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Chinese medicinal herbal residues as a bulking agent for food waste composting

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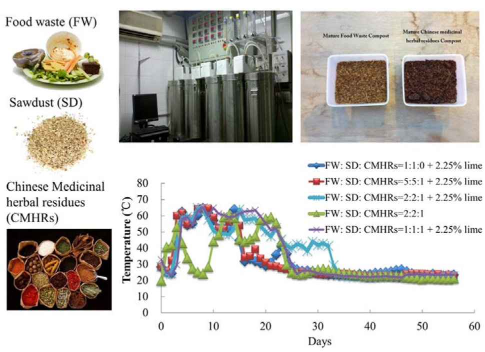
GRAPHICAL ABSTRACT



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ABSTRACT

This study aimed to co-compost Chinese medicinal herbal residues (CMHRs) as the bulking agent with food waste (FW) to develop a high value antipathogenic compost. The FW, sawdust (SD) and CMHRs were mixed at three different mixing ratios, 5:5:1, 2:2:1 and 1:1:1 on dry weight basis. Lime at 2.25% was added to the composting mix to buffer the pH during the composting. A control without lime addition was also included. The mixtures were composted in 20-L in-vessel composters for 56 days. A maximum of 67.2% organic decomposition was achieved with 1:1:1 mixing ratio within 8 weeks. The seed germination index was 157.2% in 1:1:1 mixing ratio, while other ratios showed < 130.0% and the treatment without lime showed 40.3%. Therefore use of CMHRs as the bulking agent to compost food waste at the dry weight ratio of 1:1:1 (FW: SD: CMHRs) was recommended for FW-CMHRs composting.

1. Introduction

In 2015, about 10,159 tonnes of municipal solid waste was disposed in landfills each day in Hong Kong; of which food waste (FW) represented 33% (HKEPD, 2015). Due to high putrescible property, FW is a major source of leachate and greenhouse gas emissions from landfills. Therefore sustainable technologies are to be in place to reduce the environmental threats. FW should be separated and treated by biological means to retrieve the organics and valuable nutrients and transform them into a high value end product. Composting is a robust and environmental friendly technology for organic waste treatment. The end product from composting process is a stabilized organic matter rich

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in humic substances and contains essential plant nutrients which make the compost as an organic fertilizer (Zhou et al., 2016).

Despite the intensive composting research in the past decades, FW composting is still facing a number of technical challenges due to (i) poor physical structure with low porosity of FW, (ii) high moisture content of FW, (iii) low carbon-to-nitrogen (C/N) ratio of the FW, and (iv) rapid hydrolysis and accumulation of organic acids during composting (Wang et al., 2016a; Wong et al., 2009). Therefore, it is essential to use bulking agents such as sawdust and tree barks to adjust the C/N ratio, reduce/adjust the moisture contents and porous properties suitable for composting (Zhou et al., 2014). Bulking agent is one of the most important factors that highly influence compost maturity. In turn the efficiency of the bulking agents could be influenced by the substrate-bulking agent mixing ratios. For instances, Neugebauer and Sołowiej (2017) reported that kitchen waste should be composted with at least 40% of bulking agent (garden waste) for efficient decomposition. It demonstrated that sawdust at lower mixing ratios could not support effective decomposition and accelerate the maturity (Wang et al., 2016b). Additionally, sawdust and tree barks which are widely used as the bulking agent significantly increases the cost of composting process and their availability in urban centre are diminishing. For this reason, it is important to find a cheap alternative, thereby the maturity and organic degradation could be improved while the production cost would be lowered.

Statistics from a marketing research indicated that there are 1636 kinds of Chinese medicinal herbs are used in China. Around 50,000 institutions and clinics in China and Hong Kong provides Traditional Chinese Medicine (TCM) services and consumption of Chinese medicinal herbs/plants reached 70 million tons per year (Wang and Feng, 2009). This resulted in disposal of millions of tons of medicinal herbal wastes (herbs/plants after decoction), which necessitates appropriate mechanism for treatment and disposal. During decoction or other extraction process, only less than half of the bioactive compounds are extracted thus significant portion of the active ingredients still exist. The herbal residue/waste after the extraction process is often referred as Chinese medicinal herbal residues (CMHRs). However, the researches on the utilization of CMHRs are very limited. For instance, Wu et al. (2010) used herbal residue and mushroom waste to co-compost with sludge. They reported that the thermophilic phase was prolonged for 9 days by increasing the herbal residue ratio; while more spent mushroom waste had positive impact on nitrogen preservation. Liang et al. (2009) composted the CMHRs alone and studied the effect of mature compost on soil and plant growth. Addition of complex microbial communities accelerated compost to become mature and increase compost quality. However, the research of re-use of CMHRs as a bulking agent with food waste in composting is still scarce.

