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Original Research

Study on the Effect of Kitchen Waste Compost Substrate on the Cultivation of *Brassica chinensis* L.

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Abstract

To test the effect of a substrate made from kitchen waste compost rather than partial peat on the growth of pak choi (*Brassica chinensis* L.). In indoor pots, four substrates were prepared by volume: 80% peat + 20% vermiculite (T1), 70% peat + 10% kitchen waste compost + 20% vermiculite (T2), 60% peat + 20% kitchen waste compost + 20% vermiculite (T3), and 50% peat + 30% kitchen waste compost + 20% vermiculite (T4). Soil was used as a control in the studies. The physicochemical properties of the four substrates, and the seed germination, growth, and quality of pak choi were all investigated. The results showed that the addition of kitchen waste compost increased the pH, EC, and bulk weight of the substrates while decreasing the aeration porosity. The addition of kitchen waste compost considerably enhanced the alkaline nitrogen, effective phosphorus, fast-acting potassium, and organic matter content of the substrates. Overall, the 70% peat + 10% kitchen waste compost + 20% vermiculite cultivation substrate formulation had a substantial effect on the quality indices of pak choi, delivering better growth results than soil. On the basis of this study, it is suggested that the cultivation substrate employing kitchen waste compost be optimized in order to further reduce the amount of peat utilized.

Keywords: kitchen waste, compost, pak choi, substrate, quality

Introduction

Every day, Chinese people produce a large amount of leftover food on their tables [1]. With the rise of China's economic power since 2010, the Chinese government has been able to address certain previously unresolved issues, the most important of which is environmental control, in addition to punishing corrupt officials [2, 3]. The simple incineration or dumping of kitchen waste is obviously not a desirable solution because it produces a big quantity of carbon emissions and is contrary to the Chinese government's environmental protection ideology [4-6]. The recycling of kitchen waste is then a better choice [7]. Composting kitchen waste is one of the many resource utilization methods that has become increasingly mature, and there are numerous reports on the use of kitchen waste compost in rice production [8]. However, because of the unique qualities of kitchen

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waste, there are frequently high levels of salt and oil in the compost, making it impossible to apply larger amounts of compost directly to the cultivation of dryland vegetables [9]. It is crucial for many academics to make sure that as much kitchen waste compost as possible is used in the agricultural production process while ensuring crop growth and ecological safety because the practical application of kitchen waste compost will directly influence the development of industrial technology related to the resource utilization of kitchen waste [10]. In this situation, our previous research indicated that kitchen waste compost could be used as a suitable replacement for peat in vegetable seedlings, not only to achieve a better growth promotion effect for the crop, but also to achieve a certain degree of conservation of non-renewable resources like peat [11]. The application potential of kitchen waste compost in vegetable growth needs to be further explored because, in contrast to direct fertilization, the amount of kitchen waste compost used in the preparation of seedling substrates is still relatively small and has a limited positive feedback effect on the resource utilization process of kitchen waste.

Substrates are a type of soilless cultivation that utilizes a solid medium to anchor plant roots and absorb nutrients and oxygen through the substrate [12, 13]. They are widely used for indoor gardening of organic flowers and vegetables. Due to the Chinese government's policy of epidemic prevention, a great number of Chinese citizens have been unable to access fresh and sufficient veggies in time since the COVID-19 [14]. In this situation, substrates clearly assist in reducing specific family vegetable needs and play a significant role in the balcony economy, which has a promising market [15]. Unlike seedling substrates, which are primarily utilized for seedling growth, culture substrates can provide adequate growing space and essential nutrients throughout the crop reproduction period. The successful application of kitchen waste compost in the preparation of vegetable culture substrates means that the compost may be used in a more promising manner, which will be extremely beneficial in encouraging the resourceful use of kitchen waste. In this study, kitchen waste compost was combined with peat and vermiculite in various amounts to make a cultivation substrate and to examine its effects on pat choi seed germination, seedling growth, and crop quality. The goal is to provide a more thorough theoretical foundation and application technologies for kitchen waste resource exploitation.

