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Original Research

Kitchen Waste Compost's Impact on Rice Quality, Yield, and Soil Environment

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Abstract

In order to investigate the usefulness of kitchen waste as compost for rice production, three groups of kitchen compost dosage gradients (15 t/hm^2, 30 t/hm^2, and 45 t/hm^2) were established on the basis of field plot experiments, and the local common chemical fertilizer of equivalent nitrogen (1.88 t/hm^2) and chicken manure compost (13.49 t/hm^2) were used as controls for fertilization treatments. We measured and assessed rice yield, rice quality, soil nutrients and heavy metal content. The findings demonstrated that rice yields in the kitchen waste compost treatment were greater than the chemical fertilizer treatment in the equivalent nitrogen fertilizer condition. Comparing kitchen waste compost to chemical fertilizer and chicken manure compost treatments, kitchen waste compost greatly decreased the chalkiness of rice and significantly enhanced flavor quality. The 15 t/hm^2 kitchen waste compost treatment greatly decreased the Hg concentration in rice in terms of safety quality. There was no discernible difference between the treatments in terms of the other residual rice heavy metal content, which was within the Chinese national standard's allowable limits. The addition of kitchen waste compost to the soil improved the soil's organic matter and fast-acting potassium contents. Regarding the safety of the soil, none of the treatments went beyond the heavy metals limit, and the levels were substantially below the maximum allowed by the Chinese national standard and were within the safe range. This demonstrates that, in line with national requirements, kitchen waste compost is an acceptable substitute for chemical fertilizers that provide the same amount of nitrogen for rice growing and is safe for agricultural soils.

Keywords: kitchen waste, rice yield, rice quality, heavy metals

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Introduction

Kitchen waste is currently a significant problem harming China's urban environment [1]. China's massive population and ongoing kitchen waste issue are the major causes of this. Many Chinese experts have focused their study on the creative use of kitchen waste as a solution to this issue [2-4]. Composting is one of them that has developed into a more sophisticated method of therapy [5, 6]. Composting has several challenges because of the variety of sources of kitchen waste and the fact that its makeup is impacted by regional cultures and even seasonal fluctuations [7, 8]. Only a small amount of study has been done on the use of kitchen compost on dryland crops since the salt and oil content of kitchen waste is significantly higher than that of other organic wastes and the method of removing salt and oil is not as effective as it might be [9, 10]. How to scientifically promote the use of kitchen compost under the premise of ensuring healthy crop growth and environmental safety has become a key part of the process of encouraging the resourceful use of kitchen waste. If the compost cannot be used on a large scale, it will have a negative impact on the composting of kitchen waste. The paddy field is very different from a dry land environment, and the substantial amount of water it contains can effectively dilute the salts in the compost to lessen or even eliminate the toxic effects of the salts on the crop, which opens up a wide range of possibilities for the use of kitchen waste compost in rice production [11]. In addition to ensuring that the rice grows normally in order to provide an adequate harvest, rice quality should be taken into account. This is due to the fact that as China's economy has grown, the Chinese people have mostly moved away from the suffering brought on by hunger and have instead turned their attention to matters like food safety and flavor quality [12].

When applying kitchen compost, we should pay additional attention to environmental safety. Before organic fertilizers may be used in China, the Chinese government must conduct a test for the presence of a specific level of heavy metals in the compost. There is a serious danger to the environment if heavy metals get into the soil during compost treatment. At the same time, heavy metals in the soil are gradually absorbed by crops as they grow and eventually enter the human body in the form of food [13]. Therefore, it is crucial to conduct a heavy metals test on the pertinent soil following the application of kitchen compost [14]. Naturally, several soil physical and chemical characteristics, such pH, EC, and nutrient content, are also crucial markers of soil health and should also be noted. In order to provide a theoretical foundation for the judicious application of kitchen compost in agricultural production and the effective resource utilization of kitchen waste, this study focuses on the effects of kitchen waste compost on rice yield, rice quality, and soil environment during the application of chemical fertilizers and chicken manure compost as a control.

