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Combined Aerobic Fermentation of Maricultural and Agricultural Solid Waste: Physicochemical Property and Bacterial Community Structure

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Abstract: The large-scale production of maricultural solid waste is not used effectively and has a significant impact on the environment. However, there is no report on the utilization of solid waste in mariculture of maricultural and agricultural solid waste. At present, aerobic composting is a simple and feasible means of waste resource utilization, but it also seriously pollutes the environment. This paper studied the change of physical and chemical properties (T1: solid waste + straw, T2: solid waste + cow dung + straw, T3: solid waste + cow dung + straw + 5% biochar, T4: solid waste + chicken dung + cow dung + straw + 5% biochar) and microbial succession in the composting process (T4: solid waste + chicken dung + cow dung + straw + 5% biochar) and the effect of decomposed products on seed growth. The results showed that the mixed compost of various materials had a good regulating effect on the physical and chemical indexes, and the highest temperature could reach 69.4 °C. Biochar could extend the high temperature period by 1–2 days. The germination indexes of seeds treated with T1–T4 were 75%, 80%, 81%, and 94%, respectively. Through the change of the seed germination index, it could be seen that the bacterial community structure changed significantly during composting. The Chao 1 index and Shannon index showed that the bacterial abundance and diversity index increased and then decreased. The analysis of the bacterial community structure showed that Proteobacteria and Acinetobacter were the main bacteria in composting, and the relative abundance of Proteobacteria was 81.9% at the phyla level. Acinetobacter and Pseudoxanthomonas were the main bacteria in the process of composting. Acinetobacter was the dominant bacteria in the heating stage, with an abundance of 67.2%.

Keywords: maricultural solid waste; agricultural solid waste; aerobic fermentation; physical and chemical properties; bacterial

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1. Introduction

With the increase of seafood production, the mariculture industry has been developing rapidly around the world [1]. The global aquaculture total output in 2022 reached 68.66 million tons. Mariculture solid waste such as excess food and excrement contains rich nutrients such as nitrogen and phosphorus [2], which have high commercial and nutritional value. But long-term nutrient accumulation will cause maricultural pollution and reduce mariculture production. Consequently, the recycling of solid waste from mariculture has emerged as a significant research focus in global environmental spheres. Conventional methods for handling solid waste include landfilling and incineration, both of which pose challenges to the environmental carrying capacity.

The agricultural solid waste breeding also has the problem that the output is big and needs resources to deal with it. At present, aerobic composting is a common treatment of solid waste. However, the water content of maricultural solid waste is high, the salt

content is high, and the C/N ratio is low, making it unable to meet the growth of aerobic microorganisms and making fermentation initiation difficult.

A large number of crop straws are generated every year; only a few are used for animal feed or heating [3]. Straw is rich in organic matter and carbon and is one of the commonly used carbon sources for composting. Studies have found that compared with a single compost substrate, mixed compost has outstanding performance in terms of quality and stability, especially the mixture of agricultural manure and straw, which can better regulate the C/N ratio of compost materials and enrich microbial flora [4]. He [5] et al. composted straw and sawdust with cow manure, and the highest temperatures reached 72 °C and 57 °C, respectively. Chung et al. [6] found that adding biochar to chicken manure compost could significantly reduce NH_3 emissions. Ren et al. [7] found that cow manure and straw compost enriched microbial populations and improved the seed growth index. Meng [8] et al. found that total nitrogen and temperature had significant effects on bacterial abundance during the fermentation of cow manure and straw.

Therefore, in this paper, a mixed aerobic fermentation experiment was conducted with maricultural solid waste, cow manure, and chicken manure as raw materials, and biochar and wheat straw as auxiliary materials. The physical and chemical properties of each treatment were studied, and the bacterial community structure and succession rule during the composting process was analyzed. This work aims to provide reference for the reduction, harmlessness, and efficient utilization of maricultural solid waste.

2. Materials and Methods

2.1. Composting Materials

The maricultural solid waste was collected from Dalian Fugu Aquatic Products Co., LTD., Dalian, China. The main components were fish feces and residual bait, etc. Chicken manure and cow manure were collected from the local countryside. Wheat straw and biochar were purchased from Surui straw processing plant in Baitabu Town. The composting device is a 100 L insulated foam box. In order to ensure sufficient oxygen content in the box, a number of small holes 1 cm in diameter at the bottom and 2 cm in diameter around the box were made artificially. The initial physical and chemical properties of the compost materials are shown in Table 1.

Table 1. Physical and chemical properties of compost materials.