Experimental

Materials

The experiment took place at the Center for Artificial Climate and Plant Culture, Institute of Organic Recycling (Suzhou), China Agricultural University. The test crop was pak choi ; the test kitchen waste compost was made from kitchen waste collected at the Taihu Lake Organic Waste Treatment and Utilization Demonstration Centre; the test peat and vermiculite were provided by the Liaoning Academy of Agricultural Sciences; and the test field soil was obtained from the Institute of Organic Recycling (Suzhou), China Agricultural University's vegetable test base. Table 1 shows the main physicochemical parameters of the substrates that were proportioned using air-dried raw materials.

Methods

In the experiment, five treatments were set up, with field soil serving as the control treatment (CK) and the remaining treatments using kitchen compost as an equal gradient replacement treatment for peat (T1-T4). Each treatment was replicated three times, and the volumetric weight of the substrate material corresponding to each treatment is shown in Table 2.

Cultivation Substrate Preparation

The air-dried cultivation substrate's raw material was proportionally poured into plastic pots, thoroughly mixed, and 500 g of samples were collected for testing for each treatment in accordance with the design of each treatment as given in Table 2.

Table 1. Physiochemical properties of the experiment materials.

Index	Peat	Vermiculite	Kitchen waste compost	Soil
pH	4.58	6.66	8.85	6.51
EC/($mS \cdot cm^{-1}$)	0.49	0.03	5.12	1.03
Unit weight/($g \cdot cm^{-3}$)	0.27	0.68	0.49	1.08
Aeration porosity/%	32.72	12.21	20.12	10.34
Organic matter/%	36.69	0.07	45.44	2.67
Total N/%	0.89	0.00	2.76	0.24
Ava. P/($mg \cdot kg^{-1}$)	141.1	0.00	996.27	17.83

Table 2. Volume fraction of raw materials seedling substrates in different treatment.

Treatment	Kitchen waste compost/%	Peat/%	Vermiculite/%	Proportion of peat replaced/%
T1	0.00	80.00	20.00	0.00
T2	10.00	70.00	20.00	12.50
T3	20.00	60.00	20.00	25.00
T4	30.00	50.00	20.00	37.50

Determination of the Physicochemical Properties of Cultivation Substrates

The agriculture industry standard NY/T2118-2012 was used to determine the sample substrate capacity and aeration porosity: The mass of a 200 mL ring knife with a bottom cover was weighed and recorded as M0; the new substrate sample was equally packed into the ring knife, and the mass of the ring knife and substrate was weighed and recorded as M1; the air-dried substrate sample was packed into the ring knife during seedling development in the compact condition of the substrate and secured with a perforated top cover, and the mass of the ring knife was weighed and recorded as M2. The ring knife's mass was measured and recorded as M2; the ring knife was placed in a funnel lined with filter paper and drained naturally for 3 hours before being measured and recorded as M3. The determination index was calculated in the following manner.

$$\text{Unit weight} = (M_1\text{-}M_0)/200;$$

$$\text{Ventilation porosity} = (M_2\text{-}M_3)/200;$$

The pH, EC, alkaline nitrogen, effective phosphorus, fast-acting potassium and organic matter content of the sample substrates were determined with reference to Dong's method [16].

Determination of the Germination Index of Pak Choi Seeds

The effect of kitchen waste compost substrate on the germination of pak choi seedlings was investigated using Huang's method [17]. Ten seeds of comparable size were selected and placed in petri dishes (9 cm) lined with filter paper as the control treatment (CW), with sterile water added as the rest of the treatments, with an infusion of each cultivation substrate and field soil designed in Table 2, with the infusion preparation method referring to the agricultural industry standard NY/T525-2021. Each treatment was reproduced three times, with three Petri dishes set up for each. For 5 days, the seedlings were maintained at 25ºC in a constant temperature incubator. The quantity of seeds germinated was recorded everyday, and each dish was replaced with sterile water at the proper time using the weighing method. The germination potential of pak choi seeds was tested three days later, the germination rate was measured five days later, and the germination index was determined.