Experimental

Overview of the Test Site

Materials

Nan Jing 46 is the rice variety being tested; it has a total fertility of around 165 days. Compound fertilizer used in the experiment was obtained from Jiangsu Huachang Chemical Co., Ltd., while chicken manure compost used in the experiment came from Golden Land Organic Fertilizer Co. The kitchen waste compost was provided by the institute of organic recycling, China agricultural university (Suzhou). Before transplanting the rice, all fertilizers are evenly spread as a base fertilizer, and the soil and fertilizer are then thoroughly tilled with a rototiller to a depth of 20 cm. For a summary of the fertilizers utilized in the experiments, see Table 1.

Methods

All of these treatments were applied at the same time as rice basal fertilizer. The plots were moved on June 5, 2020, and were harvested on November 17, 2020. Each treatment was randomly chosen and set up with three replications, resulting in a total of 18 plots. During the trials, the irrigation water used was untreated tap water. Flooding was maintained except for sunning at the peak of tillering and draining at maturity. In each treatment, the water layer was 5 to 8 cm deep. All of the aforementioned treatment plots had been continually planted with rice for many years. See Table 2 for details of the trial design and fertilizer application rates.

Table 1. Main physicochemical properties of the fertilizer tested.

Fertilizer	Total N (%)	Total P (%)	Total K (%)	Organic matter (%)	pH	EC/($mS\cdot cm^{-1}$)
Chemical	16.00	12.00	17.00	0.00	6.97	1.28
Chicken manure	3.07	1.17	2.14	25.6	7.56	3.24
Kitchen waste	2.76	0.48	0.40	66.24	8.05	5.79

Table 2. Experimental treatments and fertilizer application rates.

	N/(kg·hm^{-2})	P_2O_5/(kg·hm^{-2})	K_2O/(kg·hm^{-2})	Application rate/(t·hm^{-2})
CK	0	0	0	0
T1	414.00	310.5	439.88	1.88
T2	414.00	157.78	288.59	13.49
T3	414.00	72.00	60.00	15.00
T4	828.00	144.00	120.00	30.00
T5	1242.00	216.00	180.00	45.00

Measurement Items

Survey of Rice Yield and Component Factors

After harvest, the mass of all the air-dried seeds in the plot was used to compute yield. The yield components – the number of effective spikes, the number of grains per spike, the weight of 1,000 grains, and the percentage of set – were then examined inside.

Rice Quality Survey

According to the Chinese national standard GB/T 1354-2018, the total quantity of broken rice, broken millet content, incomplete grain content, yellow rice grain content, chalky grain rate, chalkiness, and whole refined rice rate of the harvested rice were assessed in each treatment. Straight-chain starch content, protein content, and taste value of rice were assessed in accordance with Jiangsu Province standard DB32/T 1762-2011, and the Hg, As, Pb, Cd, Cr, and Se content of rice was calculated in accordance with Chinese national standard GB 2762-2017.

Soil Environmental Quality Survey

On the day of rice harvest, soil samples were taken at a depth of 0 to 15 cm from the root system. They were then air-dried, powdered, and sieved through a 100 mm sieve. Using a pH meter and an EC meter, the soil's pH and soluble salt concentrations were measured. The elemental analyzer was also used to determine the total nitrogen and organic matter content of the soil, the molybdenum-antimony anti-colorimetric method to determine the effective phosphorus content of the soil and the flame photometric method to determine the fast-acting potassium content of the soil; the heavy metal content of the soil was assessed using the procedure outlined in the Chinese national standard GB 15618-2018.

Data Statistics And Analysis

Using DPS 18.1 software, the trial's raw data were submitted to one-way ANOVA after being tallied using Excel 2019.