Material	MC (%)	pH	EC (ms/cm)	OM (%)	TOC (%)	TN (%)	C/N
Maricultural solid waste	53	7.9	15	12.3	7.2	0.7	10
Chicken manure	38	6.6	7.6	24	14	1.2	11.7
Cow manure	76	8.3	6.4	19.8	11.6	0.44	26.4
Wheat straw	11	5.8	3.1	87	50	0.65	77
Biochar	30	6.7	3.6	75	44	0.56	78.57

Note: Moisture Content (MC), Electric Conductivity (EC), Organic Matter (OM), Total Organic Carbon (TOC), Total Nitrogen (TN), Carbon Nitrogen Ratio (C/N).

2.2. Fermentation Experiments

A total of 4 treatment groups were designed in the experiment, and the compost ratio is shown in Table 2. The wheat straw was chopped into 0.5 ± 0.06 cm. The materials were thoroughly mixed manually, with the moisture content adjusted to around 60%. They were then placed in the static aerobic composting device, with each heap weighing approximately 15 kg, and samples were taken regularly. Four treatments were designed: T1, solid waste + straw (1:1); T2, solid waste + cow manure + straw (1:7:3); T3, solid waste + cow manure + straw + 5% biochar (1:7:3); T4, solid waste + chicken manure + cow manure + straw + 5% biochar (1:1:7.3).

Table 2. Composting material proportions (wet weight).

Treatment	Solid Waste	Cow Manure	Chicken Manure	Wheat Straw	Biochar
T1	1	-	-	1	-
T2	1	7	-	3	-
T3	1	7	-	3	5%
T4	1	7	1	3	5%

2.3. Measuring Methods

The composting materials from the upper, middle, and lower layer were collected at the beginning and at 4, 8, 12, 20, and 30 days. The samples were collected a total of 6 times, and 200 g was taken each time. The sampling time represents the critical period in the composting process and the transition period of each period. To ensure the preservation of the sample's original parameters, testing was conducted the day following collection. Subsequent to collection, the sample was partitioned into two sections: one designated for the assessment of physical and chemical characteristics and the other reserved for microbial sequencing analysis. Additional samples were refrigerated at 4 °C.

2.4. Factors Affecting Composting

Aerobic fermentation is a complex process of physical, chemical, and biological reactions. There are many influencing factors in the process of aerobic fermentation, such as temperature, oxygen supply, water content, pH, C/N ratio, salinity, etc.; it is beneficial to the rapid fermentation of materials, improves maturity, and improves fertilizer quality.

(1) Temperature measurement: Throughout the composting experiment, temperature recorders were carefully inserted into the upper and lower regions of the composting pile for continuous temperature monitoring. Measurement intervals of 1 h were employed to record the composting temperature, from which an average value was calculated. Concurrently, ambient temperature was also measured.

(2) Determination of pH value and EC value: The sample was dried, ground, and screened with mesh number 80. A total of 10 g of the sample was weighed in a conical bottle, 100 mL of deionized water was added, and then the conical bottle was oscillated on a reciprocating constant temperature horizontal oscillator for 2 h. After resting for 30 min, the supernatant was filtered with qualitative filter paper, and the filtrate was collected to be measured. pH and EC values were determined with a Metler–Toledo bench pH meter and conductivity meter, respectively (n = 3).

(3) Determination of organic matter content: Organic matter content was measured by the burning reduction method. The porcelain crucible was first burned in a Muffle furnace at 600 °C ± 20 °C to a constant weight (the difference between two consecutive weighing was not more than 0.001 g). The meshed sample of 1 g (accurate to 0.0001 g) was burned at 600 °C ± 20 °C for 3 h. The OM was calculated as follows.

$$\mathrm{OM} = \frac{m_0 - m_1}{m} \times 100\% \quad (1)$$

where OM is the content of organic matter on a dry basis, %; m_0 is the mass weight of the crucible and the drying sample, g; m_1 is the mass weight of the crucible and the dried sample after burning, g; m is the mass weight of the dried sample, g (n = 3).

(4) Seed germination index: (GI) A total of 10 g of the composting sample was mixed with distilled water according to the solid–liquid ratio of 1:10; it was shaken for 1 h, then rested for 1 h. The supernatant was filtered, and 5 mL of that was used for the seed growth experiment for each group. Ten cucumber seeds were cultured in a constant temperature incubator at 25 °C for 48 h. The germination of the cucumber seeds was observed, and the seed growth index was measured (n = 2).

$$\mathrm{GI} = \frac{\text{Treatment germination} \times \text{root length of treatment}}{\text{Control germination} \times \text{root length of control}} \times 100\%, \quad (2)$$

(5) Determination of total nitrogen content: The total nitrogen was determined by the Kjeldahl nitrogen determination method.