$$\text{Germination rate(\%)} = \frac{\text{Number of all seeds germinating at the end of germination}}{\text{Number of seeds for testing}} \times 100\%$$

$$\text{Germination potential(\%)} = \frac{\text{Number of seeds germinated in 3d}}{\text{Number of seeds for testing}} \times 100\%$$

$$\text{Germination index(GI)} = \sum \frac{\text{Number of germinating seeds per day}}{\text{Corresponding days to germination}}$$

Seeding and Management

Each treatment was created by pouring 8000 mL of cultivation substrate into pots (25 cm×20 cm×20 cm) and planting 50 seeds per pot, with three replications of one pot each treatment. Each treatment received 1000 mL of water per pot, with 500 mL of water refilled every 2 d during the trial period, and was incubated in an artificial climate chamber at 21ºC and 80% humidity for 18 days.

Determination of Growth Indicators of Pak Choi

The number of seedlings that emerged and the seedling rate were calculated five days after seeding. The pots were then planted with 20 seedlings of uniform growth; 18 days later, five plants were picked from each pot using the five-point sample approach, and the plant height was measured with a straightedge. Leaf chlorophyll content was measured using a SPAD 502 chlorophyll content tester. The fresh weight of the plant's above-ground portions was determined using an electronic balance, after which the enzyme was destroyed at 90ºC, dried to a consistent weight at 60ºC, and weighed.

Determination of Quality Indicators of Pak Choi

At 18 d after sowing, five plants were selected from each pot by the five-point sampling method for the determination of quality indicators. The soluble protein content was determined by using the Kormas Brilliant Blue method, the total soluble sugars by using the enthrone colorimetric method and the organic acids by using the indicator titration method.

Data Processing

The raw data were counted using Excel 2019 software, and the variance was calculated using Duncan's new complex polarization approach via DPS 18.1 software.

Results

Physicochemical Properties

The addition of kitchen waste compost had a significant effect on the physicochemical parameters of the substrates, particularly in terms of pH and EC (Fig. 1), both of which increased significantly ($p<0.05$). In terms of unit weight, the substrate tended to rise with the addition of kitchen waste compost, but with the addition of 10% kitchen waste compost (T2 treatment), the substrate unit weight did not differ significantly from the treatment without the addition of kitchen waste compost (T1 treatment). In terms of aeration porosity, the addition of kitchen waste compost reduces the aeration porosity of the substrate significantly. The chemical properties of the substrate were primarily in terms of its nutrient content, with a nutrient content that was insufficient to support the growth of pak choi throughout its reproductive life, while a nutrient content that was too high would inhibit the growth of pak choi. With the addition of kitchen waste compost, the grown substrate's alkaline nitrogen, effective phosphorus, fast-acting potassium, and organic matter content rose significantly ($p<0.05$).

Seed Germination

From Fig. 2, it can be seen that the addition of kitchen waste compost had a greater effect on the germination of pak choi seeds. At 20% and 30% (T3 and T4 treatments), the germination rate, germination potential, and germination index of pak choi seeds were significantly lower ($p<0.05$) than those of the CK treatment, while the germination rate and germination potential of the T2 treatment were not significantly different from those of the CK and T1 treatments. T2 treatment germination index was substantially greater than CK treatment ($p<0.05$), but not significantly different from T1 treatment. This suggests that when the addition of kitchen waste compost exceeds 10%, the corresponding cultivation substrate may have an inhibiting effect on the germination of pak choi seeds, however when it does not exceed 10%, there may be some stimulation of germination.

Growth Indicators

Table 3 shows that when the amount of kitchen waste compost added was less than 10%, the seedling emergence rate of the grown substrate was not lower than that of the CK treatment. The addition of kitchen waste compost significantly lowered the seedling emergence rate of pak choi ($p<0.05$), similar to the germination rate in Fig. 2. However, the seedling emergence rates of both the CK and T2 treatments were significantly lower than their germination rates, most likely because germination rates were measured using leaching solutions and the effects of other physical properties on the germination

