution chamber. Then, the air enters the composting fermentation chamber through the perforated air distribution plate to provide sufficient oxygen for the smooth composting process. The tank body of the static aerobic composting device is wrapped with insulation material, which acts as insulation for the pile body and avoids excessive heat loss during the composting process, which affects the progress of the composting process

2.2 Research plan

This experiment focuses on the impact of regulating C/N on the composting effect of landscaping waste. A single factor experimental design was conducted to explore the impact of manually adding urea to regulate the initial C/N of landscaping waste on the composting effect of landscaping waste. During the experimental research process, two experimental groups were set up as treatment 1 and Treatment 2. Each treatment group was mixed with crushed camphor tree pruned branches and leaves and rice husk powder in a mass ratio of 4:1. Rice husk powder was mainly used as an inert conditioner to regulate the moisture content of the pile. The initial moisture content of the two treatment groups was adjusted to around 55%, while the control group, Treatment 1, did not artificially regulate the C/N of the pile, Its C/N is around 45. Treatment 2 regulates the C/N to around 32 by artificially adding extra urea. In the actual composting process, continuous ventilation and flipping are used to ensure the supply of oxygen

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in the pile, with a ventilation rate of approximately 1 L/min. Observe the temperature, appearance, and moisture changes of each treatment group every day, and carry out pile flipping treatment and adding an appropriate amount of water to adjust the moisture content according to the actual situation to ensure the normal progress of the composting process. During the entire experimental period of composting, the temperature, moisture content, pH value, EC value, organic matter, total organic carbon, and total nitrogen content of the pile at different stages are regularly measured using a Hanawood microcomputer temperature analyzer.

3. Results and discussion

3.1 Temperature changes during composting process

The change in temperature during the composting process is a simple indicator for evaluating the progress of composting because change in temperature of the pile during the composting process can effectively characterize the changes in microbial activity in the pile.

The temperature changes of each treatment group during the composting process of this study are shown in Figure 2. Each treatment group quickly enters the heating stage after stacking the composting raw materials, but there are certain differences in the heating process and amplitude between the two. The temperature increase of treatment 1 exceeds 31 ℃ within 1-4 days, and the temperature increase of treatment 2 is 29 ℃ within 1-4 days. At this time, microorganisms mainly consume water-soluble organic substances and other easily degradable substances, Strong activity and extensive reproduction, leading to a significant increase in the temperature of the pile body, and the temperature of each treatment group has entered a high-temperature period within 4 days. But the control group treatment 1 reached a maximum temperature of 46 ℃ on the 4th day after the composting raw materials were stacked, and then the temperature began to decrease and entered the cooling stage. Treatment 2 reaches the highest temperature of 50 ℃ on the 5th day after the composting raw materials are stacked. After 7 days, the temperature of the pile decreases slightly (Table 2). The entire pile is flipped and an appropriate amount of water is added to mix and redistribute the pile material, while also allowing for the redistribution of microorganisms. After flipping, the temperature of the pile starts to rise again. After several repetitions, the pile temperature does not rise again and enters the cooling stage, eventually tending towards the environmental temperature, Treatment 2 maintained high temperatures above 45 ℃ for more than 10 days during the composting process, while control group 1 also underwent treatments such as flipping and adding water during the composting process. However, the pile temperature only briefly increased and then began to decrease. The highest temperature and high temperature duration reached during the composting process were significantly lower than those of treatment 2 that regulated C/N, and both were lower than the national standards for composting maturity. At the end of composting, the maturity requirement is not met or it takes longer to reach maturity. Although the high temperature and high temperature duration of the treatment 2 regulating C/N in this study meet the requirements for maturity, its high temperature and high temperature duration are still lower than those of other raw materials for composting research. The reason is that the composting raw materials used in this study are garden waste and rice husk powder with a large content of lignocellulose refractory substances. During the composting process, when the easily degradable organic substances in the heap are consumed. It will significantly affect the metabolic activity of microorganisms, making it difficult to promote further increase in stack temperature and maintain high stack temperature. During the entire composting process, the temperature of treatment 2 was significantly higher than that of control group treatment 1, and the high-temperature duration of treatment 2 was also longer than that of control group treatment 1. The high-temperature duration was 10 times longer than that of control group treatment 1. This is because treatment 2, due to the addition of urea, reduced the initial C/N of the pile to a more suitable range for microbial activity, which can provide sufficient carbon and nitrogen sources for microorganisms at the same time, Significantly enhance the activity of microorganisms, while the control group treatment 1 requires a longer period of time for microorganisms to reach the C/N suitable for rapid growth and reproduction due to excessive carbon content in the pile[1]. It also requires a longer composting cycle to achieve the required maturity, indicating that regulating C/N is beneficial for increasing the temperature of the pile and prolonging its high-temperature duration during the composting process of garden waste.

