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Full Length Research Paper

Effects of zinc on metabolism and oxidative enzyme activities of microbe communities during composting

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With pig manure and crop straw as the main components for its compost material, the study simulated five levels of heavy metal pollution by adding zinc to the compost material to make it separately have five zinc contents to research on the effects of zinc on the metabolisms and oxidation-reduction enzyme activities of microbe communities of the compost material at the different zinc contents under the aerobic and high-temperature condition. It showed that where the zinc contents of the compost material were separately 0, 300, 600 and 900 mg kg^{-1}, the carbon sources that differentiate the microbes of the material were polymers and carbohydrates; where the zinc contents of the compost material were separately 300, 600 and 900 mg kg^{-1}, the dehydrogenase activities of the material appeared unstable to some extent, possibly because the heavy metal had inhibitory effect to the dehydrogenase activity and the phenomenon of the "resisting enzyme activity" took place at the same time; where the zinc content of the compost material were separately 600 and 900 mg kg^{-1}, the material is conducive to humus condensation and aromatization and the carbon source uses of its microbes at the two zinc contents did not significantly differ; and the average polyphenol oxidase and dehydrogenase activities of the compost material at the zinc content of 600 mg kg^{-1} were the highest, helpful to lignin degradation and its product transformation of the material as well as its microbe multiplication.

Key words: Pig manure, zinc, microbe community, oxidative, reductive enzyme.

INTRODUCTION

Full adoptions of intensive animal and poultry raising render decontamination and recycling dominant techniques for disposing animal and poultry wastes to get quickly improved (Dong, 1998; Shi and Lü 1999). Waste decontamination and aerobic animal and poultry waste composting with crop straw at high temperature are the main approaches for animal and poultry disposal. Currently, in order to promote their animals and poultry to rapidly grow and to improve their raising efficiencies, different feed factories and animal raising farms commonly use feed additives that have high contents of such trace elements as copper and Zinc (Wang et al., 2007), so that great amounts of heavy metals (above 95%) that the animals and poultries have not absorbed accumulate in their manures (Ren et al,. 2005; Hsu and Lo., 2001), thus exerting great influences on the successions and enzyme activities of the microbes communities in the process of composting. Researches show that composting is essentially a microbe-participated and enzyme-catalyzed biochemical process in which under the action of microbes and enzymes that they excrete, organic substances are disintegrated, and then humus is formed from the degradation products (Li and Cao, 2002). In the process of composting, the humifying progress and intensity probably can be deduced by researching on the metabolisms and oxidative enzyme activities of microbes' communities.

Biolog is a testing method whereby microbial uses of individual carbon sources are tested to assess the function diversities of their communities (Garland, 1996). Garland and Mills (1991) for the first time applied the

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Table 1. Physical and chemical properties of the compost material components (oven-dried samples used in determination).

Compost material component	Organic C/ (g kg^{-1})	Total nitrogen/ (g kg^{-1})	Total P_2O_5/ (g kg^{-1})	Total K_2O/ (g kg^{-1})	C/N	Zinc content / (mg kg^{-1})
Pig manure	409.70	34.50	9.70	10.58	11.88	244.62
Straw	394.32	5.74	0.47	27.39	68.70	35.65
Used matrix bars left	317.20	13.30	5.72	32.80	23.85	306.58

