Adding calcium oxide combined with calcium peroxide for strengthening rapid biological drying of dairy cattle manure.

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Abstract

This research explored effects of adding calcium oxide (CaO) and calcium peroxide (CaO_2) in the rapid biological drying of dairy cattle manure. Using the static aerobic composting system, the composting experiment was carried out by means of natural ventilation combined with composting piles turned. In the presence of the CaO and CaO_2, the temperature rose faster and reached the high temperature fermentation stage in advance 4-6 days during the compost. At the end of compost, the water content of CaO and CaO_2 (cont.) group was decreased to 23.5% significantly. However, the diversity in four experiment group piles had little difference at the end of the compost, which only had some changes in the process of compost. In a word, it was CaO and CaO_2 that would shorten the composting time, extend the high temperature stage, provide sufficient oxygen to meet the demand of the growth of aerobic microorganisms, had a good effect on dairy manure rapid drying and provided a new idea for dairy manure efficient treatment.

Keywords: Dairy cattle manure, aerobic composting, calcium oxide, calcium peroxide, co-strengthening, biological drying.

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Introduction

With the rapid development of livestock breeding industry intensive and scale, livestock and poultry manure waste increased dramatically, which has become the main source of agricultural organic solid wastes in China [1]. According to the statistics of the China Dairy Association, it was about 1.8 billion fecal waste that was produced in China's dairy farming every year, such as litter, feed residue and other waste [2]. A large number of organic wastes piled up together could not be treated properly, which posed a serious of threats to the surrounding environment. Composting was an effective way to reduce livestock manure and realized harmless treatment and resource utilization [3-7]. According to the determination that moisture content of non-water flushing livestock manure was about 65%~85% while the flushing livestock manure moisture content could up to 90%. The high water content had a great influence on the capacity, storage, transportation and processing effect [8-10]. How to effectively reduce the moisture content of livestock and poultry feces was an important link in fecal treatment.

At present, there are many methods for livestock droppings drying or reducing moisture in domestic and outside areas [11,12]. In relative terms, the biological drying technology attracted people's attentions because of low processing costs, product safety and high efficiency. The term biological drying of livestock manure was first proposed in 1984 by Jewell W J who was an American scientist, Cornell University. The principle was to use microbial decomposition of organic matter produce energy and increase the emission of moisture in feces, which was purposed to reduce water content then acknowledged dryness in the process of composting. Jewell thought that microbial degradation effect was the most active when the water content was 40% and the temperature was 60 degrees centigrade using the principle of bio-drying and taking batch compost, which based on the experimental research on mixing, temperature, air velocity and other factors [13]. TL Richard [14] thought composting, biological drying were related to physical and biological processes. Arrhenius enzyme kinetics equation and Albright stoichiometric equation were applied to describe the relationship between factors about temperature, ventilation rate and moisture emission rate. What's more, the corresponding model was built. It was inferred that every kilogram of volatile solids could get rid of 1 kg water every day. In other words, the moisture of manure could decrease from 75% to 57% when consumed every kilogram volatile solids every day. Richard et al [15] and Choi et al [16] put forward the continuous batch or semi continuous composting technology, which was based on the previous batch compost on. The fully mixed aerobic biological reactor was designed and manufactured as well. The experiment was done for 6 days in the reactor. The result showed that the moisture of manure could decrease by 0.46~0.78 kilogram when consumed every kilogram volatile solids. Many experiments had shown that moisture content was often higher than 30% after composting. For example, Singh [17] took vegetable waste, sawdust and cow dung as raw material for composting. The initial water content was 63.5%~76%. After 20 days composting, the final moisture content was 47.5%~72%; Roca-Perez et al [18] was in the test of straw and sludge composting, the initial moisture content was adjusted to 60.3%, after 90 days of composting, the final moisture content was 39.9% ~42%.

Our country had done some research works in the disposal of sludge drying and some organic waste using composting technology [19,20]. Chang et al. [21] in Jiangsu Academy of Agricultural Sciences conducted pig manure biological drying test in Changshu city. The results showed that using the batch compost, adding conditioner methods, the pig manure moisture decreased from 700g/Kg to 550g/Kg during 20 days composting. Chen [22] developed a complete set of equipment for drying treatment on chicken manure fermentation. Using this equipment, the moisture could be reduced from 650g/Kg to 200g/Kg in 25~35 days biological fermentation. However, there still had little research about alkaline treatment on animal manure bio-drying researches in China. Some foreign researchers had used calcium oxide as stabilizer. For examples, Babyranidevi et al. [19] found that alkaline treatment on municipal solid waste gave better composting performance. Mijaylova et al. [23] researched alkaline stabilization with lime produced a well stabilized and sterilized solution when sludge was made for composting. Bulter et al. [24] used lime as stabilizer for bio solids compost treatment to test three methods for determining compost maturity. The study on CaO_2 applied in manure aerobic composting in China was studied by professor Qu's research group and they found that the addition of CaO_2 in cow manure was shortening the composting time, extended the high temperature period and provided sufficient oxygen meeting the growth needs of aerobic microorganisms [25].

In this experiment, cow dung and tobacco waste were used as raw materials for fermentation. The CaO and CaO_2 were selected as stabilizer and oxygen supplement respectively. The variation of temperature, moisture, pH, nitrogen, phosphorus, potassium and the number of microorganism on cow manure piles in each period were analyzed and compared in the process of CaO, CaO_2 and CaO combined with CaO_2. It was expected to know clearly the effect of CaO and CaO_2 on fast bio-drying technology during compost, which could provide theoretical and technical guidance for the harmless treatment on cow dung and compost production.