(6) Determination of inorganic phosphorus content: Inorganic phosphorus was determined by phosphor molybdenum blue spectrophotometry.

2.5. Microbial Community Analysis

2.5.1. Sample Sampling Method

The aerobic fermentation process lasted for 30 days; samples were taken on day 0 (heating period, sample no. C1), day 4 (high temperature period, sample no. C2), day 8 (cooling period, sample no. C3), and day 13 (maturity period, sample no. C4). When sampling, the material was fully mixed, and then 100 g of the sample was taken by the multi-point sampling method. After sampling, the samples were divided into two parts for the determination of physical and chemical properties and high-throughput sequencing.

2.5.2. DNA Extraction Method

The DNA extraction kit e. Noah. N. ATM Mag-Bind Soil DNA Kit (OMEGA, Shanghai, China) was used to extract DNA from the genomes of four samples. The steps are as follows:

(1) Prepare 2 mL centrifuge tube, add 0.8 mL Buffer SLX Mlus, shake for 5 min.
(2) Add 80 μL Buffer DS and shake to mix.
(3) Pyrolysis in a constant-temperature metal bath at 70 °C for 10 min.
(4) 13,000 rpm centrifugation at room temperature for 5 min.
(5) Absorb 600 μL of the upper liquid into the new 2 mL centrifuge tube, add 200 μL Buffer SP2, shake and mix.
(6) Add 100 μL HTR Reagent and mix for 10 s. Ice bath for 5 min, centrifugation at room temperature for 5 min at 13,000 rpm.

2.5.3. PCR Amplification

The first round of amplification (taking the 16S v3-v4 region as an example): the qubit 3.0 DNA detection kit was used to precisely quantify the genomic DNA to determine the amount of DNA to be added to the PCR reaction. All PCR primers used in this study are shown in Table 3.

Table 3. Primers used for PCR amplification.

Project	Primers	Sequence
Bacteria 16S rRNA	341F	ATGCGTAGCCGACCTGAGA
	805R	CGTCAGACTTTCGTCCATTGC

2.5.4. Library Quality Control and Sample Mixing

In order to obtain more accurate and high-quality biological information, it is necessary to carry out quality control on the data. The obtained 16S rDNA gene sequences are tested for chimerism in the database, and the chimerism is completely removed to achieve the optimization sequence. The optimized sequences were classified into Operational Taxonomic Units (Otus, Usearch, Version: 11.0.667) based on 97% similarity. The dilution curve was analyzed based on OTU, and the Chao1 richness index, coverage index, and Shannon diversity index were calculated. Principal component analysis was used to analyze OTU similarity among the samples.

After amplification, the PCR products were analyzed for library size using 2% agarose gel electrophoresis, the amplification effect was checked, and the library concentration was determined using a qubit 3.0 fluorescence quantifier. All the samples were mixed in equal amounts of 1:1. The PCR products were constructed and sequenced at high throughput on the Llumina Miseq/Hiseq platform (lllumina, Shanghai, China).

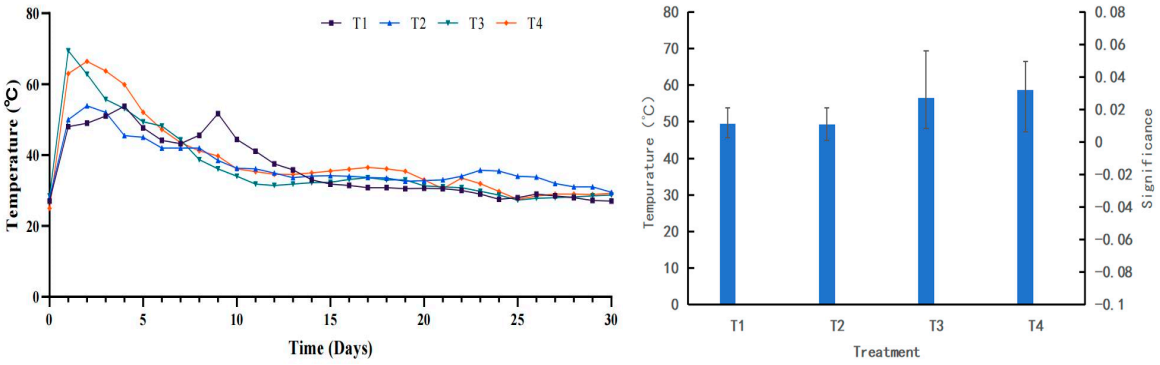
2.6. Statistic Analysis

The data were processed using Microsoft Excel 2019 software.