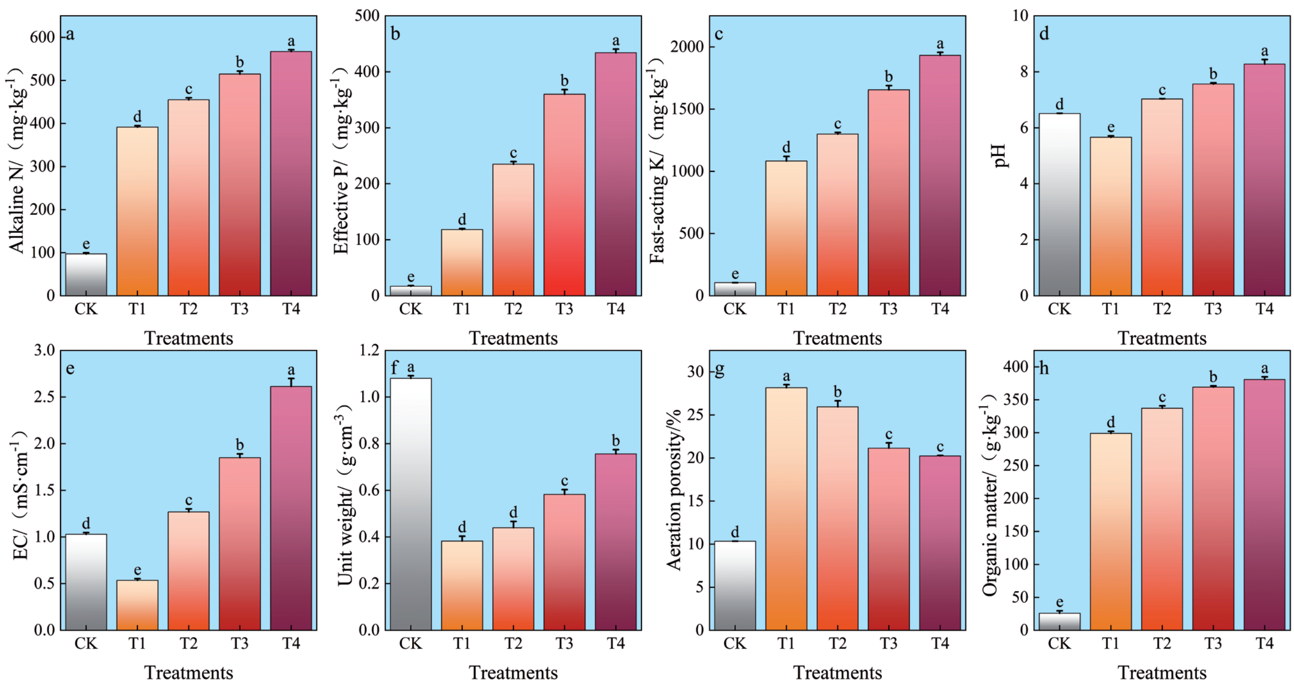

Fig. 1. Physicochemical properties of different cultivation substrates. Note: Different lowercase letters indicate significant differences ($p<0.05$)