Materials and Methods

Compost material

Fresh cow dung (collection station in Dengchuan Town, Eryuan County, Dali, China), tobacco waste (Ningfa Technology Co. Ltd in Nanning), CaO and CaO_2 (Hongsheng calcium Industry Co. Ltd in Qingyang County). The properties of compost materials were shown in Table 1.

Composting design

The research was a pilot scale experimental. The fresh cow dung and tobacco were mixed in the ratio of 5:2 and then added CaO, CaO_2, CaO and CaO_2, CaO and CaO_2 (continuous addition) to the mixture respectively. The mixture groups were piled into the shapes of windrow with 3m long, 2m wide and 1.2m high. The way for ventilation was through turning heap every 3 days during a period of 35 days. The specific experimental material compositions were shown in Table 2.

Table 1. *Properties of compost raw materials.*

Raw materials	moisture/%	pH	organics/%	TN/%	TP/%	TK/%
Cow manure	87.2	7.55	94.3	1.77	1.64	1.52
Tobacco waste	20.45	5.47	83.6	1.28	0.56	6.78

Table 2. *Experimental material compositions.*

Group	Material compositions
1	3t cow manure + 1.2 tobacco waste + 150kg CaO
2	3t cow manure + 1.2 tobacco waste + 100kg CaO_2
3	3t cow manure + 1.2 tobacco waste + 150kg CaO + 100kg CaO_2
4	3t cow manure + 1.2 tobacco waste + 150kg CaO + 100kg CaO_2 (10kg CaO_2 was added in every-time piles turning)

Analysis methods

Observing the physical characteristics of pile surface of the reactor and determining the parameters of temperature, moisture, organic matter, total nitrogen (TN), phosphorus (TP) and potassium (TK) in the composting pile process. The pile temperature was measured by ordinary thermometer with minimum scale was 1℃. The water content was determined according to the standard of NY525-2012 standard. The organic matter content was measured by potassium dichromate capacity method. Total nitrogen (TN) was measured by Kjeldahl method. Total phosphorus (TP) was applied by spectrophotometry and total potassium (TK) was applied by flame photometry method. The relative species of cow manure piles in each period was analyzed by 16S rRNA gene sequencing technology [26,27].

Results and Discussion

Changes and analysis of physical properties of compost materials

Changes and analysis of compost materials: In the beginning, the surface of group 2 pile was brown with a thick smell of fresh cow dung while group 1, 3, 4 were dark brown and fresh cow dung odor was significantly reduced because of the addition of CaO. Then, the surface of group 1, 3, 4 piles changed into black and produced white mycelium after 6 days composting. The surface of group 2 pile also appeared white mycelium but its surface color did not change. What's more, the agglomerate phenomena of group 1, 3 and 4 piles disappeared after 15 days composting and these piles began to tend to be uniform and loose. At the end of composting, the materials of group 1 and 2 piles were light brown and had a small amount of agglomerated while the compost materials were dark brown, loose, homogeneous and without caking in the group 3 and 4 piles. In summary, the group 4 effect was obvious. The finished composting of group 4 had dark brown color, no odor, obvious humus flavor and loose structure.

Changes and analysis of temperature and pH during composting: The change of temperature was an important indicator for microbial activity, which could reflect the maturity degree of compost and directly affect the rate of drying [28]. In the initial stage of composting, the content of organic substances was rich, which were decomposed by the aerobic microorganism quickly and released heat to increase the piles' temperature. The optimum composting temperature was 50~60 ℃, which was beneficial to kill pathogens in the soil. Too high or too low temperature was not beneficial to the process of cow manure composting. Too low temperature affected the decomposition rate of organic matter. On the contrary, it could inhibit and even kill some normal microorganisms [29].

Therefore, the temperature was necessary to kill pathogens, ensure the qualified hygienic indexes and maturity on aerobic compost.

In view of Figure 1a, the temperature of group 1, 3 and 4 piles heated obviously, which was higher than that of group 2. It was in the second day that group 1, 3 and 4 piles reached high temperature stage while group 2 pile needed four days, which indicated the temperature change was mainly influenced by CaO when CaO and CaO_2 were existence in piles. The temperature of group 4 piles rose to 65 ℃ only needed four days, which was because of the CaO addition and continuous addition of CaO_2 that made oxygen supplement constantly and promoted microbial metabolic activity so that the temperature reached the highest. Therefore, CaO_2 as oxygen supplement had a good effect on rapid drying and deodorization during composting, especially it worked better together with CaO.

The pH value was also an important parameter of aerobic microbial activity in composting process. It was researched that the best pH value of microorganisms was neutral or weak alkaline. When pH value was below 4.5 or more than 10.5, it would seriously affect microbial activity that most of the bacterial activity was weakened [30]. The change of pH value during composting was the result of the interaction of organic acids produced by carbon organic compounds, ammonia and proteins [31,32].

Figure 1b showed the pH trend on compost with time. In the initial stage of composting, the detection value of pH fluctuates greatly because of the addition of CaO and CaO_2. Among them, the pH value of group 2 pile was lower than other three groups, which may be as a result of the CaO without expansion. Then the pH value of four groups tended to stabilize and remained between 8~9 with the compost time going on. At the end of composting, the pH value of each group was kept below 9, which was suitable for the optimum environment for microbial growth of compost.