3. Results and Analysis

3.1. Temperature Changes during Composting

Temperature is an important factor affecting the composting process, and the change of temperature can reflect the harmlessness and microbial activity of composting [9]. The composting temperature is shown in Figure 1. The temperature of each treatment rose rapidly, and the overall temperature rose first and then fell. This was because, after the composting started, the microorganisms increased rapidly, decomposed the organic matter (OM), and released a large amount of heat. Then, 10 days later, the temperature of the pile gradually fell to a relatively stable lower level, and the composting came to an end. It can be seen that the temperature rise of the T4 group was faster, and the high temperature period (>45 °C) that was entered on the 1st day remained for 6 days. The temperature of the T1 group dropped below 45 °C on the 6th day and warmed up again on the 8th day, which may have been due to the insufficiently mixed OM in the process of turning over; this OM decomposed again and caused the temperature to rise. In the process of aerobic composting, the temperature was expected to be kept above 50 °C for at least 5 days for harmless control [10]. It illustrates that the four groups, T1 through T4, sustained temperatures above 50 °C for 3, 3, 4, and 5 days, respectively, and the temperature for each treatment peaked at T1 (53.8 °C), T2 (53.9 °C), T3 (69.4 °C), and T4 (66.4 °C). In Figure 1b, the analysis of the variance of the average temperature in the high-temperature period of each treatment showed that T4 was significantly different from T1 and T2 ($p < 0.05$) but not significantly different from T3 ($p > 0.05$). The temperatures of T3 and T4 with biochar were higher than those of T1 and T2. Therefore, it can be inferred that the incorporation of biochar can enhance the swift temperature elevation of the pile and elevate the maximum temperature, a phenomenon closely intertwined with the attributes of biochar, providing a conducive living environment for microorganisms [11,12]. The above conclusions can therefore be determined.



(**a**) Change of temperature (**b**) Significant difference in high temperature period

Figure 1. The change and significance of heap temperature during composting.

3.2. pH Value Changes during Composting

The pH value in the composting process is shown in Figure 2. The initial pH values of the four groups were 6.2 (T1), 8.2 (T2), 7.9 (T3), and 7.6 (T4), respectively. At the end of composting, the pH values of each group were 6.9 (T1), 7.6 (T2), 7.7 (T3), and 7.3 (T4), respectively. The overall pH curve showed a rising and then a decreasing trend. In addition, the pH value of all treatments was between 6.9 and 9, meeting the growth requirements of microorganisms in the appropriate pH range [13]. This is similar to the results of Ucaroglu et al. [14]. After observing the initial pH value of the materials, it was found that the pH values of the T2, T3, and T4 groups were higher than T1, because the pH value of cow manure, chicken manure, and biochar were alkaline. The pH value in the

early stage of compost was on the rise, which may be due to the intense microbial activity during the heating process of compost, the rapid decomposition of organic matter, and the formation of a large amount of ammonium nitrogen (NH_4^+ -N) [15], which increases the pH value of the pile. This result is similar to that of Cai et al. [16]. In the later stage of composting, the compost temperature gradually stabilized, organic matter basically completed decomposition, and the pH value of the pile gradually stabilized with the stability of the pile temperature. At the end of composting, the pH values of all the treatment groups were in the range suitable for normal plant growth and there was no significant difference between the treatments ($p > 0.05$) [17].

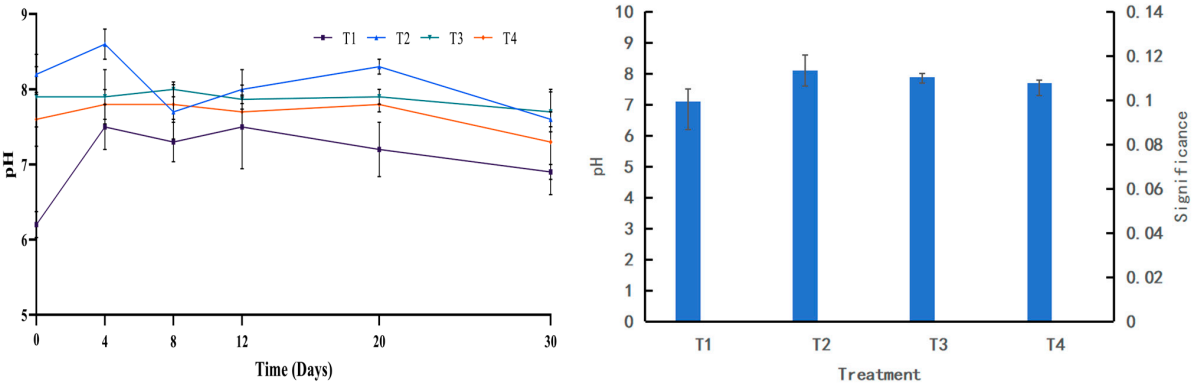


Figure 2. Changes of pile pH during composting.

