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Inactivation of bacterial pathogenic load in compost against vermicompost of organic solid waste aiming to achieve sanitation goals: A review

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A B S T R A C T

Waste management strategies for organic residues, such as composting and vermicomposting, have been implemented in some developed and developing countries to solve the problem of organic solid waste (OSW). Yet, these biological treatment technologies do not always result in good quality compost or vermicompost with regards to sanitation capacity owing to the presence of bacterial pathogenic substances in objectionable concentrations. The presence of pathogens in soil conditioners poses a potential health hazard and their occurrence is of particular significance in composts and/or vermicomposts produced from organic materials. Past and present researches demonstrated a high-degree of agreement that various pathogens survive after the composting of certain OSW but whether similar changes in bacterial pathogenic loads arise during vermitechnology has not been thoroughly elucidated. This review garners information regarding the status of various pathogenic bacteria which survived or diffused after the composting process compared to the status of these pathogens after the vermicomposting of OSW with the aim of achieving sanitation goals. This work is also indispensable for the specification of compost quality guidelines concerning pathogen loads which would be specific to treatment technology. It was hypothesized that vermicomposting process for OSW can be efficacious in sustaining the existence of pathogenic organisms most specifically; human pathogens under safety levels. In summary, earthworms can be regarded as a way of obliterating pathogenic bacteria from OSW in a manner equivalent to earthworm gut transit mechanism which classifies vermicomposting as a promising sanitation technique in comparison to composting processes.

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1. Introduction

In recent times, the rapid increase of organic residues has become a major problem in most developed and developing countries. It is necessary to explore effective waste disposal and/or management strategies. These enormous waste residues should be handled effectively by proficient methods in a sustainable and decentralized manner in order to alleviate adverse consequences on the environment and economy (Papargyropoulou et al., 2014; van der Werf et al., 2014; Pandey et al., 2016). The best option for the sustainable management of solid wastes is adopting the concept of resource recovery, reduction, reutilization, and recycling. Biological treatment methods such as composting (Munnoli and Bhosle, 2009; Purkayastha, 2012) and anaerobic digestion (Rounsefell et al., 2013; Quiroga et al., 2014) are implemented internationally to convert organic solid waste (OSW) such as food, yard and animal waste into useful soil amendment and biogas, respectively. Composting, among the different biological treatment methods, is perceived to be the most promising one since it is cheaper, tolerates Municipal Solid Waste (MSW) composition fluctuation and produces more stable organic fertilizers (Costa et al., 2016). Aerobic composting has recently received remarkable attention for recycling OSW (Chang and Chen, 2010; Zhou et al., 2014) because of its low-tech nature than anaerobic digestion, high organic content (Mohee and Soobhany, 2014), high nutritional capacity (Soobhany et al., 2015a) of MSW, profitable utilization of the finish product (Soobhany et al., 2015b) and less environmental damages than landfilling or incineration if properly conducted. After composting treatment of OSW, a valuable organic end product is obtained and is useful for agricultural purposes, which will benefit countries facing soil depletion (Hassen et al., 1998). The utilization of compost mitigates stresses on the environment; but it should be noted that plenty of zoonotic pathogens (fungi, virus, parasites such as helminth egg and bacteria) can be present in source-separated organic waste (Droffner et al., 1995; Petruzzelli, 1996; Strauch, 1996; Lalander et al., 2013; Hénault-Ethier et al., 2016) and can survive the composting process (Hassen et al., 2001). Alternatively, the application of raw or improperly composted organic manures on farms can induce the propagation and dispersion of pathogenic bacteria (Millner et al., 1994; Beffa et al., 1996) such as outbreak of *E. coli* (Beuchat, 2002; Jiang et al., 2002; Islam et al., 2005), *Salmonella* spp. and *Listeria monocytogenes* (Zhao et al., 1995) which delineated that a main challenge of composting is the uncertainty in bacterial pathogen inactivation. Pathogens inactivation after composting processes relates to the destruction of indicators organisms and is expected to occur if all particles of compost maintain temperatures greater than 55 °C for at least 3 days (US EPA, 1999; CCME, 2005).