Variation and analysis of moisture and organic matters: Moisture was also a very important parameter of composting as microbial material took only water-soluble nutrients. It was directly affecting the processing speed and maturity of cattle manure [33,34]. The moisture content, too high or too low would have a negative impact on the aerobic microbial decomposition and metabolic activities [35]. It was generally believed that the optimum moisture of compost was about 50%~60% [36,37]. Adding CaO and CaO_2 to groups of 3 and 4 piles, the water content of composting was lower than that of group 1 and 2, because the reaction among CaO, CaO_2 and water, released heat and oxygen and promoted the evaporation of water during composting.

It was showed that moisture changes of piles had the same trend in 30 days composting (Figure 2a). There had obvious change of group 1, 3 and 4 piles moisture, which were kept below group 2 pile after 30 days composting. Although moisture of each group dropped to below 30% at the end of composting, the moisture of group 3 and 4 piles were the lowest, both of which were 23.5%. It was far lower than group 1 and 2 pile at 25.1% and 27.8% respectively, which indicated that CaO and CaO_2 had certain

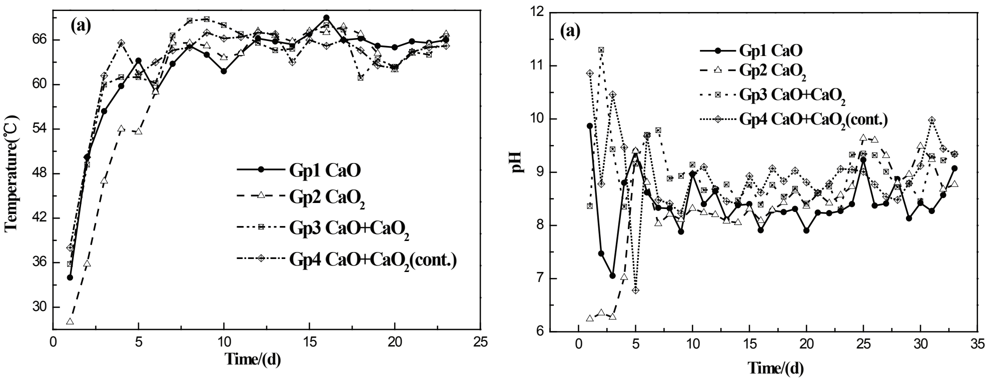

Figure 1. *Temperature and pH changes of composting piles;(a)Change of temperature in different groups, (b)Change of pH in different groups.*

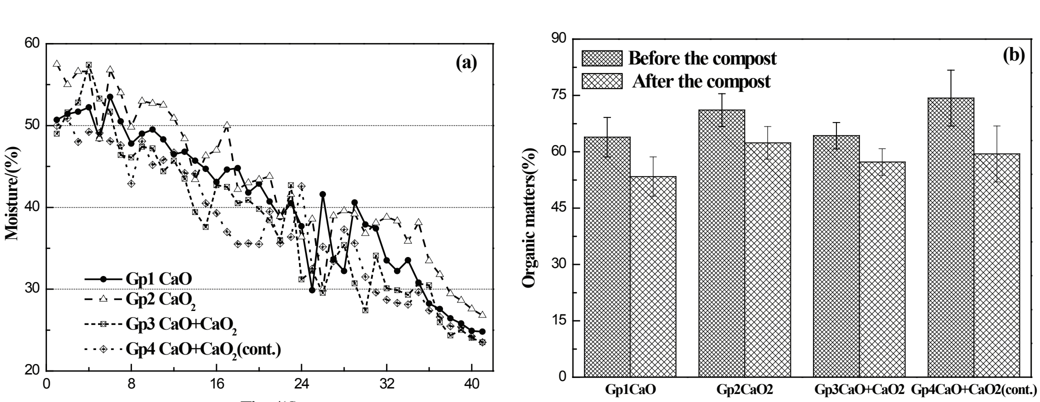

Figure 2. *Variation of moisture and organic matters in different group piles;(a)Changes of moisture in different groups,(b)Changes of organic matter in different groups.*

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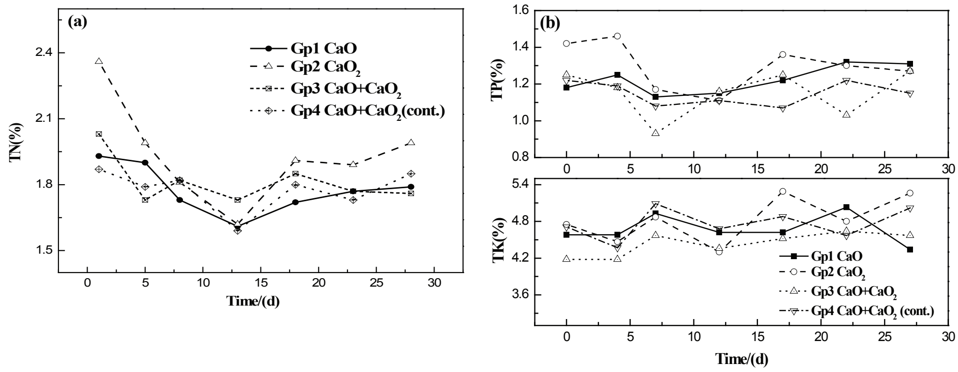

Figure 3. *Change of TN, TP and TK content in different groups;(a)Change of TN in different groups,(b)Change of TP and TK in different groups.*

synergy effects on the decline of composting piles moisture no matter what the way to adding. What's more, fluctuations of moisture might be impacted by rainfall.