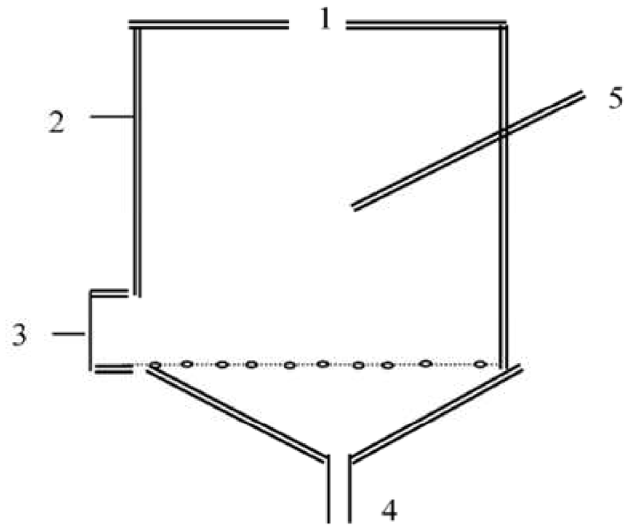

Figure 1. Fermenter for composting. 1, Feeding inlet and air outlet; 2, heat-insulating layer; 3, compost discharge mouth; 4, air inlet; 5, temperature sensor.

method to studying soil microbes' communities and from then on, the method has played an important role in studying the structures of microbe communities and identifying microbe populations in the composting process. Atkinson et al. (1997) studied structural characteristic of microbe communities in windrowed mixture of fruit peels and paper scrapes being aerobically composted. Insam et al. (1996) examined structural changes of microbe communities in the process of the composting and was carried out in the open fermentation chamber using biolog micro-plate. Fang and Wong (2000) found in their study that coal ash addition did not change dominant microbe species but caused thermophile bacteria to decrease in number and species, proving that the biolog system was fast and convenient and simple to identify microbe populations. However, there have been rare reports on effects of heavy metals on the metabolisms and enzyme activities of microbe communities of compost materials and thus, the study employed the biolog micro-plate to examine how the metabolisms and oxidative enzyme activities of agricultural waste as its compost material varied where the material was stacked or stockpiled and polluted with the heavy metal of zinc.

MATERIALS AND METHODS

The compost material of the study were composed of pig manure, crop straw and used shiitake fungus matrix bars whose properties are shown in Table 1.

The study was carried in the outdoor net house of the College of Resources and Environments of the Northwest A and F University from 12 July to 7 August, 2010. In the study, wheat straw, pig manure (from pigs that feed on forage grasses and wheat bran to which no feed additives are added), used matrix bars (that shiitake fungus culture leaves behind) were firstly mixed to form the compost material; next, the compost material was prepared to have an C/N ratio of 30 to 35:1 and adjusted with water to have water content ranging within 55 to 65%; then the compost material was fully mixed with the composite microorganism preparations to promote its fermentation (Ni and Li, 1998) and then filled into different composting chambers (Figure 1). Five levels of pollution of the compost material by the heavy metal of zinc were simulated by adding zinc to the compost material to make it have different added zinc contents (Table 2) and at the control level of pollution the added zinc content of the compost material was zero. Sampling was regularly conducted at different parts of each fermenter of the chamber and then the samples thus obtained were fully mixed to form the mixed sample for the compost material in the chamber. A part of the mixed sample was stored at 4℃ in the refrigerator and used for microbe communities' diversity analysis within 44 h; and the other part of the mixed sample was used for oxidative enzyme activity measurement.

Table 2. Zinc contents of the compost material at the different level of pollution by zinc.

level of pollution	CK	A1	A2	A3	A4
Zinc content	0	300	600	900	1200

Zinc was added in the form of $ZnSo_2 \cdot 7H_2O$.

Composting chamber

The chamber was composed of three 1 m high cylindrical fermenters (reactors) whose inner and outer diameters were 0.6 and 0.7 m, respectively. the fermenters has a shell consisting of two stainless steel layers between which there was 0.5 cm thick heat insulating material placed and a round stainless steel bottom with a hole. The compost material were placed and evenly spread on the upper surfaces of the bottoms, and air got into the compost material through the holes of the bottoms, moved up through and left it (Figure1).

Measurement and measurement method

The diversity in microbial carbon source used was determined with Biolog Eco-micro-plate. The detailed determination procedure was described in literature (Zheng et al., 2007; Kong et al., 2006). The enzyme activity was determined by the method described in Guan (1986). The polyphenol oxidase activity was determined by ether extraction and the dehydrogenase activity was determined by toluene extraction.