3.3. Changes in Electrical Conductivity during Composting

The electrical conductivity (EC) reflects the soluble salt content in the reactor [6]. Soluble salt in compost has a toxic effect on crops. In general, when the conductivity of the compost extract is <9 mS/cm, salt ions have no inhibitory effect on organic metabolism, microbial growth, and seed germination [18]. Figure 3 shows the EC curves during composting. It is obvious that the EC values of all groups remained in the safe range. In the first 4 days of composting, all the treatments showed an increase in conductivity values, which was due to the rapid rise in the temperature in the early stage of composting, the vigorous metabolism of microorganisms, the decrease in the mass of the pile during the decomposition of organic matter, and the concentration of soluble salt, which led to the increase in the EC value [19,20] and then volatilized in the form of carbon dioxide (CO_2) and ammonia (NH_3). As well as the evaporation of a large amount of water and the precipitation of mineral salts, the EC value gradually decreased [21,22]. After 30 days of fermentation, the EC values of each treatment were, from large to small, T1 > T3 > T4 > T2, and the EC values were between 5.2 and 7.1, which is not toxic to most plant growth. The results showed that the mixed compost and biochar were more beneficial to the fermentation of the pile and could regulate the conductivity of the materials.

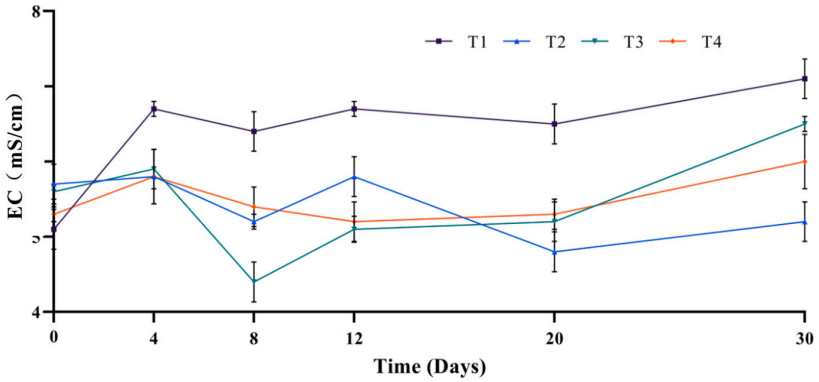


Figure 3. Changes of reactor conductivity during composting.

3.4. Changes of Organic Matter in Composting Process

The change of organic matter (OM) content in each treatment group during composting is shown in Figure 4. The change trend of OM content in all the treatment groups is roughly the same, showing a gradually decreasing trend. It is because of this that OM in compost materials is one of the main energy sources for the growth and reproduction of microorganisms. From days 0 to 8, the OM of the pile decreased rapidly during the fermentation process, and obvious decomposition of OM occurred in different treatments. This is because the compost was in a high-temperature period in the first week, microbial activities were vigorous, and the OM easily degraded and the organic matter was decomposed into carbon dioxide, water, minerals, etc. [23]. After that, as the compost entered the cooling stage, the metabolic activities of microorganisms were weakened, and the degradation rate of OM became smaller. The initial values of organic matter content in each treatment were 95% (T1), 89% (T2), 84% (T3), and 88% (T4), respectively. The OM content decreased rapidly in the first 8 days, then gradually stabilized. By the end of composting, the organic matter content of each treatment was 75% (T1), 60% (T2), 68% (T3), and 64% (T4).

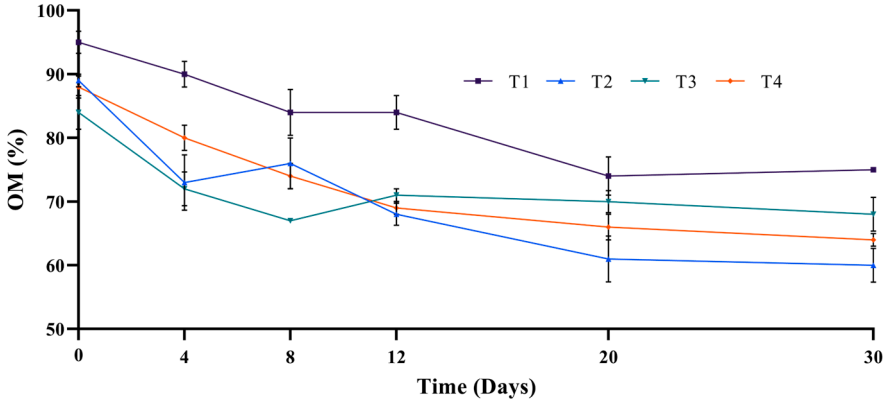


Figure 4. Changes of organic matter in the composting process.