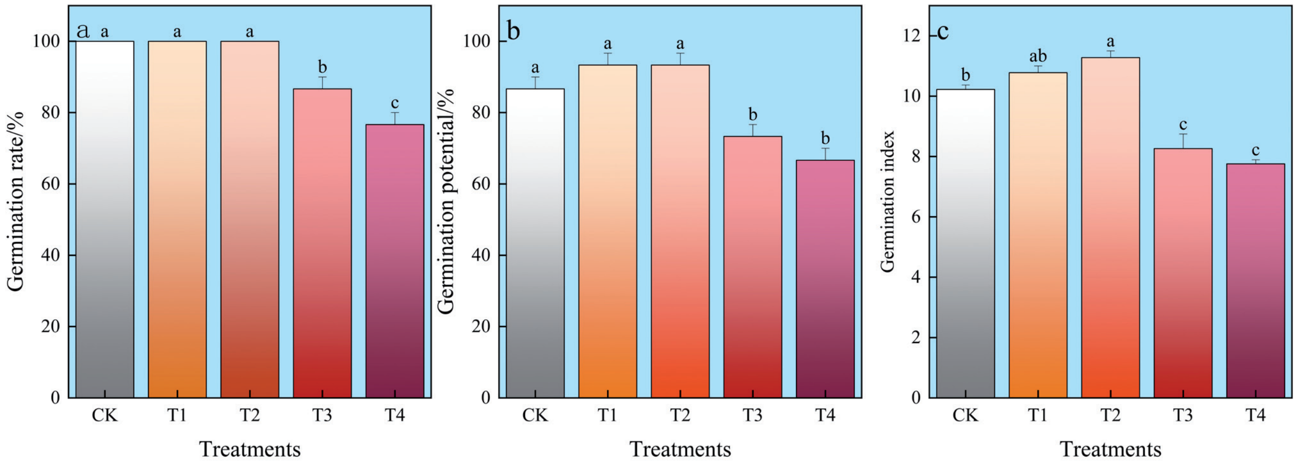

Fig. 2. Effect of different cultivation substrate extracts on the germination of pak choi seeds. Note: Different lowercase letters indicate significant differences (p<0.05)

of pak choi seeds were not reflected such as unit weight and ventilation porosity. In agricultural production, seedling emergence is a relatively excellent measure of the substrate's compatibility for crop growth. In terms of chlorophyll content, there were no significant variations between the cultivated substrates, however they were significantly higher than the soil (p<0.05). There were no significant differences in leaf area or above-ground plant biomass between the T1 and T2 treatments, however both were significantly higher than the other treatments (p<0.05). The T2 treatment had the highest values in terms of leaf area, above-ground fresh weight, and above-ground dry weight among all treatments, with 174.71%, 105.50%, and 158.75% increases in leaf area, above-ground fresh weight, and above-ground dry weight, respectively, when compared to the CK treatment, where the differences were more significant. This suggests that adding 10% kitchen waste compost to the substrate was more advantageous to the growth of pak choi plants.

Quality Indicators

The addition of kitchen waste compost improved the quality of pak choi significantly (Table 4). In terms of soluble protein content, all cultivated substrate treatments were significantly higher than the CK treatment (p<0.05), and with the addition of kitchen waste compost, the soluble protein content of pak choi showed a significant upward trend, increasing by 53.89% compared to the T1 treatment by the T4 treatment. All cultivation substrate treatments had significantly higher total soluble sugar content than the CK treatment (p<0.05), and with the addition of kitchen waste compost, the total soluble sugar content of pak choi showed a significant upward trend, with the total soluble sugar content of the T4 treatment being 27.66% higher than that of the T1 treatment. Similar to the other two quality indicators, the organic acid content increased significantly with the addition of kitchen waste compost (p<0.05), with the organic acid content in the T4 treatment increasing by 79.17% compared to the T1 treatment.

Discussion

Cultivation substrates have emerged as an emergent style of vegetable cultivation, and agriculturalists are increasingly accepting of their intense and efficient properties, implying that market demand for cultivation substrates will continue to grow [18]. Current culture substrates are comparable to seedling substrates in that they all contain a significant amount of peat, and

Table 3. Effect of different ratios of kitchen compost substrates on the growth of pak choi.

Treatment	Seedling rate/%	Chlorophyll/SPAD	Leaf area/cm^2	Fresh weight on ground/g	Dry weight on ground/g
CK	92.00±1.15b	48.10±0.25c	3.40±0.14b	6.54±0.67b	0.80±0.10b
T1	97.33±0.67a	58.53±2.14a	8.30±0.04a	11.06±1.98a	1.58±0.43a
T2	93.33±1.76b	57.70±0.44ab	9.34±1.14a	13.44±0.69a	2.07±0.02a
T3	84.00±1.15c	57.87±1.04ab	5.56±0.73b	7.06±0.54b	0.70±0.03b
T4	80.00±1.15d	53.83±1.66ab	4.72±1.24b	4.03±0.57b	0.40±0.09b

Note: Different lowercase letters in the same column represent significant differences (p<0.05)

Table 4. Effect of different ratios of kitchen compost substrates on the quality of pak choi.

