Feasibility Study on Aerobic Composting of Campus Kitchen Waste

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Abstract. Composting treatment is one of the important ways to reuse organic kitchen waste resources. In this study, based on the campus environment of middle school, the process of aerobic composting of campus kitchen waste was preliminarily explored in plastic composting barrels with kitchen waste produced in the canteen as composting raw material and commercially available organic starter as additive (the addition amount was 0.1% -0.4 %). The results showed that: a) the odor of the pile increased in intensity first and then decreased with the process, and the color changed from light to dark. At the end of the composting, the pile generally had no odor and showed dark brown; the peak temperature did not exceed 41℃; b) The temperature changes of all treatments showed a trend of increasing first and then decreasing, and the peak temperature did not exceed 41℃; c) T-3 (0.4 % additive) reached the high-temperature period on day 3, and the composting period was shortened by 56% compared with CK; d) The composting effect of 0.4% additive dosage was the best. This study can provide some reference value for the promotion and practice of kitchen waste composting in middle school campus.

1 Introduction

Kitchen waste refers to food residues produced in the process of food production by households or catering services, including vegetable leaves, fruit peels, eggshells, etc. [1]. According to statistics, China produces an average of more than 30 million tons of kitchen waste every year [2]. Food waste that has not been properly disposed of is extremely perishable, resulting in a large number of harmful microorganisms such as parasites, pathogens and other harmful organisms that threaten human health as well as harmful gases such as ammonia (NH_3) and hydrogen sulfide (H_2S) that pollute the atmospheric environment [3,4]. At present, the conventional harmless treatment methods of kitchen waste mainly include landfills and incineration [5], which have the advantages of simple operation and short-term efficiency. However, greenhouse gases such as methane (CH_4) and carbon dioxide (CO_2) are released during the process, and the energy released by combustion is less [6,7]. Kitchen waste contains about 1.8% nitrogen (N), 0.2% phosphorus (P) and 1.9% potassium (K) and other nutrients [7]. Traditional treatment methods cannot achieve the reuse of nutrients, ignoring part of the economic and nutritional value of kitchen waste [8]. Composting of organic waste is a useful treatment method, which has been widely used in agricultural cultivation, soil remediation, ecological improvement and so on [9-11].

The conversion of kitchen waste into organic fertilizer rich in humic acid by composting can effectively promote plant growth [12]. In the 1970s, Europe began to try composting to treat municipal waste on a large scale, but due to the imperfect classification of waste, the produced fertilizer was often doped with impurities and heavy metals [13]. After 1985, after the improvement of waste classification, organic waste with high purity was obtained, and research on kitchen waste composting began to appear in Europe [14]. At present, the research on kitchen waste composting mostly focuses on improving composting efficiency and quality. Some scholars have formulated a compound microbial agent that can increase the degradation rate of kitchen waste by 31% and shorten the composting cycle by 40% [15]; some scholars have found that the NH_3 emission of adding mushroom bran to food waste is 36.49% of adding straw [16]. In addition, some scholars have successfully reduced the carbon-nitrogen ratio (C/N) of compost by using an EM microbial agent as an exogenous microbial additive [17].

The canteen is one of the main places for schools to produce kitchen waste, and the composting method and maturity evaluation system suitable for the middle school campus environment are rarely reported. Based on the background of the middle school campus environment, this study used the kitchen waste produced in the canteen as the composting raw material and supplemented by additives, and used a simple composting device to preliminarily explore the process and maturity of aerobic composting of campus kitchen waste.

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2 Materials and methods

2.1 Overview of the study area

This study was conducted at RCF Experimental School (N39°57'14"-59'17", E116°25'06 "-28' 06"-28'07", H 34 m), Chaoyang District, Beijing, China. The experimental site was a vegetable garden in the northeast of the campus. The climate of the test site is a temperate continental subhumid monsoon climate with four distinct seasons. The annual rainfall is 550-570 mm, and the precipitation is concentrated in July. The average annual temperature was 11℃-13℃, and the average temperature during the experiment was 7.9℃-20.3℃.

The soil of the experiment site is brown soil, and the average soil thickness is 20-40 m. The main tree species are elm *Ulmus pumila* L. and *Pinus tabulaeformis* Carr. The main shrubs were *Syringa oblata* Lindl., *Ligustrum obtusifolium* S. Et Z.. The main herbs are *Iris tectorum* Maxim. and *Carex siderosticta* Hance.

2.2 Test materials and methods

The experiment began on April 18, 2024 and ended on May 22, 2024, with a duration of 34 days.