Results

Effect of Different Treatments on Rice Yield

As shown in Table 3, each application rate of kitchen waste compost significantly increased rice production as compared to treatments using chemical fertilizers. The increases were 3.75%, 9.96%, and 13.14%, respectively, for treatments T3, T4, and T5. Also substantially different ($P<0.05$) in the high kitchen waste compost application rate (T5) compared to the chemical fertilizer and chicken manure compost treatments were the effective number of spikes, thousand grain weight, and fruit set rate. The number

Table 3. Rice yield and its components under different fertilizer treatments.

	Effective number of spikes/(10^4·hm^{-2})	Grains per spike/grain	1000 grain weight/g	Fruition rate/%	Yield/(kg·hm^{-2})
CK	430.50±17.62c	65.33±9.01b	27.97±0.71a	91.63±1.58cd	6018.90±16.97a
T1	456.03±16.38bc	68.67±9.66b	25.75±1.80b	94.19±3.02bc	7617.45±17.48b
T2	434.39±15.80c	70.67±8.50b	28.46±0.51a	98.27±0.74a	8532.75±14.45c
T3	446.93±26.60c	95.78±1.26a	24.21±0.41bc	96.98±0.62ab	7903.94±15.54d
T4	483.44±35.17ab	94.53±6.28a	23.13±0.68c	93.89±0.78bc	8376.16±25.68e
T5	503.33±13.93a	105.17±12.50a	21.53±0.15d	90.28±2.22d	8618.21±11.56f

Note: Significant differences between treatments are indicated in the same column by different letters ($p<0.05$), same below.

of grains per spike in the kitchen waste compost treatment was likewise considerably larger ($P<0.05$) than in the other treatments. The aforementioned findings show that adding kitchen waste compost does increase rice output when nitrogen levels are equivalent.

Effect of Different Treatments on Rice Quality

Processing Quality

According to Table 4, the kitchen waste compost treatments (T3, T4, and T5) significantly ($p<0.05$) reduced the total amount of broken rice, broken millet content, and yellow rice grain content of rice when compared to the chemical fertilizer treatment (T1) and the chicken manure compost treatment (T2). As the amount of kitchen waste compost application increased, the total amount of broken rice and broken millet content decreased, and the incomplete grain and yellow rice grain content increased. The fineness rate rose as the amount of compost applied increased, although this was not significantly different from the other treatments. It is clear that using kitchen compost in place of artificial fertilizers would enhance the quality of the processing.

Taste Quality

The kitchen waste compost treatment reduced the chalkiness and chalkiness of the rice compared to the chemical fertilizer treatment and the chicken manure compost treatment, with the T5 treatment having the lowest chalkiness and the T3 treatment having the lowest chalkiness (Table 5). The taste value for the composted kitchen treatments were usually higher than those for the chemical fertilizer treatments, with the T3 treatment having the highest ratings but not by a great deal. The protein content and taste value are closely associated, according to earlier studies. The treatments in this experiment with relatively modest protein contents scored highly on the taste scale. This demonstrates how using kitchen compost in place of artificial fertilizers may enhance the rice's look and flavor.

Safety Quality

While Cr, As, Se, Cd, and Pb concentrations did not consistently vary among fertilizer treatments, the T3 treatment rice had the lowest Hg content, which was considerably lower than the chicken manure compost treatment and the chemical fertilizer treatment (Table 6). The heavy metal concentrations of rice in all treatments in this research complied with the Chinese national guideline GB 2762-2005 for rice contaminant limits (Hg 0.02 mg/kg, As 0.15 mg/kg, Pb 0.2 mg/kg, Cd 0.2 mg/kg, Cr 1 mg/kg, and Se 0.3 mg/kg).

Effects of Different Fertilizer Treatments on the Soil Environment

Physical and Chemical Properties of the Soil

Table 7 shows how applying kitchen waste compost greatly boosted the soil's organic matter and fast-acting potassium levels. The fact that kitchen waste compost

Table 4. Effect of different fertilizer treatments on the processing quality of rice.