Treatment	Soluble protein/(mg·g^{-1})	Total soluble sugar/(mg·g^{-1})	Organic acid/%
CK	7.46±0.08d	37.63±0.66d	0.24±0.01e
T1	8.51±0.23c	41.04±0.34c	0.28±0.01d
T2	9.77±0.11b	42.70±0.58c	0.33±0.01c
T3	10.18±0.11b	47.40±0.87b	0.37±0.01b
T4	11.48±0.16a	52.39±0.68a	0.43±0.01a

Note: Different lowercase letters in the same column represent significant differences ($p<0.05$).

large-scale peat exploitation poses a substantial threat to the ecological environment [19-21]. We previously successfully constructed a seedling substrate for cucumber seedlings using a combination of kitchen waste compost and other organic wastes, implying that kitchen waste compost might be used for vegetable production [8]. The amount of replacement obviously affected the physicochemical qualities of the substrate and the growing condition of the chard in the current investigation, where peat was partially replaced by kitchen waste compost and the matching substrate was made with vermiculite. There is no agricultural industry standard for vegetable cultivation substrates in China yet, so for a simple evaluation of the cultivation substrates in this study, refer to the Hebei provincial local standard DB13/T 2880-2018, which specifies in detail the physicochemical indicators of leafy vegetable cultivation substrates. According to this standard, the bulk weight should be 0.30~0.60/(g·cm^{-3}), the aeration porosity should be 15~20%, the pH should be 5.5~7.0, the EC should be 500~800/(μS·cm^{-1}), the organic matter content should be 10~35% and the quick-acting nutrient content should be 8~20%. The T1 and T2 treatments in this trial were pretty close to the standards, but did not entirely comply with the relevant quality factors. In comparison to garden soil, the substrate containing 10% kitchen waste compost exhibited superior development in terms of leaf area, chlorophyll content, and above-ground biomass.

According to our group's research in Jiangsu and Liaoning, vegetables produced in cultivated substrates are frequently provided to the middle and high end of the market due to the cost and accordingly higher quality requirements of the veggies. In this study, we assessed the influence of culture by measuring the quality of pak choi on various substrates. The soluble protein concentration, total soluble sugar content, and organic acid content all increased dramatically, most likely due to the salt content in the kitchen waste compost creating varying degrees of salt stress to the pak choi development. Plants will actively accumulate some soluble compounds, such as amino acids, sugars, and polyols, to reduce the osmotic potential in the cytoplasm and so safeguard the integrity and function of the cells in order to alleviate the stress impact induced by salinity [22, 23]. Taking into mind the growing condition of pak choi, particularly the above-ground fresh weight, the substrate treated with 10% kitchen waste compost, was shown to be more favorable for the culture of pak choi. Furthermore, the germination index and other indicators were employed in this study to analyze the substrates from a different perspective, based on the method used for seedling substrates. A germination index greater than 100% implies good seedling performance for seedling substrates, and a high germination index is also indicative of a good cultivation substrate [24]. In this study, the T2 treatment exhibited the greatest germination index, indicating that a substrate containing 10% kitchen waste compost is beneficial for the growth of baby greens.

In this study, it was shown that kitchen waste compost could partially replace peat as a cultivation substrate and significantly contribute to the growth and quality of pak choi, but the optimum addition was only 10% and the corresponding cultivation substrate still contained 70% peat, leaving room for further substitution. Peat can be further substituted by organic waste fermentation products such as straw compost, with the pH and other physicochemical features of the fermentation products being important [25, 26]. Compost and other fermentation products are frequently alkaline, which can cause the pH of the substrate to be too high for crop growth [27]. This characteristics is also present in this study's kitchen waste compost, since our previous research on seedling substrates discovered that the addition of exogenous compounds such as agro-amino acids or sulphur powder could effectively lower the pH and therefore produce good crop growth. Based on the findings given here, it is advised that the peat be further replaced by other organic waste fermentation products. By combining exogenous substances, etc., to make a suitable substrate for the growing of vegetable crops such as pak choi, the physical and chemical qualities of the formulations will be improved.

Conclusions

The effect of kitchen waste compost on the cultivation of pak choi was investigated in four ways in this paper: the physicochemical properties of the substrate, seed germination, growth, and quality of pak choi. The study's findings revealed that adding 10% kitchen waste compost had a substantial effect on the development and quality of pak choi. It is suggested that the kitchen waste compost substrate be optimized based on the findings of this study in order to reduce the amount of peat utilized even further.

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Conflict of Interest

The authors declare no conflict of interest.

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