The organic compounds were gradually oxidized and decomposed by aerobic microorganisms in the process of composting [38,39]. At the same time, the contents of TN, TP and TK remained relatively stable or slightly increased and the fertilizer efficiency could be continuously enhanced [40-44]. The organics were decomposed into CO_2, water and minerals in the process of composting. The decomposition products were also synthesized into new hemic substances under the action of microorganisms. According to Figure 2b, the organic matters in all experiment group piles had a certain reduction. However, the organics of group 4 decreased the most, which was mostly because the continuous addition of CaO_2 that could provide more oxygen to the compost in the piles in the high temperature stage. What's more, the microorganisms' metabolic activities could consume more organic matter in the composting piles with the addition of CaO_2.

Change of total nitrogen, phosphorus and potassium content: Due to the organic matter decomposition by microorganisms during composting, however, generally the TN concentration slightly decreased or the TP and TK concentration increased slightly during composting due to the concentration effect. The changes of each group of TN contents in the composting process showed first decrease and then increase (Figure 3a). At the end of the compost, the TN content of each treatment group was less than the initial TN content. The final TN content of group 2 pile was greater than that of the other groups. However, the initial TN content of group 2 pile value was much larger than the other groups. Furthermore, the TN content of group 2 piles reduced the largest. Therefore, about TN loss in group 2 piles greatly needed to be further research and analyzed during the composting process.

The TP in four group piles showed a trend for "rising and falling" in the process of composting (Figure 3b). At the end of composting, the TP of group 1 and 3 piles was larger than the initial value. However, the TP of group 1 pile was greater than other groups at final while the initial TP content of group 1 pile was smaller than in the other three groups. Furthermore, the TP content of group 1 was increased the largest. Therefore, about TP increased greatly on group 1 pile needed to be further research and analyzed during the composting process.

It was shown that the changes of TK in four groups appeared a more regular "down-up-down-up" trend in the composting process (Figure 3b). At the end of composting, the TK of group 2 and 4 piles was greater than the initial value. However, the TK of group 2 pile was higher than other three groups at final while the initial TK content of group 2 was smaller than other groups. Furthermore, the TK content of group 2 was increased the largest. Therefore, about TK increased greatly on group 2 pile also needed to be further research and analyzed during the composting.

Changes and analysis of biomass properties of compost materials

OTU rarefaction: The OTU rarefaction curve could be used to compare the richness of different sample species with different sequencing numbers and it was also to indicate whether the sampling was reasonable. When the curve flattened out, it was indicated that the sampling depth had been basically covered in all the species in the sample [45,46]. In Figure 4, except in the start-up and initial heating period, OTU rarefaction curve were almost leveled off, which indicated that sampling had been basically covered in all the species.

In Figure 4, it was shown that the OTU rarefaction curve in four experiment group piles were shaking in the start-up and initial warming period, because the microbial bacteria began to multiply during aerobic composting. Therefore, the richness of four experiment group piles were relative larger especially group 2 pile. During the high temperature period, the OTU rarefaction curve of group 1, 2 and 3 sample were leveled off while the OTU rarefaction curve of group 4 sample was always shaking, because the composting pile need to be turned when the continue addition of CaO_2 happens. In the maturity period, the OTU rarefaction curve of four experiment groups were almost leveled off, which might be the species of microbial bacteria tend to be stable. What's more, the OTU rarefaction curve of the effective microbial agent was also displayed in the bottom of Figure 4. The results showed that the sampling on the ordinary effective microbial agent was also basically covered in all the species and its richness was worse than four experiment group piles at any time.

Alpha diversity: Alpha diversity is the biological diversity within the sample, which is not related to other samples. The Alpha diversity of microorganism in each sample having the parameters of calculation are included PD_whole_tree, Chao1, Shannon as well as Simpson and so on [47,48]. The Chao1 and the PD_whole_tree indexes reflect the richness of community

