DOCTORAL THESIS

Nitrogen conservation by struvite formation during composting process with food wastes

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ABSTRACT

Food waste as a dominant fraction of municipal solid waste was in most of cases buried in landfills creating a burden on big cities with large populations such as Hong Kong. Composting provided an environmentally viable technology to divert food waste to resource utilization for the production of valuable organic fertilizer. The main problem associated with food waste composting was the intensive acidification prior the commencement of the composting process, which is commonly adjusted by the addition of alkaline materials such as lime. However, more than 50% of the initial nitrogen will be lost as ammonia, which not just reduces the nutrient value of the compost but also leads to serious odour generation. Therefore the objective of this study was to develop means to reduce the nitrogen loss through struvite formation.

The first experiment of this research investigated the feasibility of controlling the nitrogen loss through struvite formation during food waste composting. Struvite forms when magnesium (Mg), phosphorus (P) and nitrogen (N) salts exist in equimolar ratio at a slightly alkaline pH. Thus to fix the ammonia, MgO and K_2HPO_4 were added to food waste indifferent molar ratios (P1, 0.05M/kg MgO and 0.05M/kg K_2HPO_4; P2, 0.05M/kg MgO and 0.1M/kg K_2HPO_4) to induce struvite formation that can fix the compost-borne ammonia during composting. The pH of the composting mass of P1 was below 5 for more than one. However, the pH of P2 was controlled in a narrow range from 6.8 to 8.7. This slightly alkaline pH ensured a good microbial activity and improved the degradation rate as well as the precipitation of struvite. In treatment P2, the formation of struvite effectively reduced the nitrogen loss from 40.8% to 23.3% when compared to treatment with lime amendment. However, electrical conductivity (EC) of the compost increased to 6.4 mS/cm due to the addition of Mg and P salts. High salinity of the compost retarded seed germination which required further investigation to reduce the salinity while maintaining good nitrogen removal.

To overcome this issue, lime as the more effective alkaline amendment, was supplemented in different concentrations along with struvite salts (to P1 treatment having less Mg salt that could reduce the salinity) to alleviate the low pH and struvite formation. The pH of the composting masses were effectively increased with increasing lime dosages and 2.25% lime was sufficient to maintain the pH in alkaline condition that significantly improved the degradation of active organic compounds resulting in increased dissolved organic carbon (DOC) and soluble organic nitrogen (SON) contents. With 2.25% lime and struvite salts, ammonia emission was significantly reduced from 44.3 to 27.4% through struvite formation compared with lime alone treatment. Furthermore, the EC were also decreased from 5.21to 3.40 mS/cm when lime amendment rate increased from 0.75% to 3%. However, the ammonia emission increased with an increase in lime dosage.

Interfering ions such as calcium and potassium were reported to affect the struvite formation and pH control. Therefore, in the subsequent experiment, the influence of different types of P salts was investigated to reduce the salinity as well as N loss. When K_2HPO_4, Na_2HPO_4 and H_3PO_4 were used as the supplementary P salts, there were no significant differences on nitrogen conservation. In addition, the results indicated that K^+ and Na^+ were attached on the surface of struvite rather than constituted the crystal structure. Compared with other P salts, the presence of K^+ in K_2HPO_4 also made a contribution to total nutrient content that benefited the final product. When CaO was gradually

substituted with MgO as pH amendment, ammonia emission was significantly reduced implying that Ca^{2+} ions would influence the struvite formation, either by competing for phosphate ions or by interfering with the crystallization. However, this negative effect could be ignored when the Ca^{2+}/Mg^{2+} ratio was below 1:2. Considering the cost of MgO, supplementation of Ca^{2+}/Mg^{2+} ratio at 1:2 (0.15M CaO and 0.3M MgO) with 0.05M K_2HPO_4 was identified as the optimum conditions (Treatment M0.3) that effectively reduced the nitrogen loss to 28% in contrast to 46% with lime addition.

The significant reduction of ammonia emission through struvite formation was observed with the optimum condition that the odour unit (OU) of ammonia emission was reduced to 1.8×10^4 when compared with lime treatment (3.0×10^4) indicating a significant reduction of OI_{MAX} (maximum odour index). Meanwhile, the well-controlled pH of this technology ensured the effective decomposition of organic matter that significantly reduced the emission of volatile fatty acids (VFAs) also. The population of total bacteria was also improved due to the addition of phosphate salts.

The total nutrient content of struvite composts of treatment with optimum condition (M0.3) was 4.14% (1.5% N, 0.44% P and 2.2% K) that was higher than normal lime treated compost 2.92% (1.3% N, 0.34% P and 1.28% K). In pot experiment, soil was amended with composts at 0, 2.5%, 5% or 10% (w/w dry wt. basis). At the same application rate, the biomass yields of Chinese cabbage and cherry tomato plants were improved by struvite compost when compared tonormal compost. Considering the increasing salinity of soil with high application rate, the optimum dosage of 5% struvite compost is recommended.

To conclude, a food waste composting technology was developed to achieve good nitrogen conservation and decomposition that alleviated odour issue and produced compost with higher nutrient contents, which increased its application value.

Tableof Contents