Data processing

The data obtained from the Inoculated Eco-microplates after they were incubated for 96 h were analyzed by the principal component analysis (PCA) (Zhang et al., 2007). Data processing was performed using Excel (V2003), SAS (V8.1) and SPSS (16.0).

RESULTS AND DISCUSSION

Metabolic variations of microbe communities in the process of composting

Composting is completed by microbial metabolisms, that is, synthesis and decompositions, and it is of important significance to revealing biological behaviors of composting to study microbial metabolisms in the process of composting.

Effects of zinc on carbon source use diversity of microbe communities in the process of composting

Microbial carbon use can indicate categories of microbial metabolic functions. Figure 3 shows that in the whole period of composting, the use ratios of the six carbon sources by the microbe communities at the temperature rising stage were the highest increased, followed by those at the temperature dropping stage, and the use ratios of the six carbon sources by the microbe communities at the high temperature stage were the lowest; and all the use ratios of the aromatic compounds by the microbe communities were low at the different zinc content. Microbial uses of the different carbon sources at the different stages of composting showed that at the temperate-rising stage, the microbial use ratios at the different zinc contents were the highest and at the high temperature stage ,the microbial use ratios of carbohydrates at the different zinc contents were the highest, at the temperature declining stage, the microbial use ratios of polymers at the zinc contents of the control and A2 were the highest, the microbial use ratios of carbohydrates at the zinc contents of A1 and A3 were the highest and the microbial use ratios of amino acids at the zinc content of A4 were the highest because A4 had a very high zinc content so that the microbes of the compost material at the zinc content of A4 changed their preferences in carbon use. Wenderoth and Reber (1999) revealed in study that microbes adapted to heavy metals probably at the cost of reducing some of their specific or rare metabolic capacities, whereas, Gremion et al. (2004) found in study that in heavy polluted soil, the microbial use ratios of amino acids, amines and amides as carbon sources were low. These differed with the results of the study and the mechanism for the difference needed further exploring.

Therefore, the microbes communities of the compost material mainly used polymers and carbohydrates as their carbon sources at the low zinc contents and all their use ratios of aromatic compounds were low at all the zinc contents.

Carbon source diversity of microbe communities in the process of composting by the PCA

Heavy metal pollution not only exerts influence on microbial metabolic activity but also changes the structure and diversity of microbe communities, so that microbes change their biological metabolisms and then their selections and uses of carbon sources.

Table 4 shows that at the temperature rising stage, high temperature stage and temperature dropping stage, the carbohydrate proportions of the carbon sources contributing most to PC1 (whose eigenvectors were above 0.50) were the highest (30, 33 and 29%, respectively), followed by their carboxylic acid proportions(25, 33 and 25%), and the amino acid and carbohydrate proportions of the carbon sources contributing most to PC2 (whose eigenvectors were above 0.50) were high. Therefore, the carbon sources that differentiated PC1 and PC2 were carbohydrates and carboxylic acids.

The microbial uses of the six carbon sources at the different stages of composting were comparatively examined by PCA (Table 2 to 7), which showed that, the microbial uses of the six carbon sources very evidently differed with the different heavy metal contents in the PCA coordinate system. These differences mainly

Table 3. Microbial use ratios of the six carbon sources at the different zinc contents.