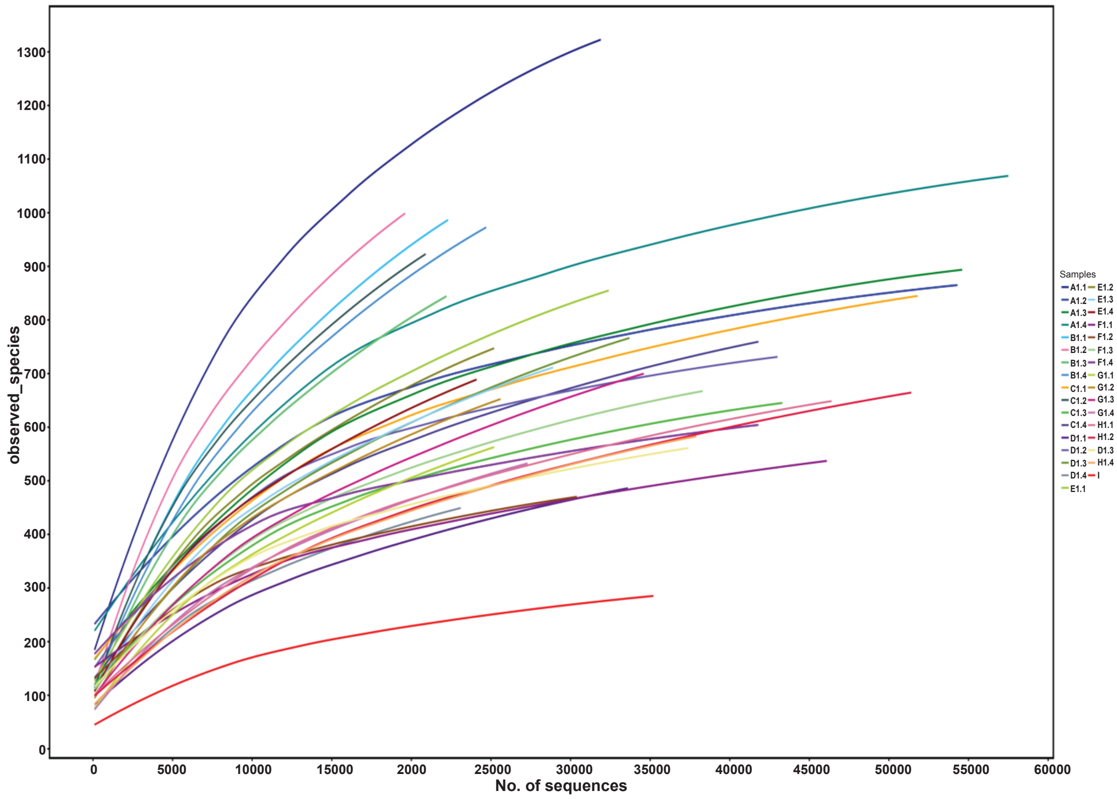

Figure 4. *OTU rarefaction curve in sample.(Horizontal axis: the number of sequences randomly selected from the sample; Vertical axis: the number of OTU constructed based on the number of sequenced number. 1.1 as the group 1; 1.2 as the group 2; 1.3 as the group 3; 1.4 as the group 4; A represents the start-up phase samples, B, C, D on behalf of the heating period samples, E, F, G on behalf of the high temperature samples, H on behalf of the maturity of samples, I represents microbial agent).*

in the sample, which simply refers to the number of species (number of OTU), or to the abundance of each species in the community. The greater the value, the more abundant species were in samples.

In Figures 5a and 5b, it was shown that the charts of PD_whole_tree and the Chao1 indexes in four experiment group piles were shaking and the index value was greater in the start-up and initial warming period, because the microbial bacteria began to multiply during aerobic composting. So, the sampling was hard to include all the number of microbial. The differences between in start-up as well as initial warming period and warming, high temperature as well as maturity period in the chart of Chao1 index was obvious than that in PD_whole_tree. During the high temperature period, the index value of PD_whole_tree and Chao1 curve of group 1, 2 and 3 piles were almost leveled off and the values were basically in the same while the group 4 pile was shaking and the value was higher than other there groups, because the composting pile need to be turned with the continue addition of CaO_2. In the maturity period, the PD_whole_tree and Chao1 curve of four experiment group piles were leveled off, and the species of microbial bacteria tend to be stable. What's more, the PD_whole_tree and Chao1 curve of the effective microbial agent was also displayed in the bottom of Figure 5a and b. The results showed that the richness on the ordinary effective microbial agent was worse than experiment compost in each period.

Shannon and Simpson reflect the index of microbial diversity in the sample. In Figure 5c, the Shannon curve rose in a straight line at first, because the number of the sequence was not enough to cover the samples. With the composting going, the curve flattened out, which indicated that the sequencing data was large enough to reflect the vast majority of microbial species information in the sample. This was consistent with the results of OTU rarefaction curve.

The Simpson curve was used to estimate the diversity of microorganisms in the samples and it was proposed by Edward Hugh Simpson (1949). It was used to quantitatively describe the biodiversity of a region in ecology. The larger the Simpson index, the higher the diversity of community [49,50]. In Figure 5d, it was showed that the Simpson curve in four experiment group piles were larger in the start-up, especially group 2 pile, because the addition of CaO_2 make the microbial bacteria began to multiply. During the warming and high temperature period, the Simpson value would slightly reduce, which might because the microbes was screened by composting temperature. In the maturity period, the Simpson index of group 3 pile was slightly higher than other there groups, because the addition of CaO and CaO_2 made the suitable moisture, temperature and more oxygen. What's more, the Simpson curve of the effective microbial agent was also displayed in the bottom of Figure 5d. The results showed that the diversity on microbial of piles' sampling was larger than the ordinary effective microbial agent.

Relative abundance was used to explain two aspects of sample diversity, which were the richness and uniformity of the species in the sample. The richness of the species was reflected by the length of the curve on the horizontal axis. The wider the curve, the richer the composition was in the species. The uniform degree of species composition was reflected by the shape of the

