DOCTORAL THESIS

Composting of food waste with Chinese medicinal herbal residues as a bulking agent to produce a high-end organic fertilizer with antipathogenic effect

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Abstract

Composting is a sustainable method to deal with huge amount of daily organic waste due to its robustness and easy operation. However, food waste (FW) as the main material in composting has disadvantages such as the heterogenous properties, high foreign matters contamination, high moisture content, low C/N ratio, poor structure, low porosity and high acidity during the initial phase of composting. These shortcomings not only influence degradation efficiency but also cease the composting process. Therefore, a bulking agent is required to increase the porosity and adjust the moisture content as well as C/N ratio of the composting mixture (Wong et al., 2010). For previous research, sawdust (SD) and tree barks were commonly used as the bulking agent in composting system but the demand for sawdust and tree barks significantly increased the cost of the composting process, and this has stimulated the demand of alternative substitutes. Therefore, the ideal situation is to find the bulking agent which is not only suitable for composting but is also a waste. Traditional Chinese medicine is widely used nowadays and huge amount of residues are accumulated and treated in landfilling (Wang and Li, 2013). According to previous research, only 5% of the active ingredients can be extracted from the medicinal plants which means there are still a large fraction of active ingredients remain in the herbal residues (Wu et al., 2013). In addition to the bulking property of Chinese medicinal herbal residues (CMHRs), it is assumed mature CMHRs compost have the ability to hinder regular metabolic pathway of phytopathogens after land application (Bernal-Vicente et al., 2008).

The first experiment of this study investigated the formula between food waste, sawdust and CMHRs in order to achieve efficient composting. The experimental results demonstrated positively the use of CHMRs is a suitable candidate to co-compost with food waste. In terms of biodegradation decomposition efficiency and compost maturity, the treatment 1:1:1 (FW: SD: CHMRs, dry wt. basis) showed the best performance among all treatments with 67% organic matter degradation and 157% seed germination index. Only well-matured composting product can suppress plant diseases in soil since it has some microorganisms which can inhibit phytopathogens. The treatment 5:5:1 (FW: SD: CHMRs, dry wt. basis) also reached maturity but with a longer composting period; however, it was the treatment which could accommodate the highest quantity of food waste. The log copy number of the bacterial population was 7-8 initially, which decreased and stabilized along the composting. Results revealed that the CHMRs can be used as a bulking agent with

food waste, and a dry weight ratio of 1:1:1 (FW: SD: CHMRs) would be optimum to achieve higher organic decomposition and faster maturity. However, the initial lower microbial population in the treatment, though without any adverse effect on the overall microbial decomposition, will warrant further work to indicate the total population is not a practical means to illuminate the effective microbial decomposition. Besides, the advantage in using CHMRs will need further experiment to indicate its potential pathogen suppression capability.

Humification during co-composting of food waste, sawdust and CMHRs was investigated to reveal its correlation with compost maturity. The huge decrease in the treatment 1:1:1 (FW: SD: CHMRs, dry wt. basis) of aliphatic organics in humic acids (HA) demonstrated the degradation of the readily available organics, while an increase in aromatic functional groups indicated the maturity of compost. Disappearance of hemicellulose and weak intensity of lignin in the CMHRs treatments indicated that the lignin provided the nucleus for HA formation; and the CMHRs accelerated the compost maturity. Humic acid to fulvic acid (HA/FA) ratio of 1:1:1 treatment was the highest at the end of composting and showed a clear correlation with compost maturity as also evidenced through the presence of higher aromatic functional groups in the HA fraction. Pyr-TMAH-GC-MS results indicated that dominant groups were aliphatic and alicyclic esters and ethers at the early composting stages in all treatments. Long chain fatty acids were broken down into smaller molecular compounds earlier in treatment 1:1:1 (FW: SD: CHMRs, dry wt. basis), resulting from the faster decomposition rate. The complicated ring-structure components appeared dominantly at the later phase of composting. The peak intensities in treatment 1:1:1 (FW: SD: CHMRs, dry wt. basis) indicated that the composts became mature earlier than the other two treatments. In brief, the treatment with dry weight ratio 1:1:1 had greatest humification degree with more cyclic structures and stable final products at the end of composting.