Recently, a few researchers are committed to identify new bulking agent to improve the composting process and efficiency. However, the use of CMHRs as a bulking agent with FW has not been given due significance. As a matter of fact, CMHRs mainly contain fibrous plant materials and are rich in carbon; thus can be used as a bulking material for composting instead of disposal in landfills (Liang et al., 2009; Wu et al., 2010). The phytochemicals in CMHRs may provide better compost quality with high antipathogenic properties, through both biotic and abiotic mechanisms. Based on our previous research, CMHR-induced changes in the antagonistic and mycoparasitic abilities of the bacteria and fungi contributed to the specific inhibition against soil-borne phytopathogens due to due to their chitinolytic characteristics and the ability to produce antifungal proteins (Zhou et al., 2016). It was agreed to Zhang et al's research that CMHRs effectively reduced most of the targeted ARGs with inhibitory effects on potential human pathogens in the aerobic composting products by changing microbial community structures (Zhang et al., 2017). Besides, these bioactive compounds from alkaloids and flavonoids groups in CMHRs may influence the composting process by regulating the microbial populations which also needs systematic investigation.

Therefore, this study investigated the use of CMHRs as a bulking agent for FW composting to obtain a high-end organic fertilizer with possible antipathogenic property. Since the moisture content of the CMHRs was also very high, sawdust (SD) was added to adjust the moisture content of mixture before composting. Different mixing ratios were setup and composted in 20-L in-vessel composters over a period of 56 days. The organic degradation and maturity of compost were monitored to assess the efficiency of composting process, while other conventional monitoring parameters were tested to compare different treatments.

2. Material and methods

2.1. Experimental design of composting of FW with CMHRs

The CMHRs was collected from the School of Chinese Medicine in Hong Kong Baptist University. The daily collection was lasted for one month and the collected materials were mixed together to overcome the sample heterogeneity. The FW was artificially prepared by mixing boiled rice, bread, cabbage and boiled pork in the ratio of 13:10:10:5 (fresh wt. basis) and the size of the raw materials was reduced to 0.5 cm^3, if necessary as reported previously (Wong et al., 2009). This ratio simulated the physicochemical properties of the food waste from dietary structure of local people and facilitated the repeatability of the experiments and compare results of different experiments. The sawdust was purchased from Wong Yee Kee Co Ltd, Hong Kong. Selected properties of raw materials are presented in Table 1.

The FW, sawdust and CMHRs were mixed in the ratios of 5:5:1, 2:2:1 and 1:1:1 (dry weight basis, wt. $wt.^{-1}$), while FW to sawdust ratio was maintained at 1:1 in the control with 1 kg plastic beads as bulking agent, to reveal the influence of CMHRs on composting efficiency (Table 2). Lime at 2.25% (dry weight basis, wt. $wt.^{-1}$) was added to the total composting mass (Wong et al., 2009), except an additional control with the mixing ratio of 2:2:1 to reveal the effect alkaline buffering effects. The C/N ratio was calculated by sum of total carbon contents of each substrate multiplied by its weight divided by sum of total nitrogen contents of each substrate multiplied by its weight (dry weight basis) (Eq. (1)). The C/N ratio of all the treatments was between 25 and 26, while the initial moisture contents varied between 55% and 60%.

$$C/N = \frac{\Sigma \text{total carbon of each substrate} * \text{dry weightof each substrate}}{\Sigma \text{total nitrogen of each substrate} * \text{dry weightof each substrate}} \quad (1)$$

About 7.5 kg of composting mixture was prepared for each mixing ratio and composted for 56 days in the 20-L bench-scale composting reactor. The composting systems were connected with computerized

Table 1
Selected properties of the food waste, sawdust and Chinese medicinal herbal residues (CMHRs) used as raw materials in the study.

Parameters	Food waste	Sawdust	Chinese medicinal herbal residues	
			Summer	Winter
Moisture content (%, dw)	59.0 (0.02)	7.24 (0.03)	63.0 (0.13)	65.1 (0.16)
Total organic carbon (%, dw)	45.5 (1.70)	52.9 (0.91)	48.0 (0.41)	47.0 (0.48)
Total Kjeldahl nitrogen (%, dw)	3.28 (0.04)	0.59 (0.04)	1.62 (1.32)	1.55 (0.08)
C/N ratio	13.9 (0.35)	89.8 (4.56)	29.6 (2.21)	30.3 (2.67)
pH	4.39 (0.07)	5.02 (0.02)	5.15 (0.12)	5.12 (0.09)
Total phosphorus (%, dw)	0.56 (0.04)	0.01 (0.00)	0.49 (0.91)	0.50 (0.88)
Ammonium (mg/kg, dw)	–	–	40.63 (2.26)	42.01 (1.85)