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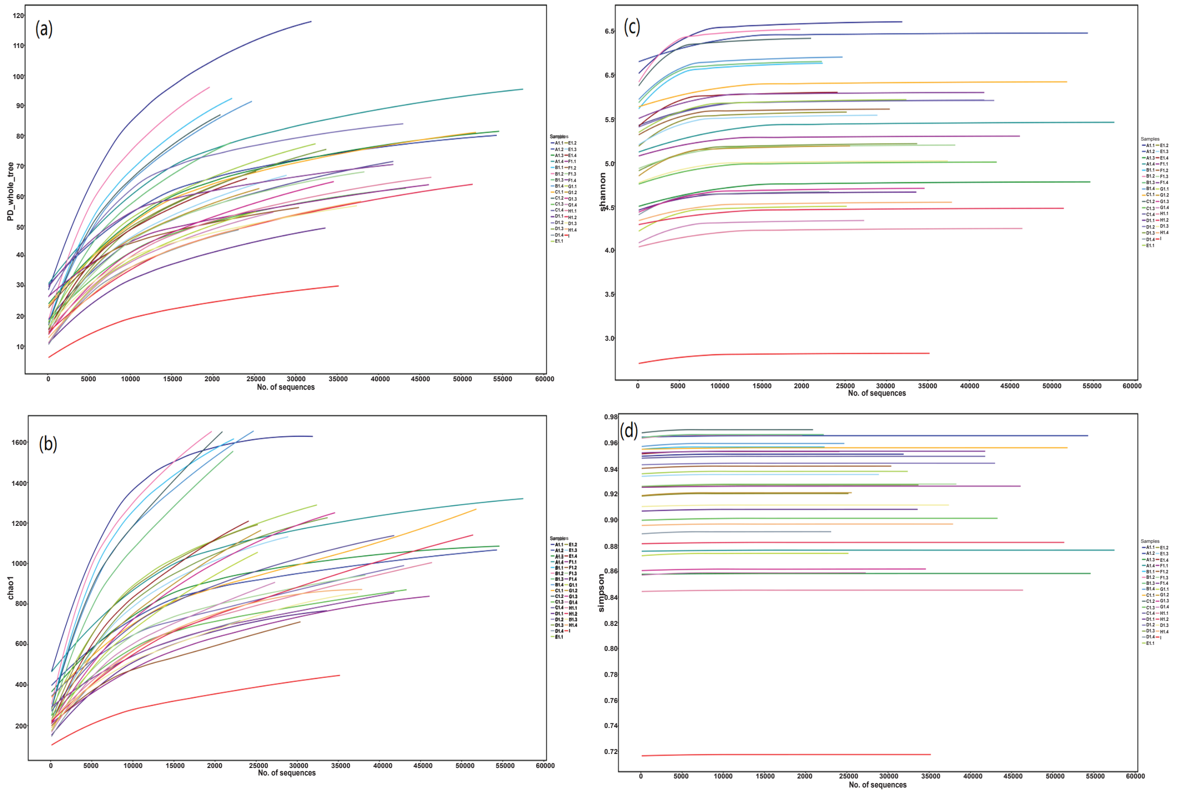

Figure 5. *The PD_whole_tree, Chao1, Shannon and Simpson curve in sample.(1.1 as the group 1; 1.2 as the group 2; 1.3 as the group 3; 1.4 as the group 4; A represents the start-up phase samples, B, C, D on behalf of the heating period samples, E, F, G on behalf of the high temperature samples, H on behalf of the maturity of samples, I represents microbial agent).*

curve, the flatter the curve, the higher the uniformity were the species [51].

In Figure 6, it was shown that the relative abundance curve in four experiment group piles were wider and uniform in the start-up period, because indigenous microorganism began to multiply. During the warming and high temperature period, the relative abundance curve became slightly narrow, which might be the microbes screened by composting temperature. In the maturity period, the four group piles had little difference. What's more, the relative abundance curve of the effective microbial agent was also displayed. The curve was both short and narrow compared with the four experiment group, which indicated that the species richness and uniformity of ordinary effective microbial agent was worse than four experiment group piles.

Beta diversity: Beta diversity is the comparison of biological diversity among samples, which has no related to other samples. Commonly the Unifrac methods and Nonmetric Multidimensional Scaling (NMDS) were used to calculate Unweight or Weighted matrices. Then, according to this matrix, the analysis of PCoA and NMDS were carried out. The difference between individuals or groups can be observed through PCoA. The closer distance between two samples on the axis, the more similar to two samples were [52,53]

As shown in Figure 7 (a), the PCoA diagram of the sample was analyzed under Unweight. In initial stage of composting, the microbial composition of 2, 3 and 4 group samples had little difference. Group 1 sample had large difference with other three groups, which might because there was not enough oxygen supply without CaO_2. In the heating period of composting, the microbial composition of four experiment group samples had little difference. With the composting going, the four groups began to have some difference. However, the microbial composition between group 3 and 4 samples was more similar because of the shorter distance in the PCoA diagram. In the whole high temperature period of compost, the distance among in group 2, 3 and 4 group samples were closer, which might be related to the similar oxygen content. At the end of composting, the distance among four experiment group samples were close. Combined with the above physical and biomass properties analysis, it was had the strengthening effect on rapid biological drying of dairy cattle manure with the addition of CaO, CaO_2 as well as CaO and CaO_2 of which the CaO and CaO_2 had some synergistic effects.