Stage of composting	Zinc content /(mg.kg^{-1})	Amino acids	Carboxylic acids	Carbohydrates	Amines and amides	Polymers	Aromatic compounds
Temperature Rising stage	CK	1.68 ab	1.46 b	1.95 a	1.36 b	1.99 a	1.31 b
	300	1.56 a	1.10 bc	1.42 ab	1.49 a	1.69 a	0.93 c
	600	1.68 ab	1.46 b	1.95 a	1.36 b	1.99 a	1.31 b
	900	1.91 abc	1.60 bc	2.10 ab	1.83 abc	2.23 a	1.53 c
	1200	1.85 a	1.50 b	1.98 a	1.21 b	2.13 a	1.32 b
High temperature stage	CK	1.03 a	0.86 a	1.06 a	1.06 a	0.88 a	0.67 a
	300	1.20 ab	0.87 b	1.52 a	1.21 ab	1.43 a	0.82 b
	600	1.64 b	1.66 b	2.13 a	1.15 c	1.30 bc	1.25 c
	900	1.41 ab	1.01 b	1.66 a	1.16 ab	0.92 b	0.82 b
	1200	1.42 a	0.90 a	1.42 a	0.96 a	1.05 a	1.13 a
Temperature Dropping stage	CK	1.16 a	0.87 b	0.84 b	1.02 ab	1.20 a	0.56 c
	300	1.41 cd	1.20 d	2.04 a	1.66 bc	1.82 ab	1.29 d
	600	1.38 ab	0.97 c	1.59 a	1.14 bc	1.61 a	0.45 d
	900	1.45 b	1.11 c	1.75 a	1.46 b	1.77 a	1.16 c
	1200	0.83 a	0.47bc	0.76 ab	0.60 ab	0.76 ab	0.28 c

In the same columns, different letters indicate significant differences (P<0.05).

Table 4. Numbers of carbon sources contributing to PC1 and PC2 at an eigenvector above 0.50.

Carbon source	Stage					
	Temperature rising		High temperature		Temperature dropping	
	PC1	PC2	PC1	PC2	PC1	PC2
Carbohydrates	6	0	5	1	7	1
Carboxylic acids	5	3	5	2	6	2
Amino acids	4	1	2	3	4	1
Amines	1	1	0	0	2	0
Polymers	2	0	1	0	3	0
Aromatic compounds	2	1	2	0	2	1
Total	20	6	15	6	24	5

appeared in PC1 at the temperature rising stage and the high-temperature stage. At the temperature rising stage, the microbial uses of the carbon sources at the zinc content of A3 and A2 stood at the positive end of PC1 and the microbial uses of the carbon sources at the zinc content of A1 stood at the negative end of PC1; and analysis of variances on the microbial uses of the carbon sources showed that the eigenvectors of PC1 significantly differed (F=8.99, P<0.05), which was mainly embodied in that the eigenvectors at the zinc content of A2 significantly differed from those at the zinc contents of the Control and A1. At the temperature dropping stage, this difference was mainly embodied in PC2. The eigenvectors at the zinc contents of the Control, A1, A2 and A3 stood at the positive end of PC2 and the eigenvectors at the zinc content of A4 stood at the negative end of PC, so that the eigenvectors significantly differed (P<0.01), which was mainly embodied in that the eigenvectors at the zinc content of A4 differed significantly from all those at the zinc content of the Control, A1, A2 and A3. It follows that the eigenvectors at the zinc contents of A2 and A3 significantly differed from those at the zinc contents of A1 and A4 and the eigenvectors at the zinc contents of A2 and A3 did not significantly differ. In addition, the dispersion coefficients of the component score coefficients at the zinc contents of A3 and A2 remained low in the process of composting. So the microbe communities at the zinc contents of A2 and A3 were more stable than them at the other zinc contents in the process of composting.

Table 5. Loads of the principal components after the 96 h incubation at the temperature rising stage.

Zinc content (mg kg^{-1})	Repeatability (3 times)	PC1 (41.39%)	PC2 (12.11%)
	R1	0.33	0.20
CK	R2	0.18	-0.15
	R3	-0.35	-0.99
	R1	-2.16	-1.27
300	R2	-1.35	1.01
	R3	-1.76	1.53
	R1	0.52	-0.15
600	R2	0.66	-0.98
	R3	0.53	-1.49
	R1	0.90	1.15
900	R2	0.98	1.10
	R3	0.82	-0.83
	R1	0.81	1.05
1200	R2	0.14	0.36
	R3	-0.23	-0.55

Table 6. Loads of the principal components after the 96 h incubation at the high temperature stage.