ISSN 2616-5880 Vol. 4, Issue 7: 60-68, DOI: 10.25236/AJMC.2023.040710

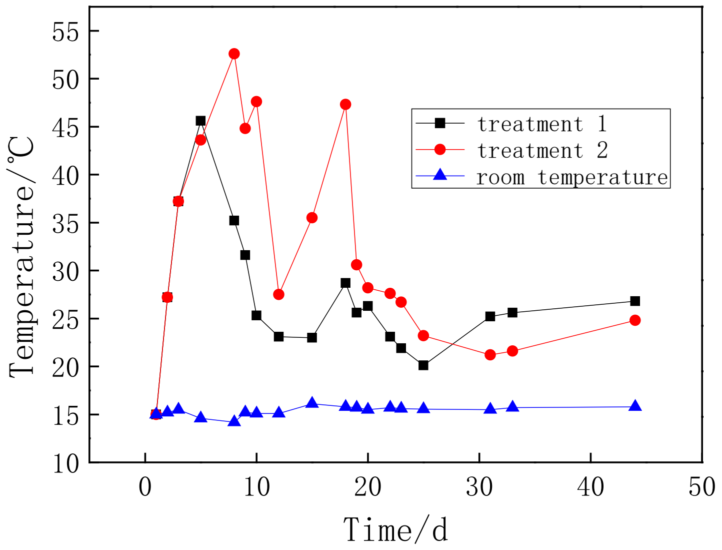

Figure 2: Changes of temperature in composting

Table 2: Analysis of changes of temperature in composting

group	maximum temperature/°C	High temperature period time consumption/d	High temperature duration/d
Treatment 1	46	4	1
Treatment 2	50	5	10

3.2 Changes in pH and EC values during composting process

pH value will affect the growth and reproduction of microorganisms in the pile. The pH changes of each treatment during the composting process in this study are shown in Figure 3. The trend of pH changes in each treatment during the composting process is similar to the research results of Song Caihong, indicating an increase to decrease thus to increase process. The pH value of each treatment from the beginning of composting to the end of composting roughly varies between 7.5 and 9.0. When the raw materials were just stacked, the pH values of control group treatment 1 and adjusted C/N treatment 2 were 7.52 and 7.63, respectively, and there was no significant difference between the two. The pH values of each treatment group began to rise after the raw material was stacked, but the increase in treatment 2 was greater than the increase in treatment 1. At the beginning of the raw material stacking, the pH value was around 7.5. As the pile temperature continued to rise and the pile rapidly entered the heating period, a large amount of ammonia was generated in a short period of time due to the degradation of a large amount of nitrogen-containing organic matter, and a large amount of ammonia did not volatilize in time, resulting in an increase in the pH value of the compost; The pH values of treatment 1 and treatment 2 decreased on the 13th and 10th days, respectively, and the time when the pH value began to decrease coincided with the high-temperature stage of the pile. The reason for the decrease in pH value is due to the arrival of the high-temperature period of the reactor, which causes most of the enerated ammonia to volatilize and lose under the action of high temperature[2]. During the high-temperature stage, due to the degradation and utilization of most organic matter by microorganisms and the production of a large number of small molecule organic acids, the efficiency of the generated ammonia in increasing pH value should be significantly weaker than that of the pH value reduction caused by small molecule organic acids, ultimately leading to a decrease in pH value; After that, the pH values of the two treatment groups began to rise again on the 16th day after the raw materials were stacked, which is consistent with the time when the pile was flipped and the pile began to cool down. The pH value rose again because as the pile temperature decreased and entered the cooling stage, a large amount of ammonia volatilization was reduced, and the excess organic acids generated during the high-temperature stage were gradually consumed, thereby promoting the pH value of the pile to rise again, At the end of composting, the pH value of treatment 2, which adjusted C/N, remained stable at around 9.0, while the pH value of control group treatment 1 still showed a downward trend and did not reach a stable state. It is generally believed that the maximum composting rate can be achieved during the composting process when the pH value of the pile is between 7.5 and 8.5. Compost that meets the maturity standard is generally weakly alkaline, with a pH value of around 8.0~9.0. From this prospective, it can be seen that the pH value of treatment