As shown in Figure 7 (b), the PCoA diagram of the sample was analyzed under Weighted. Similar to those under Unweight in the initial stage and the heating period of composting, the microbial composition of group 2, 3 and 4 samples had little difference in initial stage of composting. Group 1 sample also had large difference with other three groups. The microbial composition of four experiment group samples had little difference in the heating period of composting. However, there had some differences with analysis under Unweight in the whole high temperature period of compost. With the composting, the distance between in group 2 and group 4 samples were closer, which might be related to the similar content of CaO_2. At the end of composting, the distance among four experiment group piles were close. Combined with analysis on Unweighted, it was

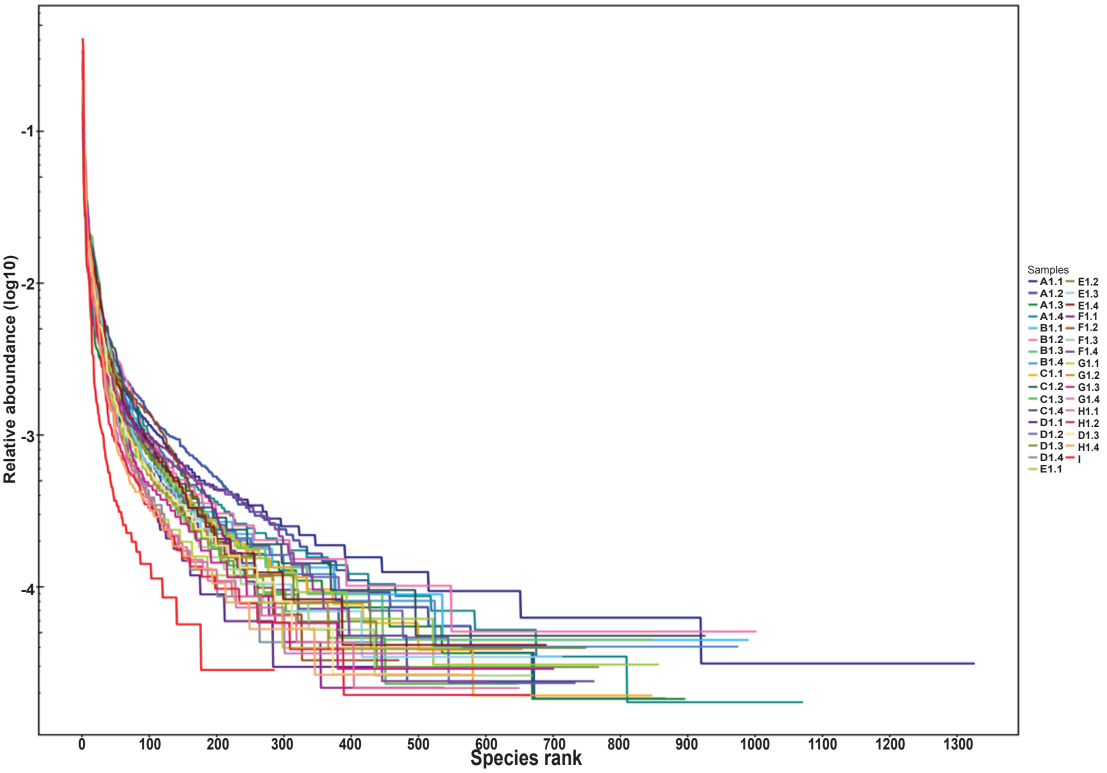

Figure 6. *Relative abundance in sample.(1.1 as the group 1; 1.2 as the group 2; 1.3 as the group 3; 1.4 as the group 4; A represents the start-up phase samples, B, C, D on behalf of the heating period samples, E, F, G on behalf of the high temperature samples, H on behalf of the maturity of samples, I represents microbial agent).*

had the strengthening effect on rapid biological drying of dairy cattle manure with the addition of CaO, CaO_2 as well as CaO and CaO_2.

NMDS is characterized by the information contained in the sample, which is reflected in the multi-dimensional space in the form of points. The degree of difference between different samples is shown by the distance among points and finally the spatial location map of the sample is obtained.

As shown in Figure 7 (c), the NMDS diagram of the sample was analyzed under Unweighted. In initial stage of composting, the microbial composition of group 2, 3 and 4 samples had some difference. Group 1 sample also had large difference with other three groups, which also might be related to CaO_2. In the heating period of composting, the microbial composition of four experiment group samples also had a little difference. With the composting going, the four groups began to have some obvious differences. However, the microbial composition between group 1 and group 4 samples as well as group 1 sample and group 4 sample was more similar because of the shorter distance in the NMDS diagram. In the whole high temperature period of compost, the distance among in group 2, 3 and 4 samples were closer, which also might be related to the similar content of oxygen. At the end of composting, the distance among four experiment group samples were also close. The analysis results were consistent with the PCoA analysis of the sample under Unweighted.

As shown in Figure 7 (d), the NMDS diagram of the sample was analyzed under Weighted. Similar to those analyze under Unweighted in the initial stage and the heating period of composting, the microbial composition of group 2, 3 and 4 samples had little difference. Group 1 sample had large difference with other three groups. In the heating period of composting, the microbial composition of four experiment group samples also had a little difference. The distance between in group 1 and group 2 samples as well as between group 3 and group 4 samples was relative closer respectively. However, there had some differences with analysis on piles under Unweighted in the whole high temperature period of compost. With the composting, the distance between in group1 and group 4 samples were closer, which also might be related to the similar content CaO. At the end of composting, the distance among four experiment group samples were close. The analysis results were consistent with the PCoA analysis on the sample under Weighted.

Conclusion and Prospect

All physical indexes detected in the experiments were accorded with the national standard of organic fertilizer agriculture. The CaO and CaO_2 could accelerate the temperature rise, advance the reactor piles into high temperature stages and reduce water content of the composting piles rapidly. At the end of compost, the moisture decreased to below 30% and decreased by 6.0%~8.0% compared with the control group 1 and 2 piles. What's more, no matter alpha or beta diversity in four experiment group piles had little difference at the end of the compost. They only had some changes in the process of compost.