3.5. Changes of Seed Germination Index

The seed germination index (GI) is a useful indicator that reflects the biological index of plant toxicity in compost. It is generally believed that when the seed GI of compost products is greater than 80%, compost is not toxic to plants, and it is considered to be completely decomposed [24,25]. It can be observed from Figure 5 that at the beginning of composting, the GIs of the four groups were only 43%, 41%, 50%, and 52%. After one month of composting, the GIs were significantly increased, reaching 75%, 80%, 81%, and 94%, respectively. The addition of biochar and chicken manure in group T4 further improved the seed germination rate [26].

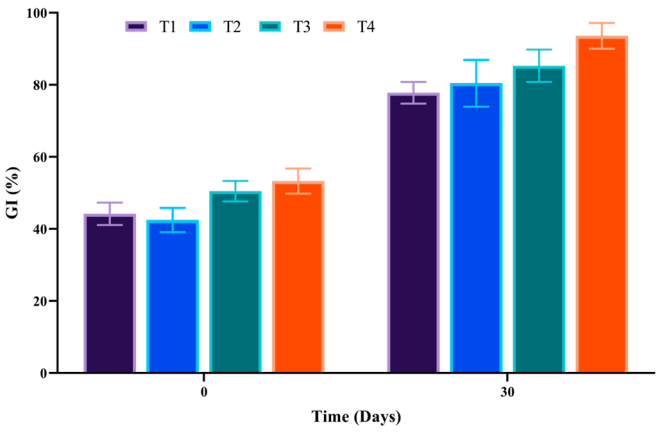


Figure 5. Changes of seed germination index during composting.

3.6. Changes in Total Nitrogen Content during Composting

Nitrogen is one of the essential elements for microbial life maintenance. The influence of total nitrogen (TN) content is shown in Figure 6. The TN content was relatively stable. At the end of composting, the nitrogen content in groups T1–T4 increased by 6%, 5%, 13%, and 33%, respectively. It can be seen that the total nitrogen content of the T3 and T4 groups was significantly higher than that of T1 and T2 groups after composting. This indicates that biochar could fix nitrogen and reduce nitrogen loss [27]. Nitrogen is a kind of nutrient element for plant growth. The increase of nitrogen content in compost is helpful to provide nutrients for plants.

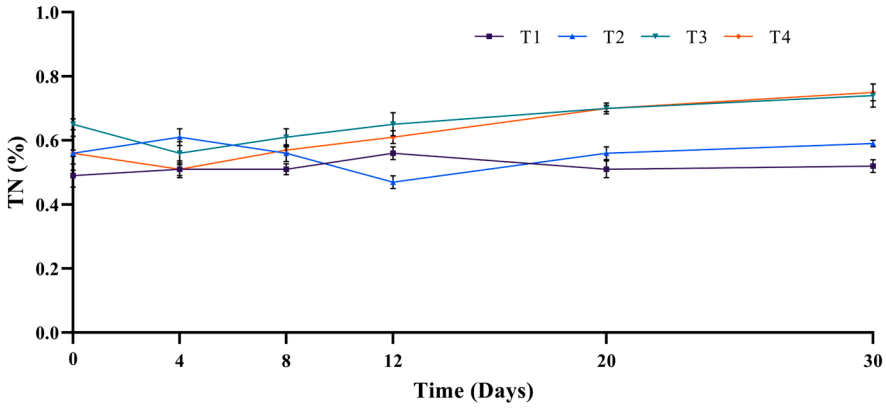


Figure 6. Changes of total nitrogen content.

3.7. Changes in Inorganic Phosphorus Content during Composting

The effects of different treatments on inorganic phosphorus (IP) content are shown in Figure 7. Phosphorus stands as a pivotal element in agricultural production, facilitating the growth of plant roots and enhancing yield. The content of IP in all the composting groups was increased because, in the composting process, with the degradation of OM and the reduction of gaseous substances and water content, the dry mass decreases, and the relative content of phosphorus increases due to the difference in composting efficiency [28].