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2 meets the requirement of weak alkaline composting at the end of composting. Due to the addition of urea, the initial nitrogen content of treatment 2 is significantly higher than that of treatment 1. Therefore, more ammonia nitrogen is accumulated during the composting process, resulting in a higher pH value than treatment 1. This indicates that regulating C/N is beneficial for promoting the increase of pH value in garden waste composting, It is beneficial for the rapid growth and reproduction of microorganisms in the pile, promoting the rapid appearance of weak alkalinity in garden waste compost, and accelerating the maturation process of garden waste compost[3].

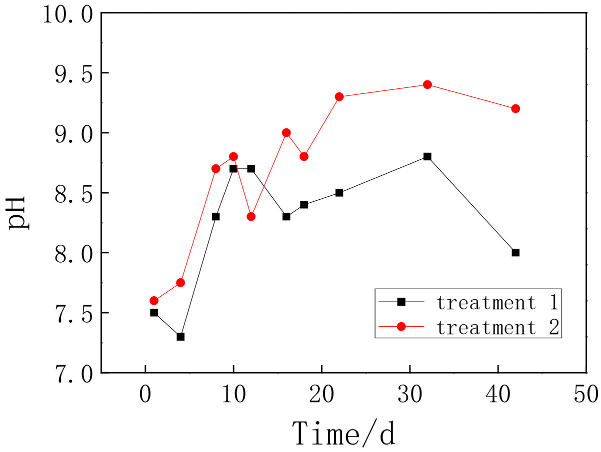

Figure 3: Changes of pH in composting

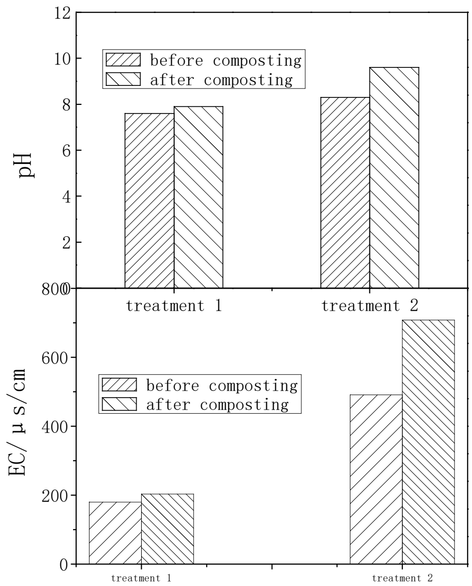

Figure 4: Changes of pH value or EC value before and after composting

The EC value can be used to reflect the soluble salt content in compost, and also to indicate whether compost will have a toxic effect on plants. To some extent, it can indicate the toxicity of compost to plants and the extent of its inhibitory effect on plant growth. If the salt content of compost products is higher, their EC value will also be higher. Applying this compost product to the soil will more easily cause soil salinization and cause a certain degree of damage to the plant's frontal and root functions, thus having a greater inhibitory effect on plant growth.