2.2.1 Preparation of compost materials

The kitchen waste raw materials (canteen pre-meal waste, the main components were rape, cabbage, taro, lotus root, a small amount of onion and tomato) and litter accessories (the fallen leaves of sycamore and boxwood) produced by the school daily were collected. The two kinds of raw materials were cut into small pieces by using pruning shears and were put into collection bags for use. The compost raw materials were crushed by a small household feed grinder (Hunan Jiangfeng Agricultural Machinery Co., Ltd., Loudi, Hunan, China), and then collected by a 15 mm mesh sieve (Hebei Chuangyuan Mesh Products Co., Ltd., Hengshui, Hebei, China). The adjustment of the moisture content of the pile body adopts the empirical value instead of the actual measurement—the state of grasping the raw materials by hand but not dripping was the appropriate initial moisture content (mass ratio 55%-65%).

2.2.2 Composting and turning pile

The commercially available organic fertilizer fermentation agent (Shandong Junde Biotechnology Co., Ltd., Weifang, Shandong, China) was selected as the composting additive. The main components were Bacillus, natto, actinomycetes, Trichoderma, yeast and various secretory extraspore enzymes. According to the different amounts of additives (0.1 %-0.4% volume), this experiment set up 3 treatment groups and 1 control group (CK) (Table 1). The raw materials in 2.2.1 and the additives in 2.2.2 were uniformly mixed according to the ratio in Table 1, and loaded into a commercially available 60 L plastic barrel (Shanghai Huanglongchi Packaging Materials Co., Ltd., Shanghai, China). A digital food thermometer with a probe length of 15 cm (Wenzhou Mitel Intelligent Technology Co., Ltd., Yueqing, Zhejiang, China) was used to record the initial temperature of the center point of the composting bucket.

Table 1. Composition of Kitchen Waste Compost Treatments.

Treat ment	Composting raw material ratio (Kitchen waste: Dry leaves, v/v)	Additive proportion (v/%)
T-1	6:4	0.1
T-2	6:4	0.2
T-3	6:4	0.4
T-4	6:4	0

2.2.3 Judgment of compost maturity

According to the actual conditions of the school, the apparent characteristics and temperature of the pile were selected as the maturity index of kitchen waste composting.The monitoring method of compost temperature (T) was the same as that of obtaining the initial temperature of the compost in 2.2.2. The temperature of the heap was collected and recorded regularly once a day (except Saturday/Sunday), and the heap was turned according to the temperature change. Changes in color (light to black or dark brown), odor (fading to disappearing), and structure (grainy to soft) were recorded each time the heap was turned.

2.3 Analysis Method

In this study, WPS (WPS, V6.1.0, Beijing Kingsoft Office Co., LTD., Beijing, China) software was used to analyze the trend change between the apparent characteristics and the heap temperature data during the process of food waste composting and plot the chart.

3 Results

3.1 Smell and color change of kitchen waste compost

The odor of all treatment groups showed a shift of first increasing and then decreasing (Table 2). The odor of T-1 was heaviest on day 12 and remained for 5 days. The heavier odor of T-2 appeared on day 5; T-3 reached the strongest odor on day 3, and then gradually decreased. The smell of T-4 reached its heaviest on day 18. The peak odor period of T1-T3 was 6 days, 13 days and 15 days earlier than that of T-4.

The color changes of T1-T4 are from light to dark (Table 2). T-1 changed from white-green of the initial raw material to uniform dark brown, and the color reached and maintained at the darkest on day 20. The darkest color of T-2 appeared on day 8; T-3 reached the darkest color on day 5; the darkest color of T-4 appeared on day 22. The color of T1-T3 reached the darkest 2 days, 14 days and 17 days earlier than that of T-4, respectively.

Table 2. Odor and Color Changes of Kitchen Waste Compost Treatments.

Time	T-1		T-2		T-3		T-4	
	Odor	Color	Odor	Color	Odor	Color	Odor	Color
day 1	L	L	L	L	RL	L	L	L
day 2	L	L	RL	L	M	RL	L	L
day 3	L	L	M	RL	RH	M	L	L
day 4	L	L	M	M	RH	RH		
day 5	L	L	RH	RD	M	H	L	RL
day 6	L	L	RH	RD			L	RL
day 7	L	L	RH	RD	RL	H	L	RL
day 8	L	RL	RH	D	RL	H	RL	RL
day 9	M	RL	RL	D	RL	H	RL	RL
day 10	M	RL	RL	D	RL	H	M	RL
day 11	M	M	RL	D			M	M
day 12	RH	M			L	H	M	M
day 13			RL	D	L	H	M	M
day 14	RH	M	RL	D	L	H		
day 15			RL	D	L	H	RH	RD
day 16	RH	M	L	D				
day 17	M	RD					RH	RD
day 18	M	RD	L	D			H	RD
day 19	RL	RD	L	D			RH	RD
day 20	RL	D	L	D			M	RD
day 21	RL	D	L	D			M	RD
day 22	RL	D					RL	D
day 23	RL	D					RL	D
day 24							RL	D
day 25	L	D						
day 26	L	D					L	D
day 27	L	D					L	D
day 28	L	D					L	D
day 29							L	D
day 30	L	D						
day 31	L	D					L	D
day 32	L	D					L	D
day 33	L	D					L	D
day 34							L	D