	Total broken rice/%	Broken millet content/%	Incomplete grain/%	Yellow rice grain content/%	Fineness rate/%
CK	16.90±1.34 a	0.41±0.02 a	2.51±0.24 c	0.12±0.01 e	83.12±9.87 a
T1	11.50±0.56 b	0.34±0.01 b	3.84±0.57 a	1.33±0.05 a	88.57±8.73 a
T2	10.60±0.97 b	0.25±0.00 c	2.67±0.28 bc	0.78±0.06 b	89.40±7.21 a
T3	7.40±0.47 c	0.15±0.02 d	2.78±0.03 bc	0.27±0.00 d	90.65±10.02 a
T4	6.20±0.35 cd	0.12±0.00 e	2.98±0.47 abc	0.28±0.01 d	93.17±9.98 a
T5	4.90±0.38 d	0.05±0.00 f	3.49±0.79 ab	0.58±0.06 c	95.19±5.24 a

Table 5. Effect of different fertilizer treatments on the taste quality of rice.

	Chalk rate/%	Chalkiness/%	Protein content/%	Starch content/%	Taste value/score
CK	7.81±0.23 d	1.88±0.27 c	7.40±0.67 a	17.71±1.09 a	84.70±2.62 a
T1	17.87±1.58 a	5.74±0.98 a	7.42±0.58 a	17.39±1.87 a	85.12±2.57 a
T2	13.29±1.04 b	3.89±0.52 b	7.19±0.51 a	17.00±0.97 a	87.96±1.32 a
T3	13.03±0.98 b	2.69±0.49 c	7.10±0.27 a	17.22±2.57 a	88.13±2.44 a
T4	12.21±1.37 b	3.81±0.58 b	7.21±0.54 a	17.89±3.14 a	85.95±0.78 a
T5	9.79±0.83 c	3.81±0.37 b	7.59±0.81 a	17.72±2.18 a	85.26±2.31 a

Table 6. Effect of different treatments on the content of heavy metals in rice.

	Hg/(μg·kg^{-1})	Cr/(mg·kg^{-1})	As/(mg·kg^{-1})	Se/(mg·kg^{-1})	Cd/(mg·kg^{-1})	Pb/(mg·kg^{-1})
CK	4.02±0.32 bc	0.19±0.02 b	0.10±0.00 a	0.08±0.01 ab	0.01±0.00 a	0.03±0.01 a
T1	5.29±0.32 a	0.26±0.00 ab	0.11±0.00 a	0.09±0.01 ab	0.01±0.00 a	0.02±0.00 a
T2	5.35±0.43 a	0.26±0.06 ab	0.11±0.01 a	0.07±0.00 b	0.01±0.00 a	0.02±0.00 a
T3	3.77±0.61 c	0.22±0.05 b	0.10±0.01 a	0.10±0.01 a	0.02±0.00 a	0.02±0.02 a
T4	4.64±0.31 ab	0.32±0.04 a	0.10±0.04 a	0.09±0.00 ab	0.01±0.00 a	0.04±0.00 a
T5	5.34±0.59 a	0.21±0.03 b	0.15±0.01 b	0.09±0.03 ab	0.01±0.00 a	0.07±0.02 b

Table 7. Changes in soil physicochemical properties under different fertilizer treatments.

	Organic matter/(g·kg^{-1})	Total N/%	Ava.P/(mg·kg^{-1})	Ava.K/(mg·kg^{-1})	pH	EC/(mS·cm^{-1})
CK	24.65±0.95c	0.20±0.02a	23.76±3.09c	47.33±1.80d	6.30±0.12a	0.62±0.01d
T1	20.84±1.08d	0.21±0.02a	24.42±2.77c	93.58±5.29c	6.29±0.25a	0.71±0.03cd
T2	25.29±1.55c	0.22±0.02a	27.29±3.53bc	103.53±10.40c	6.33±0.21a	0.75±0.03bc
T3	31.70±1.40b	0.23±0.03a	30.39±2.29abc	141.47±6.78b	6.35±0.31a	0.83±0.06abc
T4	33.45±1.39b	0.24±0.08a	35.21±2.48ab	153.65±5.94b	6.39±0.07a	0.87±0.07ab
T5	40.95±0.61a	0.28±0.05a	38.07±3.59a	196.23±11.13a	6.45±0.16a	0.95±0.04a