The changes in EC values of each treatment during the composting process of this study are shown in Figure 4, and their EC values show a gradually increasing trend during the composting process. When the raw materials for composting were just stacked, the EC values of each treatment were 134.8 μ S/cm and 182.9 μ S/cm, respectively. At this time, the difference between the two was not significant. Treatment 2 had an ion concentration higher than Treatment 1 due to the addition of urea, resulting in an initial EC value slightly higher than Treatment 1. There are significant differences in the changes in EC values of each treatment group after composting. The comparison of EC values of each treatment pile before and after composting is shown in Figure 4. The EC value of treatment 2 pile increased from 182.9

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μ S/cm at the beginning of composting to 729.0 μ S/cm at the end of composting before and after composting, and increased by three times compared to before composting; The EC value of pile 1 increased from 134.8 μ S/cm at the beginning of composting to 491.0 μ S/cm at the end of composting before and after composting. After composting, it increased by 2.6 times compared to before composting; At the end of composting, the EC value of treatment 2 was 1.5 times that of treatment 1, and the increase in EC value was significantly higher than that of treatment 1. The main reason for the increase in EC value during the composting process was due to the decomposition of organic matter by microorganisms and the production of ammonium ions and mineral salts, as well as the continuous decrease in the mass and volume of the pile[4]. On the 16th day of composting, there was a significant decrease in the EC value of the treatment 2 pile. At this time, the pile was just flipped and an appropriate amount of water was added. The organic matter and microorganisms in the pile were redistributed, and the degradation rate of the pile material was significantly accelerated. The pile temperature also began to rise back to the high-temperature stage. A large amount of organic matter in the pile was further degraded, resulting in excess ammonia and volatilization The deposition of a large number of mineral salt ions to the lower part of the pile and the continuous accumulation of humic acid and other substances during this process led to a decrease in the EC value of the treated pile 2. From the perspective of the entire composting process, the increase in EC value of treatment 1 is significantly lower than that of treatment 2, indicating that the soluble salt content in the pile of treatment 1 is significantly lower than that of treatment 2. This indicates that the organic matter degradation activity of treatment 1 is lower than that of treatment 2, and there is still a large amount of organic matter in the pile that has not been degraded and utilized at the end of composting. In this study, the EC value of the treated 2 piles stabilized at around 800 μ S/cm after composting, and its EC value was significantly less than 1200 μ S/cm, meeting the local standards for the EC value requirements of compost as a soil amendment or cultivation substrate. The reason why the EC value of treatment 2 pile is significantly higher than that of treatment 1 is that adding urea to the compost raw material in treatment 2 increases the ammonium nitrogen content during the stacking process, which is significantly higher than that of treatment 1. This indicates that regulating C/N can increase the EC value of the pile within a certain range and effectively improve the microbial degradation activity of organic matter. At the same time, it does not cause the EC value of the pile to be too high. It can accelerate the composting process and ensure the quality of composting products.

3.3 Changes in organic matter content during composting process

The organic matter in composting raw materials can provide carbon sources for microbial life activities. During the composting process, the degradable organic matter is continuously decomposed and transformed by microorganisms into inorganic substances such as CO2, water, minerals, and more stable humic acids. At the same time, sufficient nutrients are added to microorganisms to maintain their own growth and reproduction. So, to a certain extent, the changes in organic matter content can be used to indicate the process and progress of composting.

The changes in organic matter content of each treatment group during the composting process of this study are shown in Figure 5. The initial organic matter content of each treatment group when the raw materials were just stacked was 91.65% and 92.23%, respectively, indicating that there was no significant difference in the initial organic matter content between the two treatments at this time. After the composting raw materials are stacked, as the composting process progresses, the organic matter content of both treatment groups shows a decreasing trend. In the first 10 days of the composting process, both groups of organic matter are degraded at a faster rate, and the difference is not significant. This stage is the heating and high-temperature stage of the pile, during which the easily degradable organic matter in the pile is extensively decomposed and utilized by microorganisms, The difficult to degrade organic matter is partially degraded at a lower degradation rate, and then the pile is turned over to ensure that the organic matter degradation rate further increases after the material is remixed[5]. The maximum organic matter degradation rate occurs during the high-temperature period from the 12th to the 16th day throughout the entire composting process.

With the extension of composting time and the progress of the composting process, the temperature of the pile gradually begins to decrease and enters the cooling stage. At this time, the easily degradable organic matter has been consumed, and the microbial activity has also significantly decreased, resulting in a decrease in the degradation rate of organic matter in the pile material. After the completion of composting, the organic matter content of treatment 1 and treatment 2 was 88.8% and 86.9%, respectively[6]. However, the degradation rate of organic matter by treatment 2 was 1.6 times higher than that of treatment 1.