Water and acetone extract of composts with food waste and CMHRs were tested with their antipathogenic effect on two kinds of commonly found phytopathogens, Alternaria *solani* (A. *solani*) and Fusarium *oxysporum* (F. *oxysporum*). Seventeen bacterial species and 22 fungal species were isolated and identified as prevalently existed microbes during composting process. The results of MIC_{50} indicated that the treatment with dry weight ratio 1:1:1 (FW: SD: CHMRs, dry wt. basis) required least concentration of composts extraction to kill half quantity of the phytopathogens, 16% for A. *solani* and 22% for F. *oxysporum* extracted by acetone. The phytopathogen suppression capacity of composts was partially due to antagonistic abilities from some of the isolated microorganisms as well as the inhibition of active compounds. As shown in the comparison, the interfere/compete between antagonistic microorganisms

and target pathogens were more powerful than individually influenced by chemical compounds. However, the influencing factors should not be considered independently since antagonistic interactions between microbes in composts and phytopathogens are highly dependent on the abiotic properties of the composts and the alternative environment. In a word, the antipathogenic effects from composts were synergism of both antagonism and chemical factors.

Suppressive capacity on phytopathogens is one of the major function of mature composts and the antipathogenic effect was stimulated when CMHRs was used as the bulking agent in composting process. The abiotic inhibitory rates of treatment 1:1:1 (FW: SD: CHMRs, dry wt. basis) indicated that more powerful bioactive components were remained at the end of composting than in the treatment 5:5:1 and control which had no CMHRs but plastic beads as the bulking agent. Hence sensitive and comprehensive analytical technique of ultra-performance liquid chromatography coupled with time-of-flight mass spectrometry (UPLC-QTOF-MS) was utilized to acquire a better understanding of the complicated structures of final composting products. Seven dominant among 22 active compounds with antibacterial/antifungal properties were obtained in the treatments with CMHRs while 17 kinds of compounds with higher contents were shared in all treatments, which should be derived from food waste. The bioactive components from CMHRs composting were mainly from the groups of alkaloids, flavonoids and coumarins.

Mature composts were used as biofertilizer to protect plants (*Brassica chinensis* and *Lycopersicon esculentum*) from phytopathogenic infection. This study showed the crop yields were increased with the addition of mature CMHRs composts to acid soil, and 5% CMHRs compost was the optimum application rate, while at the higher application rate of 10% (dry weight basis, w/w) plant growth was inhibited which might be due to the higher salt contents and the phytotoxicity of alkaloids, flavonoids and coumarins in the CMHRs. According to the biomass results, *Brassica chinensis* was more sensitive to the inhibitory effect of phytopathogen inoculation, while nutrient supply was to a less extent due to the short growth period as compared to *Lycopersicon esculentum*. The present study showed clearly that mature compost provided *Lycopersicon esculentum* and *Brassica chinensis* sufficient nutrients such as nitrogen and phosphorus. Additionally, the advantage of using mature CMHRs compost as a soil conditioner was also observed for blocking phytopathogenic infection from plant roots. The mechanism was mainly derived from the bioactive components in mature CMHRs compost which inhibited phytopathogenic activities in soil. Many identified compounds were alkaloids, flavonoids and coumarins which have powerful antifungal and antibacterial abilities and most of them maintained during growth period though their amounts reduced greatly due to their photolytic and

pyrolytic properties. Therefore, mature CMHRs compost can be the substitute to reduce the usage of fungicides and its associated environmental hazards. The present study demonstrates clearly the beneficial effects of using CMHRs as a bulking agent to co-compost with food waste with the additional phytopathogens suppression property.

Therefore, it is concluded that Chinese medicinal herbal residues can be a good choice of bulking agent in food waste composting system. Organic matter degradation and humification process were accelerated by CMHRs addition and mature CMHRs compost had antipathogenic effect and protect plants from infection.

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