itself contains a sizable amount of organic matter, which directly supplements the field soil's organic matter content, accounts for the largest increase in soil organic matter content. In comparison to no application, the application of 15 t/hm^2 of kitchen waste compost raised the soil's organic matter content by 28.60%; this was a much better result than applying chemical fertilizers and chicken manure compost in an equivalent amount of nitrogen. The soil's organic matter content rose by 66.13% when the compost application reached 45 t/hm^2. With an application rate of 15 t/hm^2 already achieving 198.90%, 51.18%, and 36.65% higher than the no-fertilizer, chemical fertilizer, and chicken manure compost treatments, respectively, the application of kitchen waste compost was also successful in increasing the fast-acting potassium content of the soil. This effect grew as the application rate of kitchen waste compost increased. The total nutrient content, which included total N, active phosphorus, and fast-acting potassium, revealed no significant differences between the treatments, owing primarily to the higher content of total N compared to active phosphorus and fast-acting potassium. If the total soil nutrient content had been calculated using total phosphorus and total potassium content, the outcome might have been different. Additionally, the effects of each fertilizer treatment on the soil's electrical conductivity (EC) varied, with all treatments – all but the chemical fertilizer treatment – significantly boosting the EC($P<0.05$). Once more, this is presumably caused by the fact that organic fertilizers contain a certain amount of salts, which during application result in the accumulation of soil salts. None of the fertilizer treatments significantly differed from the non-fertilizer treatments in terms of total soil nitrogen concentration or pH.

Heavy Metal Content

Regarding the use of kitchen waste compost in agricultural production, soil safety has always been a significant concern, and the impact on the soil's heavy metal level is of utmost significance. The application of kitchen waste compost had no discernible impact on the concentrations of Cr, As, Zn, Cu, and Ni in the rice soil, as shown in Table 8, however there may have been an increase in the concentrations of two heavy metals, Hg and Pb. There were no appreciable changes in the levels of these two heavy metals among the various fertilizer treatments, but all treatments – including fertilizer application – led to higher levels of Hg and Pb in the soil compared to the no-fertilizer treatment. The addition of fertilizer also resulted in a modest decrease in the soil's Cd concentration, however the T2-T4 treatments did not differ significantly from CK in this regard. This is possibly because fertilizer use encouraged rice growth and also encouraged the uptake of Cd, one of the heavy metals that rice can most easily absorb. The quantities of heavy metals in agricultural soils are defined by Chinese national standard GB15618-2018, and none of the heavy metals in this trial surpassed those limits. However, we should still think about the question of cumulative impacts, or whether using kitchen compost over an extended period of time will result in a steady buildup of heavy metals.

Table 8. Effect of different fertilizer treatments on soil heavy metal content.

	Hg/ ($mg \cdot kg^{-1}$)	Pb/ ($mg \cdot kg^{-1}$)	Cd/ ($mg \cdot kg^{-1}$)	Cr/ ($mg \cdot kg^{-1}$)	As/ ($mg \cdot kg^{-1}$)	Zn/ ($mg \cdot kg^{-1}$)	Cu/ ($mg \cdot kg^{-1}$)	Ni/ ($mg \cdot kg^{-1}$)
CK	0.10±0.02 b	29.12±3.21 c	0.22±0.03 a	61.57±5.23 a	8.62±1.78 a	58.19±4.79 a	30.17±5.41 a	33.46±3.81 a
T1	0.17±0.01 a	38.68±2.59 b	0.16±0.02 b	64.79±3.98 a	11.90±3.46 a	59.94±3.86 a	31.13±3.19 a	34.81±3.46 a
T2	0.16±0.01 a	58.80±5.07 a	0.19±0.02 ab	62.11±6.15 a	12.96±2.13 a	59.90±5.33 a	30.25±1.65 a	32.68±5.38 a
T3	0.15±0.01 a	59.50±4.79 a	0.22±0.01 a	61.76±6.78 a	11.42±2.19 a	57.32±4.37 a	37.50±5.41 a	33.81±2.99 a
T4	0.16±0.02 a	52.94±1.78 a	0.18±0.06 ab	64.57±6.14 a	12.18±0.79 a	57.91±5.96 a	31.79±7.12 a	32.97±4.48 a
T5	0.16±0.03 a	54.47±3.76 a	0.15±0.01 b	66.10±1.57 a	13.09±2.99 a	59.88±8.73 a	34.11±9.11 a	35.82±6.63 a