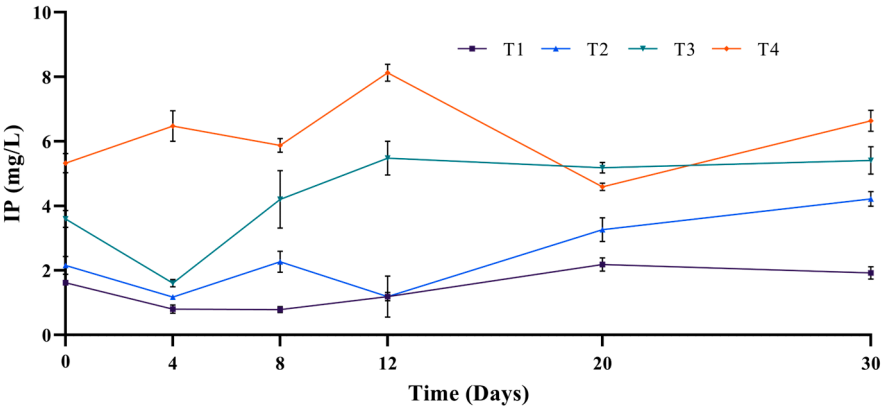


Figure 7. Changes of inorganic phosphorus content.

3.8. Bacterial Abundance and Diversity of Compost Samples

Table 4 shows the bacterial richness and diversity of the T4 group; a total of 131,754 high-quality bacterial sequences were obtained, and C3 exhibited the highest value, signifying the peak bacterial community abundance during the cooling phase in this compost.

The Shannon and Ace indexes, for representing diversity of the bacterial community, respectively, are illustrated. The Simpson index is one of the indexes used to estimate microbial diversity. The higher the Simpson index value, the lower the microbial community diversity. Table 4 shows that the Shannon, Ace, and Simpson indexes changed in the same

way: C3 is the highest, and C1 is the lowest. In the composting process, the abundance of bacterial flora was the highest in the cooling period and the lowest in the heating period. The coverage index reflects whether the sequencing result represents the real situation of the sample. The closer the value is to 1, the lower the probability that the sequence in the sample is not detected. It can be seen that the coverage index of all the samples is 1, indicating that the sequencing results could fully demonstrate the real community structure of the different samples. In summary, the C1 and C2 treatments led to a rapid increase of bacteria in the fermentation process, and the C3 treatment reached the highest bacterial abundance, while the C4 treatment was already decomposed, the reactor temperature was consistent with the ambient temperature, and the bacterial abundance was the lowest.

Table 4. Bacterial richness and diversity in composting samples.

Sample	Number	OTUs	Shannon	Chao 1	Ace	Simpson	Coverage
C1	32,393	825	2.37	838.49	872.93	0.41	1
C2	30,131	905	4.17	923.78	966.86	0.04	1
C3	31,752	1010	4.84	1028.28	1069.44	0.02	1
C4	37,478	904	4.03	933.36	981.61	0.06	1

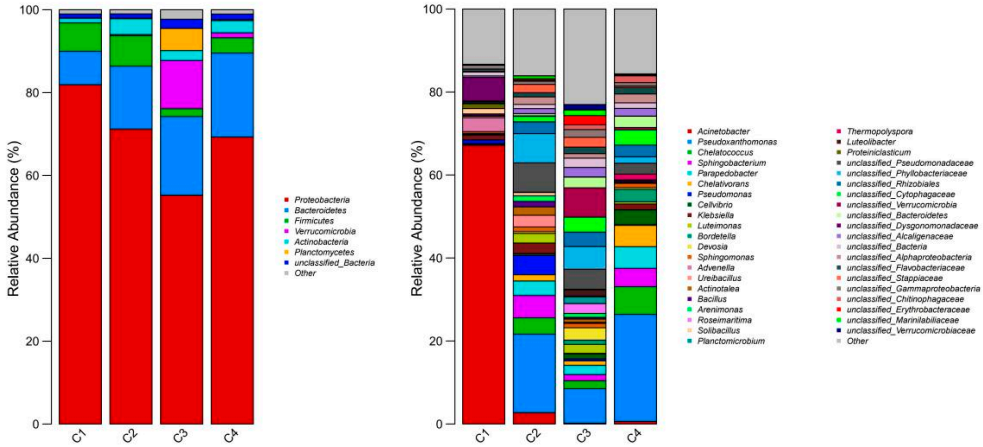
Note: C1 is the heating phase; C2 is the thermophilic phase; C3 is the cooling phase; C4 is the ripening phase.

