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Safety of Decentralized Composting of Human Waste for Improved Nutrient Cycling in Urban Agriculture

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Abstract

There are important synergies between recovery of perishable food for food banks, source separation of organic waste, decentralized composting, and co-composting of human waste, all of which contribute to a more circular economy of agricultural nutrients in urban centers. These synergies are present in the environmental programs of the Social Service of Commerce (SESC), which operates Mesa Brasil, a food bank that recovered and distributed 44 million kg of food in 2022, much of it from source-separated perishable foods from retailers and wholesalers (Tenuta et al. 2021). SESC also promotes and practices decentralized composting from its kitchen and hotel sites (BRASIL 2017), and has experimented with dry toilets and co-composting of human waste (Andrade 2020). Composting of human waste is an unreliable method for pathogen reduction if there is poor control of temperature, as in turned windrow systems (Wichuk and McCartney, 2007). However, static piles can provide much more temperature uniformity and co-composting with other organic wastes can provide the high temperatures necessary for pathogen inactivation. Two forms of human waste, sewage sludge from a WWTP (wastewater treatment plant), and a urine and feces mixture from a public dry toilet station, were separately co-composted with source-separated OFMSW (organic fraction of municipal solid waste) along with selected yard trimmings in the form of straw and chipped brush in naturally aerated static piles using the UFSC method (Miller and Inácio 2022). External, porous, straw walls insulate the interior for uniformly high temperatures of applied wastes. Temperatures were evaluated in the composting piles throughout the process. Pathogens were evaluated before, during, and after composting (Andrade 2020, Teixeira 2012). The composted dry toilet waste was then inoculated with *Escherichia coli*, and applied to soil 24 hours before transplanting lettuce. Residual microbial activity was measured up to harvest (Ferreira et al. 2022). Macronutrient levels of the compost were 38 g N, 53 g P_2O_5, and 34 g K_2O per kg dry matter, analyzed for

proper application rates. Co-composting with static piles provided uniformly high temperatures and met all legislation for time and temperature required for pathogen inactivation. All helminth eggs in sewage sludge were inactivated, and thermotolerant *E. coli* were reduced 99%, from 10^5 to less than 10^3/g sludge after composting. *Enterococcus faecalis* in dry toilet waste decreased by 99% during the thermophilic phase of composting. These bacteria increased in abundance during the maturation phase, because of humid warm conditions, poor aeration and external sources of inoculum, but disappeared entirely during dry storage. Once applied to the soil for lettuce cultivation, calibrated quantities of reintroduced *E. coli* dwindled rapidly, due to fully aerobic conditions in soil, and intense microbial competition. Risk analysis indicates that from planting to harvest and consumption of lettuce, there was higher risk to farm workers during the application of the material to the soil, through inhalation or skin contact, and negligible risk of *E. coli* contamination to harvesters and consumers.

Keywords: UFSC method, co-composting, pathogen reduction

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