Zinc content (mg kg^{-1})	Repeatability (3 times)	PC1 (28.39%)	PC2 (14.88%)
	R1	-1.24	0.55
CK	R2	-0.43	0.62
	R3	-1.10	-2.95
	R1	-0.24	0.01
300	R2	-0.49	0.35
	R3	-0.11	-0.72
	R1	1.80	-0.06
600	R2	1.78	-0.47
	R3	1.26	0.55
	R1	-0.63	0.24
900	R2	0.24	-0.14
	R3	0.55	0.59
	R1	0.09	-0.29
1200	R2	0.06	-0.02
	R3	-1.15	1.72

Knight et al. (1997) reported that the contents of heavy metals could significantly affect the diversity of soil microbe communities and the study presented in this paper indicated that the carbon use modes of the microbes of the compost material had something to do with the heavy metal content of the compost material. PCA showed that the microbes of the compost material differed in carbon source selection and use with their

Table 7. Loads of the principal components after the 96 h incubation at the temperature dropping stage.

Zinc content (mg.kg^{-1})	Repeatability (3 times)	PC1 (54.71%)	PC2 (10.65%)
	R1	-2.16	1.96
CK	R2	-0.67	0.46
	R3	-1.07	0.69
	R1	1.33	0.50
300	R2	1.42	0.07
	R3	0.86	0.24
	R1	-0.22	-0.09
600	R2	0.36	0.13
	R3	0.18	0.21
	R1	0.76	0.18
900	R2	0.76	0.43
	R3	0.58	0.31
	R1	-0.61	-1.94
1200	R2	-0.77	-1.38
	R3	-0.75	-1.77

different contents of the heavy metal in the process of composting and this reflected that the microbes differed in carbon source type with the different zinc contents, so that it could be deduced that the critical content of the heavy metal helpful to pig manure composting probably ranged between A2 and A3, implying that the heavy metal of the compost material at high contents damaged their original ecosystems, rendering their communities to lose their normal functions and correspondingly change their structure and function diversity .

Effects of zinc on the oxidative enzymes activities

In the process of composting, biochemical reactions are enzyme catalyzed and enzyme activity represents the orientations and intensities of various biological processes. Oxidative enzymes are closely related to such fundamental metabolic substances as carbon, nitrogen and phosphorous and the analysis on the activities and their dynamic trends of relevant enzymes can reveal substance transformations of compost materials (Tan et al., 2006).

Polyphenol oxidase activity in the process of composting

Because of its large molecule size and water insolubility, lignin is not able to enter into cellwall and thus its disintegration has to rely on extracellular degrading enzymes that microbes excrete. Lignin degrading enzymes include two main groups, peroxidase and polyphenol oxidase. Currently, most studies are focused on polyphenol oxidase, which does not only catalyze lignin degrading but also enables quinine and amino acids, products of lignin oxidation to be condensed into humic acids (Wang, 2003).

Table 8 shows that at the beginning stage of composting, the polyphenol oxidase activities of the compost material at the zinc contents of A1, A2 and A3 increased and simultaneously reached their first peaks on the third composting day as the temperatures of the compost material increased, and the peaks at the zinc contents of A1, A2 and A3 were 11.74 mg pyrogallol.g^{-1}.h^{-1}, 13.71 mg pyrogallol.g^{-1}.h^{-1} and 13.37 mg pyrogallol·g^{-1}·h^{-1}, respectively. The polyphenol oxidase activity of the compost material at the zinc content of the Control began to increase on the second composting day and reached its first peak of 10.72 mg pyrogallol.g^{-1}.h^{-1} on the fourth composting day. The polyphenol oxidase activities of the compost material at the zinc contents of A2 and A3 were higher in the late composting period than in the early composting period and this was probably related to lignin disintegration and humic acid formation occurring in the middle to late composting period (Zhang et al., 2001). In the late composting period, the major biochemical reaction was humus synthesis and the polyphenol oxidase activity at the zinc content of A2 was higher than those at the other zinc contents in most cases, so that lignin degrading and its product transformation were more favorably promoted.