3.9. Bacterial Community Structure and Dominant Flora in Compost

The results of the relative abundance of bacterial communities in compost samples at the phylum and genus levels are shown in Figure 8. Figure 8a shows phyla level bacteria classification (species with relative abundance < 1% are classified as others). It mainly includes Proteobacteria, Bacteroidetes, Firmicutes, Verrucomicrobia, Actinobacteria, and Planctomycetes. Proteobacteria was the first dominant bacteria in the early stage of composting, with a relative abundance of 81.9%. However, with the progress of composting, the relative abundance gradually decreased, and the relative abundance was 71.2% and 55.2% in the high-temperature and low-temperature periods, respectively, and increased in the mature stage, with a relative abundance of 69.3%. This result is consistent with the conclusions drawn by Sun [29] and Wang [30] et al. In contrast to Proteobacteria, the relative abundance of Bacteroidetes increased gradually with the composting process, and the relative abundance accounted for 8.1–20.3%. Firmicutes had the largest relative abundance (7.4%) in the high-temperature periods, because Firmicutes produce spores to resist high-temperature conditions [7]. The relative abundance of Verrucomicrobia in the cooling period was higher (11.6%), which is conducive to the degradation of dissolved organic matter (DOM) and the formation of humus [31]. The relative abundance of Actinomycetes ranged from 1.1% to 3.8%, among which the relative abundance was the highest (3.8%) at the high temperature. Actinomycetes have the capability to produce a variety of antibiotics that can eliminate pathogenic bacteria present in the pile and mitigate the toxicity of the compost [32]. The phyllophyla appeared for the first time in the cooling period and basically disappeared in the rotting period.

Figure 8b shows the classification of bacteria at the generic level (species with relative abundance < 1% are classified as others). As shown in Figure 8b, the main bacterial groups in the initial stage included Acinetobacter, unclassified Dysgonomonadaceae, and Advenella, with relative abundances of 67.2%, 5.7%, and 3.4%, respectively. With the progress of composting, the dominant bacteria in the initial samples basically disappeared in the later fermentation stage and may have been killed during the fermentation process. When the compost entered the high-temperature stage, the main bacteria groups change into Pseudoxanthomonas, the unclassified Pseudomonadaceae, and the unclassified Phyllobacteriaceae. The relative abundance was 18.9%, 7.1%, and 7%, respectively. In the cooling stage, the compost was dominated by Pseudomonas with a relative abundance of 8.3%. Pseudomonas, Chelatococcus, and Chelativorans were the main compost species with high relative abundance in the maturation stage, and their relative abundance was 25.8%, 6.7%, and 5.1%, respectively. These bacteria are widely found in nature, such as in

soil, mariculture, fresh water, sludge, sewage, etc., and can even be detected in different composts. Among them, Acinetobacter and alcaligenes dominated the initial stage of composting, but their relative abundance gradually decreased with composting, and these bacteria could not be detected after composting entered the rot stage. When Chang [33] and Xu [34] et al. used cow manure as the raw material for composting, Acinetobacter and Advenella were detected in the early stage of composting, but the compost basically disappeared after entering the rot stage. This study detected that these genera are related to compost raw materials. Pseudoxanthomonas is the dominant bacterium in the stages of high temperature, cooling, and decomposition, and it has a strong control effect on the southern root-node nematode, which can effectively reduce the diseases and pests in the heap [35]. As the main dominant bacteria in the maturation stage, Chelicococcus and rhizobium have the function of degrading penicillin [36]. Rhizobium is a kind of aerobic denitrifying bacteria, which can degrade Ethylenediaminetetraacetic acid (EDTA) substances to a certain extent [37].



(**a**) Phylum level (**b**) Genus level

Figure 8. Bacterial species and relative abundance of compost samples at the phyla and genus levels.

4. Conclusions

The effect of the combination fermentation of maricultural and agricultural solid waste on physicochemical properties and bacterial community structure was studied. Compared with a single compost substrate, the combination of different types of waste could effectively regulate the physical and chemical properties and shortened the composting time. The combined composting with agricultural waste weakened the inhibitory impact of the high electrical conductivity from the maricultural solid waste on aerobic fermentation. Additionally, the inclusion of biochar enhanced the maximum compost temperature and extended the high-temperature phase by 1–2 days. The peak temperature reached 69.4 °C. The EC values ranged from 5.2 to 7.2 ms/cm. The GI of the T4 group reached 94%. The dynamic changes of the bacterial community in each stage of the composting process under the T4 treatment were significant. The Chao1 index and Shannon index showed that the bacterial abundance was the highest in the high-temperature and low-temperature periods. At the phylum and genus levels, Proteobacteria, Acinetobacter, and Pseudoxanthomonas were dominant. This work provides a theoretical and practical basis for the recycling of maricultural and agricultural solid waste.

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