In addition, Harrison (2004) observed problems regarding the quality of compost obtained from OSW in terms of sanitation although OSW compost is commonly believed to be a high quality product. In certain cases, the survivability of pathogenic organisms in a compost pile has been attributed to uneven heating temperatures (lower temperature on the surface of the piles), lack of homogenization owing to improper mixing (Gerba et al., 1995; Elving et al., 2010), cross contamination with working tools (Pereira-Neto et al., 1986; Harrison, 2004), leachate contact (Donaldson et al., 2013) and addition of feed materials or young compost to the mature compost. The regrowth and recontamination of pathogens in compost is widely reported, which are challenges of composting. Pandey et al. (2016) developed a heating system for the purpose of enhancing the temperature of compost pile for inactivating the pathogens in the compost but although *E. coli* persisted after the curing phase. The persistence of pathogenic bacteria after the curing phase is commonly termed as reactivation or regrowth. Regrowth is a problem only for certain bacterial pathogens such as *Salmonella* spp. and *E. coli* which, unlike some other bacterial species, viruses, protozoa and helminths, do not require a host organism for reproduction (Haug, 1993; Wichuk and McCartney, 2007). Storino et al. (2016) reported that composts obtained with meat waste showed the presence of *E. coli*, that exceeded the limits included in the technical purpose of European Commission (2014) for biowaste composted only in two out of twelve bins. The application of un-stabilized OSW, especially human waste, can cause health hazards such as rampant infections that have unbearable consequences (Sinha et al., 2010). Both environment concern and human health problems arise from successive accumulation of pathogenic organisms in human tissues, pathogenic bacteria uptake by vegetation and biomagnifications through the food chain. The verotoxins produced by *E. coli* can result in hemorrhagic colitis (diarrhea that becomes profuse and bloody), hemolytic uremic syndrome (bloody diarrhea followed by renal failure), and thrombocytopenic purpura (Pell, 1997). Death often occurs in patients with hemolytic uremic syndrome and thrombocytopenic purpura (Pell, 1997). The toxins produced by *Salmonella* spp. can result to clinical manifestations such as gastroenteritis, septicemia or typhoid fever (Ohl and Miller, 2001; Debbie, 2009). Strauch (1996) determined that *Salmonella*, *Shigella*, *E. coli*, *Enterobacter*, and Streptococci and the emergence of these bacteria from compost can harm compost trainers and agricultural laborers. In view with the increased interest on the public health, crop safety and environmental pollution, there is a growing demand for pathogen-free compost (Pandey et al., 2016). Additionally, pathogen-free compost can have unlimited use whereas lower quality compost may have restricted applications, for instance not in agriculture but for restoration of degraded sites or landfill capping. Actually, the subsistence of pathogenic loads in compost generated from OSW is a topic under consideration and the subject of massive debate which needs to be explored. In accordance with the last trend of environmental policies, vermicomposting, i.e. the treatment of organic wastes by earthworms acting in synergy with microbial populations, has proven to be an environmentally sustainable technology. Vermicomposting facilities have already been involved in domestic and industrial marketing in developed countries like Canada, United Kingdom, Spain, Italy, United States, Hong Kong, Australia, New Zealand, and Japan (Edwards et al., 2011). Yet, the decomposition of waste employing earthworms is growing popularity in developing nations owing to its low operational costs and high value vermicompost (Davison et al., 2006; Kumar and Shweta, 2011).

Many studies have been conducted on vermicomposting which discerned that a safe pathogen level can be achieved due to the microbial and enzymatic activity. It has been determined that vermicomposting may reduce pathogenic concentrations such as *E. coli*, *Salmonella enteriditis*, total and fecal coliforms, and helminthes ova in various categories of OSW (Monroy et al., 2009; Edwards, 2011). Nevertheless, the decline of the pathogenic indicators greatly depends on the earthworm species and/or the pathogen considered. However, one of the main issues associated to vermitechnology is the potential availability of high level human