Studies have shown that there is no significant correlation between the degradation rate of organic matter and its content. As the main raw materials for composting in this study are garden green waste and rice husk powder, although garden green waste contains a variety of rich organic matter, the content of difficult to degrade lignocellulosic substances in garden green waste and rice husk powder is high, making it difficult for microorganisms to quickly decompose them in the short term, This leads to a lower degradation rate of organic matter. Overall, the organic matter degradation rates of both treatment groups were at a relatively low level, but the degradation rate of treatment 2, which regulated C/N, was still higher than that of control group treatment 1. Research analysis shows that in the initial stage of composting raw materials stacking, both treatment groups contain sufficient carbon and nitrogen sources, and the degradation of both is relatively consistent. Organic matter is degraded at a faster rate[7]. Subsequently, treatment 1 has a high carbon content and insufficient nitrogen, which affects the activity of microorganisms. On the contrary, treatment 2 believes that the addition of urea provides sufficient carbon and nitrogen sources suitable for the growth and reproduction of microorganisms, thereby promoting the decomposition of organic matter. Indicating that regulating C/N can significantly improve the degradation rate and degradation rate of organic matter in garden waste compost.

3.4 Changes in C/N and T values during composting process

C/N is one of the most critical factors determining the maturity cycle of compost and affecting the final quality of compost products. It is a classic parameter commonly used to evaluate the degree of maturity of compost products. The size of C/N can be used to characterize the maturity and stability of compost products. A good composting process should have a continuous decrease in C/N. If the C/N of compost is too high, it indicates that it has not reached a fully decomposed state. If this compost product is applied to the soil, it not only cannot achieve good fertilizer efficiency, but also may compete with plants due to the large number of microorganisms applied to the soil with compost, and consume a large amount of nitrogen in the soil, thereby affecting plant growth[8]. It is generally believed that a C/N value less than 20 is an important requirement for composting to achieve maturity. However, in the actual composting process, due to the diverse characteristics of various raw materials, especially many raw materials with C/N values below 20, the standard is usually used as a necessary indicator for composting to achieve maturity. Therefore, some researchers have proposed using the T value as an indicator to evaluate the maturity of compost, with T value=(endpoint C/N)/(initial C/N), Evaluating the maturity of compost with a T-value can solve the imbalance in evaluation caused by the difference in initial C/N of raw materials, and it is believed that the T-value of compost products that meet the maturity requirements should be less than 0.6.

The changes in C/N and T values of each treatment group during the composting process of this study are shown in Figure 5 and Figure 6, respectively. There are significant differences in the initial C/N of each treatment group when the raw materials are just stacked. Treatment 2 has significantly lower C/N of the pile due to the artificial addition of urea. The initial C/N of the two processing groups is 45 and 32, respectively. After the stacking of composting raw materials, as the composting time extends and the composting process progresses, the C/N and T values of Treatment 2 show a continuous downward trend[9]. During the heating and high temperature periods of the composting process, a large amount of organic matter is degraded, and the degradation rate of carbon by microorganisms is significantly higher than that of nitrogen, resulting in a significant reduction in the mass and volume of the pile, leading to a rapid decrease in the C/N and T values of the pile. Subsequently, with the end of the high-temperature period of composting, the pile enters the cooling stage. At this time, the microbial activity decreases, and easily degradable organic matter has been decomposed completely. The difficult to degrade organic matter is slowly degraded by the microorganisms at a reduced rate, resulting in a slow decrease in the C/N and T values of the pile, which tend to stabilize in the later stage of composting. After treatment 2, the C/N decreases from the initial 32 to 17, and its T value also decreases to 0.55. Treatment 2 compost has met the requirements for C/N and T values for mature compost. However, by observing the changes in C/N and T values of treatment 1, it can be seen that there is a significant difference between treatment 1 and treatment 2. When treatment 1 is just stacked, the pile can also quickly enter the heating period. At this time, both carbon and nitrogen sources in the pile can maintain microbial activity, resulting in a decrease in C/N and T values. However, after a few days, the nitrogen source in the pile cannot guarantee efficient microbial activity, and excessive carbon sources lead to a decrease in microbial activity. The decrease in organic matter degradation leads to an increase in the C/N and T values of the pile. When microorganisms spend a lot of time slowly decomposing the excess carbon source in the pile, the composting process proceeds further[10]. However, the C/N and T values have only decreased slowly at a relatively low rate, and after the composting is completed, their C/N is still higher than 30, and the T value is also greater than 0.6, which does not meet the requirements of composting. Treatment 1 did not regulate C/N, which became a limiting factor for microbial activity due to insufficient nitrogen source during the stacking process, resulting in insufficient degradation of organic matter[11]. In treatment 2, due to the addition of urea, provided sufficient carbon and nitrogen sources for microorganisms to promote a large amount of organic matter degradation, indicating that regulating C/N is beneficial for accelerating the decrease of C/N and T values in compost and accelerating the process of composting maturity.