Note: L represents Light, RL represents Relatively Light, M represents Medium, RH represents Relatively Heavy, H represents Heavy, RD represents Relatively Dark, and D represents Dark.

3.2 Temperature change of food waste compost

The reactor temperature of T-1 showed a trend of first increasing and then decreasing over time (Fig. 1a). The peak temperature occurred on day 22, which was 40.7℃. On day 6 and day 11, the reactor temperature decreased by 28.6% and 43.3% compared with the initial temperature, respectively. The reactor temperature leveled off on day 31. The temperature change of T-2 was similar to that of T-1 (Fig. 1b). The peak temperature appeared on day 13. and it began to stabilize on day 19. The temperature of T-3 also showed a change of first increasing and then decreasing (Fig. 1c). The peak temperature occurred on day 3, which was 40.8°C, 10.3℃ higher than the initial temperature. The temperature plateau occurred on day 13, with a decrease of 33.6% from the peak temperature. The temperature of T-4 peaked at 40.7℃ on day 22, 1.62 times the initial temperature (Fig. 1d). On day 11, the reactor temperature decreased significantly.

The peak temperature between different treatments did not exceed 41℃. The high-temperature period of T-3 appeared earliest, which was 16 days earlier than that of T-1. The composting period of T-3 was the shortest, which was 56% shorter than that of T-4.