Average polyphenol oxidase activities in the process of composting (Table 9) showed that the polyphenol oxidase

Table 8. Polyphenol oxidase activities in the process of composting.

Zinc content (mg kg^{-1})	Composting day/d											Average
	1	2	3	4	5	8	11	14	18	22	27	
CK	9.44	12.15	11.33	12.87	11.10	10.93	11.34	12.87	9.30	8.26	13.94	11.23
300	9.15	10.27	11.74	9.09	7.53	12.10	9.78	9.34	9.80	12.71	12.47	10.36
600	7.11	9.74	13.71	14.04	10.65	11.27	11.05	9.22	13.88	12.68	15.26	11.69
900	9.24	11.17	13.37	7.63	8.02	12.92	9.97	12.26	9.59	9.07	9.55	10.25
1200	8.11	7.02	8.79	10.72	8.68	11.53	8.33	11.94	9.94	7.96	10.69	9.43

Table 9. Polyphenol oxidase activities at the different zinc contents in the process of composting.

Zinc content /(mg.kg^{-1})	Temperature Rising stage	High temperature stage	Temperature dropping stage	After composting	Average in the period of composting
CK	9.44 a	11.61 b	11.11 ab	11.10 c	11.14 b
300	9.15 ab	9.66 cd	10.25 c	12.59 b	10.36 c
600	7.11 c	12.04 a	11.35 a	13.97 a	11.69 a
900	9.24 a	10.05 c	11.18 a	9.31 d	10.25 c
1200	7.57 bc	9.40 d	10.44 bc	9.32 d	9.43 d

In the same columns, different letters indicate significant differences (P<0.05).

Table 10. Dehydrogenase activities in the process of composting.

Zinc content/ (mg.kg^{-1})	Composting day/d											Average
	1	2	3	4	5	8	11	14	18	22	27	
CK	18.82	10.16	17.36	16.02	10.22	8.22	7.83	9.28	4.42	21.04	23.67	13.37
300	15.22	9.66	17.92	19.28	10.28	14.74	16.01	8.56	3.19	16.43	9.86	12.83
600	22.76	10.95	15.71	16.01	12.27	9.97	12.87	10.36	6.24	22.80	21.68	14.69
900	20.80	6.17	13.15	20.94	9.96	8.92	7.29	8.92	2.40	25.42	11.67	12.33
1200	18.94	7.60	12.24	12.25	10.19	10.63	10.60	10.70	5.20	10.94	12.77	11.10

activity at the zinc content of A2 appeared as the highest reaching 11.69 mg pyrogallol.g^{-1}.h^{-1}, 14.94% higher than that at the zinc content of the Control, 12.84% higher than that at the zinc content of A1, 14.05% higher than that at the zinc content of A3, 8.70% higher than higher than that at the zinc content of A4 and that all significantly (P<0.05). It follows that zinc had activating effect on the polyphenol oxidase activity at a low content (600 mg.kg^{-1}) (Huang and Shindo, 2000), thus helpful to degrading lignin and condensing quinone and amino acids into humic acids in the compost material.

Dehydrogenase activities in the process of composting

Dehydrogenase, an oxidative enzyme, mainly occurs in microbial excretion activities and can be used to indicate microbial reduction and oxidation capacities as well as quantities and organic-substance degrading activities of active microbes in compost materials (Dai et al., 2005).

Table 10 shows that the dehydrogenase activities of the compost material at all the zinc contents decreased as the temperature of the compost material rose and this was probably because at the temperature rising stage, the composting material rapidly increased its temperature and microbes adaptable to low temperature were unable to adapt to the high temperature thus, reducing their dehydrogenase excretion. After the high temperature stage, as the compost material decreased its temperature, its thermopile microbes multiply in great quantities and excreted a large amount of dehydrogenase, so that its dehydrogenase activity increased. In the middle period of composting high dehydrogenase activity means that oxidation mainly takes place in the middle period of composting. During the whole period of composting, the dehydrogenase activities at the zinc contents of A1, A2 and A3 greatly varied, peaking and bottoming several times, so that they had certain instability. It was possible

Table 10. Dehydrogenase activities in the process of composting.