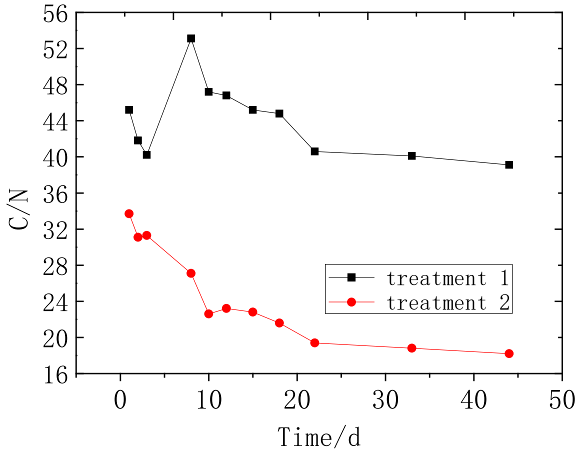

Figure 5: Changes of C/N ratio in composting

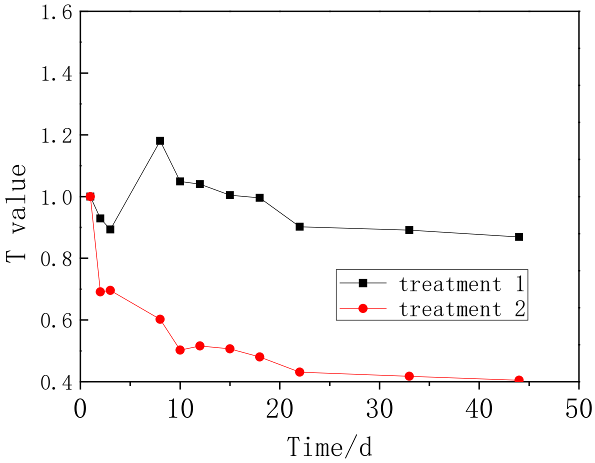

Figure 6: Changes of T value in composting

4. Summary

Using garden waste as composting material without regulating C/N, the composting progress is slow, the composting maturity cycle is significantly prolonged, and the effect of good composting cannot be achieved; Adjusting the C/N of landscaping waste to around 32 for composting can ensure the smooth progress of the composting process. The composting reaches a mature state in approximately 45 days and achieves good composting results. The first 17 days of composting in this study were the heating and high temperature periods for regulating C/N composting. During this period, rapid increases in pH and EC values occurred, and reached relative stability during the cooling stage, at around 9.0 and 729.0 μ S/cm, respectively. Regulating C/N can promote the rise of reactor temperature and increase the duration of high temperature; Promote the formation of weak alkalinity in the reactor as soon as possible, without causing too high EC values; Accelerate the decrease of C/N and T values; Shorten the maturity cycle of compost and accelerate its maturation process.

Acknowledgments

This work was supported by grants from institute-level scientific research projects of Nanjing Vocational Institute of Transport Technology (No:JZ2018), high level Scientific Research Foundation for the ntroduction of talent in Nanjing Vocational Institute of Transport Technology and college Student Innovation and Entrepreneurship Project in Jiangsu province, China (No:202112804028Y) .

ISSN 2616-5880 Vol. 4, Issue 7: 60-68, DOI: 10.25236/AJMC.2023.040710

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