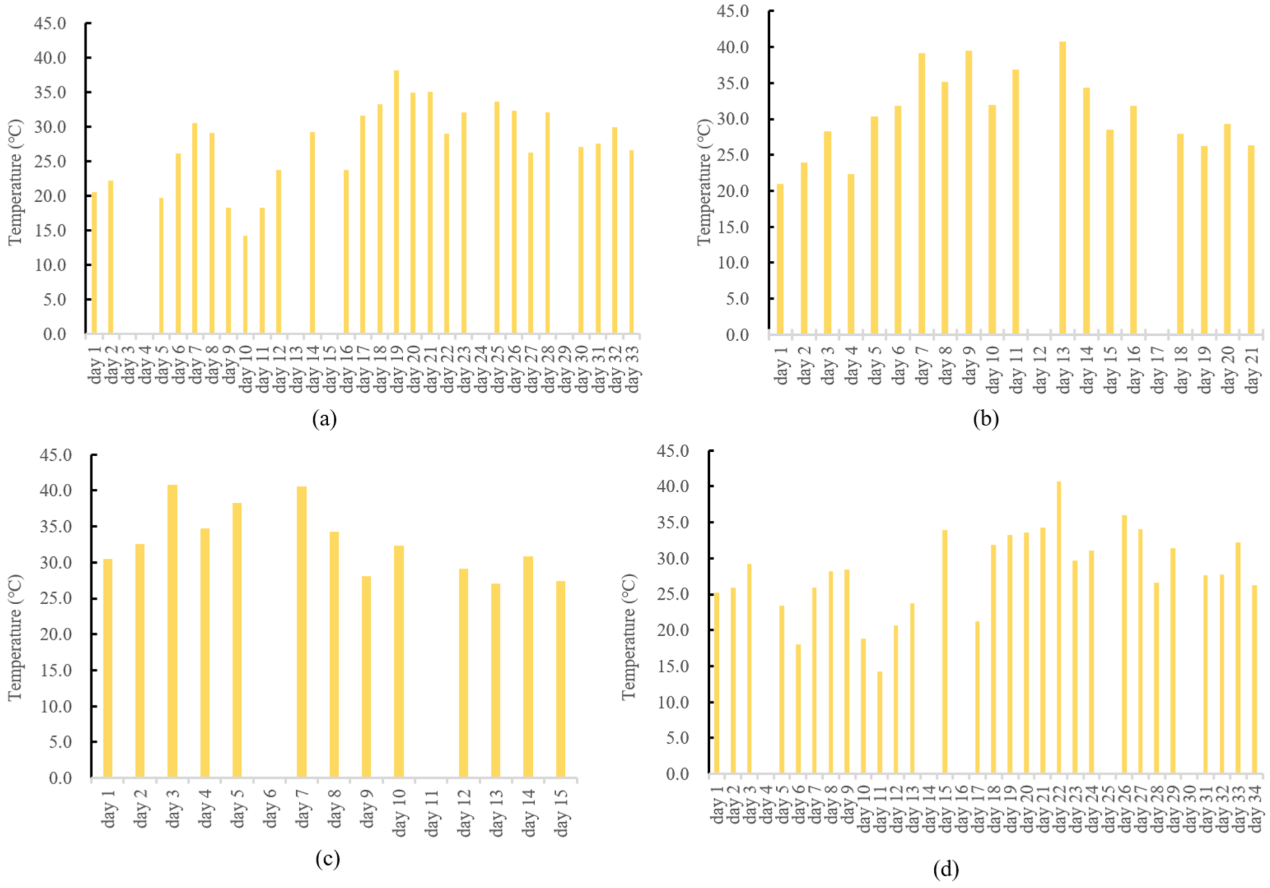

Fig. 1. Temperature Changes during Composting in Treatments. **(a), (b), (c)** and **(d)** are represent T-1, T-2, T-3 and T-4, respectively.

4 Discussions

4.1 Study on the technical means of kitchen waste composting in campus environment

The devices suitable for kitchen waste composting in campus environment include plastic barrels, wooden bins, etc. Some scholars have used 200 L rotary, perforated plastic barrels for 43 days of kitchen waste composting, and the peak temperature (49°C) appeared on day 4 [18]; some scholars have found that the pile can reach the peak temperature of 70°C during the heating period by using a wooden composting bin with a volume of 1 m^3 (450kg) composting raw materials [19].In this study, a plastic barrel with a top seal, a filter at the bottom, and a water outlet was used as a composting container. Its advantages are easy installation, small footprint, low cost, and meet the requirements of aerobic composting tests. It can support the generally recognized composting temperature change law. In the future, the barrel wall can be perforated to increase the permeability of the pile and improve the aerobic level; a large volume composting bin can be built on the campus to expand the processing capacity of kitchen waste while allowing more students to participate in the composting process, given its educational significance.

Some specific strains in compost additives can quickly and effectively degrade proteins and polysaccharides in compost raw materials and release the heat required for the pile [20]. The results of this study showed that the use of 0.4% additives could significantly improve the composting efficiency, which was manifested in the early peak temperature and short composting period. In the study of aerobic composting agents, some scholars found that the pile reached the peak temperature on day 4 [21]. Some scholars observed that the composting period could be shortened by up to 20% after adding exogenous additives, which was similar to the trend observed in this study [22].

4.2 Research on monitoring the process of food waste composting in campus environment

This study focused on the monitoring and statistical analysis of the apparent indicators and temperature changes during the composting process of kitchen waste. The results showed that the odor of the pile increased first and then decreased, and the color changed from light to dark, which was consistent with the results of Xing [1]. The emission rate of NH_3 and H_2S increased during the high-temperature period, and the cumulative emission of gas showed a gentle trend in the later period, which was similar to the change of odor observed by Cui et al. [23]. The temperature change of the reactor in this study showed a trend of increasing first and then decreasing, with slightly varying peak temperatures. Some scholars have used garden waste as an auxiliary material for kitchen waste composting, and the peak temperature during the composting process is higher than 75°C [24]. Some scholars have also measured that the peak temperature is lower than 50°C (49°C) in the study of aerobic composting of campus organic waste [18]. The peak temperature range of this study is 38.2°C-40.8°C, which is lower than the generally accepted high-temperature period of aerobic compost (50°C). The reasons may be: a) The current equipment only relies on heap turning to supply oxygen, which is not enough to ensure the energy required for aerobic microbial metabolism; 2) The high proportion of litter in compost raw materials inhibits microbial degradation due to the lignin it contains.

In summary, additives can improve the decomposition environment of composting microorganisms and shorten the composting cycle. Limited by the experimental conditions of middle school campus, this study only explored the simple equipment and simple index observation of kitchen waste composting, while composting maturity and quality evaluation lacked physical, chemical and biological indicators. In the following research, this experiment will continue to improve the technical means and maturity evaluation of kitchen waste composting in the campus environment: a) Obtain the pH change of composting through commercial pH test paper; b) Collect compost leachate, simulate seed germination test through household seedling raising device, and verify the maturity of kitchen waste compost; c) Conduct pot experiments to study the effect of compost on plant growth to verify the fertilizer efficacy. The results of this study can provide a certain research basis for the promotion of aerobic composting mode of kitchen waste in middle school campus.

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