Zinc content ($mgkg^{-1}$)	Composting day/d											Average
	1	2	3	4	5	8	11	14	18	22	27	
CK	18.82	10.16	17.36	16.02	10.22	8.22	7.83	9.28	4.42	21.04	23.67	13.37
300	15.22	9.66	17.92	19.28	10.28	14.74	16.01	8.56	3.19	16.43	9.86	12.83
600	22.76	10.95	15.71	16.01	12.27	9.97	12.87	10.36	6.24	22.80	21.68	14.69
900	20.80	6.17	13.15	20.94	9.96	8.92	7.29	8.92	2.40	25.42	11.67	12.33
1200	18.94	7.60	12.24	12.25	10.19	10.63	10.60	10.70	5.20	10.94	12.77	11.10

Table 11. Dehydrogenase activities at the different zinc contents in the process of composting.

Zinc content ($mg\ kg^{-1}$)	Temperature Rising stage	High temperature stage	Temperature Dropping period	After composting	Average in the period of composting
CK	18.82 c	13.44 b	7.44 d	22.36 a	13.37 b
300	15.22 d	14.29 a	10.63 a	13.14 c	12.83 bc
600	22.76 a	13.74 b	9.86 b	22.24 a	14.69 a
900	20.80 b	12.55 c	6.88 e	18.54 b	12.33 c
1200	13.27 e	11.56 d	9.28 c	11.86 d	11.10 d

In the same columns, different letters indicate significant differences ($P<0.05$).

that while heavy metals inhibit dehydrogenase activity, the phenomenon of the “resisting enzyme activity” occurs, that is, when soil heavy metal reached a certain mass fraction, a majority of soil microbes die and only a small number of them survive the pollution by the heavy metal, multiplying and producing resisting enzymes, so that the soil enzymatic activity first decline and then increase, sometimes even presenting several resisting enzyme activity peaks (Lin et al., 2005). Yan et al. (2008) revealed in their study that while the heavy metal Cr was externally added to soil, soil urease presented the phenomenon of the resisting enzyme activity.

Average dehydrogenase activities in the process of composting (Table 6) showed that the dehydrogenase activity of the compost material at the zinc content of A2 appeared to be the highest, reaching 14.69 TFug/g.h, 9.92% higher than that at the zinc content of the Control, 14.50% higher than that at the Control zinc content of A1, 19.17% higher than that at the Control zinc content of A3, and 32.41% higher than that at the Control zinc content of A4, and that all significantly ($P<0.05$). The zinc content of A2 and the pH of the compost material were helpful for the microbes to multiply and thus, excrete a great amount of dehydrogenase and consequently the dehydrogenase activity at the zinc content of A2 was higher than those at the other two zinc contents. It follows that the heavy metal was beneficial to the oxidation and reduction of the compost material.

Conclusion

1) Where the compost material had low zinc content, its microbes used polymers and carbohydrates most efficiently but aromatic compounds at a lower ratio. Where the contents of the compost material were separately 600 and 900 $mg \cdot kg^{-1}$, its microbial use ratios on the carbon sources did not significantly differ and its microbe communities were more stable than where its zinc contents were not the two zinc contents.

2) Where the compost material had a zinc content of 600 $mg.kg^{-1}$, its polyphenol activity appeared to be the highest, reaching 11.69 mg $pyrogallol.g^{-1}\ h^{-1}$, helpful for its lignin to degrade, meanwhile, its dehydrogenase activity appeared to be the highest, reaching 14.69 TFug/g.h, helpful for its microbe multiplication, oxidation and reduction. In the meantime, where the zinc contents of the compost material were separately 300, 600 and 900 $mg.kg^{-1}$, the dehydrogenase activities varied greatly, presenting certain instability.

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