Combined with the physical and biomass properties analysis, it was had the strengthening effect on rapid biological drying of dairy cattle manure with the addition of CaO, CaO_2 as well

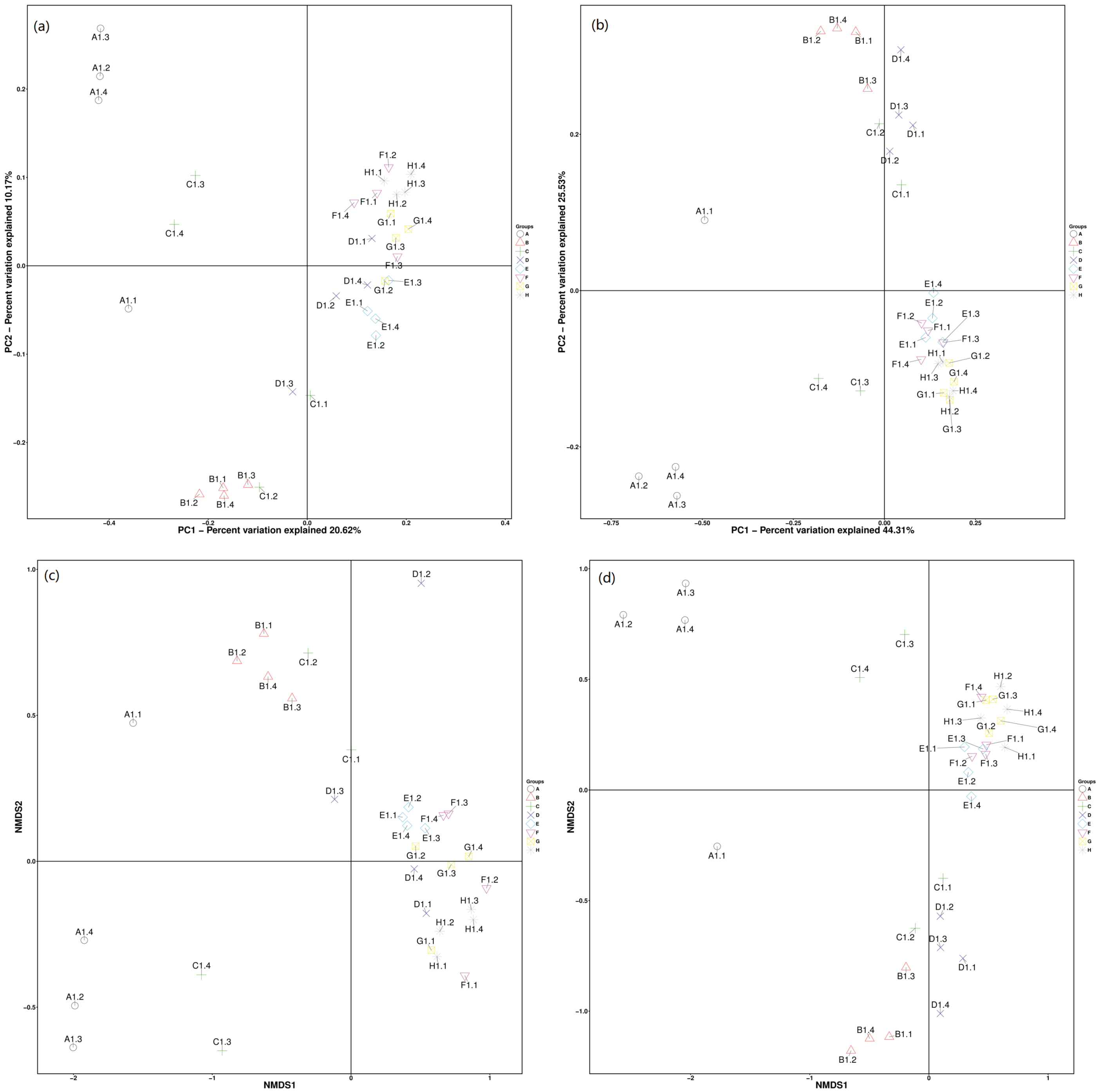

Figure 7. *Chart of PCoA and NMDS (Unweight and Weighted Unifrac)*;*(a) Chart of PCoA under Unweighted Unifrac, (b) Chart of PCoA under Weighted Unifrac*, *(c) Chart of NMDS under Unweighted Unifrac, (d) Chart of NMDS under Weighted Unifrac. (1.1 as the group 1; 1.2 as the group 2; 1.3 as the group 3; 1.4 as the group 4; A represents the start-up phase samples, B, C, D on behalf of the heating period samples, E, F, G on behalf of the high temperature samples, H on behalf of the maturity of samples, I represents microbial agent).*

as CaO and CaO_2, of which the CaO and CaO_2 (cont.) had the best effects on cow manure composting in the research. It was in the second days that composting came into high temperature stage. In the heating stage, it was only in fourth days that the temperature reached the highest 65℃ and the heating effect was remarkable. At the end of the composting, the moisture was 23.5%. Compared with other treatment groups, the moisture content decreased to minimum value, which was far better than the specified value of agricultural organic fertilizer standard (30%). What's more, the pH values of all cow manure piles were only about 9.0 after composting rotten, which could be well neutralized by the gradually acidified soil in the southwest of China.

The following researches we will study and analyze further about TN loss in group 2, TP increased greatly on group 1 and TK increased greatly on group 2 during the composting.

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