Discussion

As a relatively new method of treating kitchen waste, composting is more environmentally friendly and produces less carbon dioxide than other treatment options like landfilling and incineration [15]. The high oil and salt content of kitchen waste, however, has introduced a number of challenges to its use in agriculture. In Jiangsu Province, the use of kitchen waste compost in rice cultivation has been reported, but it has not been thoroughly investigated. The kitchen waste compost treatment had a significant impact on rice yield in this experiment compared to the chemical fertilizer and chicken manure compost treatments, which was examined because the kitchen compost could significantly increase the number of effective spikes and the number of grains per spike of rice, which was consistent with the findings of earlier studies. It was also found that the application of kitchen waste compost was effective in improving the processing quality, appearance and taste quality of rice, and had no significant effect on most heavy metals in rice, with the treatment with 15.00 t/hm^2 of kitchen compost also significantly reducing the Hg content in rice. There is no discernible difference in soil safety between the treatments, indicating that kitchen waste compost is safe for paddy soils and can enhance the physicochemical properties of the soil in a specific application. As an organic fertilizer, kitchen waste compost is able to increase the organic matter and fast-acting potassium content of the soil with a higher effect than both the chemical fertilizer treatment and the chicken manure compost treatment.

China, the most populous nation on earth, wastes an astounding amount of food every year [16]. There is no doubt that today's Chinese people are more concerned with environmental issues than they should be with hunger [17-19]. Therefore, the Chinese government and scientists now have to figure out how to deal with the enormous amount of kitchen waste that is created every day. This is especially true in the Yangtze River Delta region of China. In order to encourage the creative use of kitchen garbage throughout China, Han Zheng, a member of the Standing Committee of the Political Bureau of the Chinese Central Committee, also offered instructions for the development of an institution in the Yangtze River Delta region in 2019 [20]. However, it should be recognized that China is a sizable area with a varied food culture [21]. Researchers are already struggling with the amount of salt and oil in kitchen waste in the Yangtze River Delta, where diets are frequently low in salt and high in sugar. One can only speculate how challenging it would be to recycle the food waste produced in the north-eastern part of China, where residents often consume a diet heavy in salt and oil [22]. As the Chinese government has pledged to achieve carbon neutrality by 2060, it is vital to enhance study into the separate use of kitchen waste in various regions [23]. However, the resourceful use of kitchen waste does cut carbon emissions. The Yangtze River Delta region provided the kitchen waste for this study, and the trial's findings demonstrated that it is safe to use this waste in the production of rice. This does not imply that kitchen waste from all parts of China may be composted successfully, though. It's possible that as China's population grows and regional culinary customs become more uniform across the nation, compost will become more consistent in both composition and nature. Although there are variances in the efficiency of kitchen waste compost made from kitchen waste across China, this study nevertheless offers a high reference value for other regions of China to carry out resource utilization of kitchen trash. The differences in the effectiveness of kitchen waste compost formed from kitchen waste across China will be related in a separate article.

Conclusions

The findings of this study demonstrate that the use of household compost during rice growing improves rice yield and quality while having a little negative influence on the soil environment. This study should serve as the foundation for a comparison with other typical areas of China where kitchen compost is employed.

Acknowledgments

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Conflict of Interest

The authors declare no conflict of interest.

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