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Review

Rapid composting techniques in Indian context and utilization of black soldier fly for enhanced decomposition of biodegradable wastes - A comprehensive review

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ABSTRACT

In the present scenario, solid waste management (SWM) has become one of the main concerns for urban waste managers in the developing world. This article reviews the recent trends and technologies associated with the process of composting. Utilization of black soldier fly (BSF) larvae can be one of the rapid methods for treatment of biodegradable wastes. A detailed review of the literature indicated that more importance is to be given on the pre-processing of Municipal Solid Waste (MSW) which includes segregation of biodegradables, inerts, metals for preparing the requisite substrate for application of the suitable technology. In developing countries, major emphasis should be given on curtailing the environmental and health impacts caused due to improper management of MSW and for developing some innovative as well as economically feasible systems for proper handling of MSW. BSF can transform the biodegradable wastes into biofuels and byproducts at a minimal cost. The utilization of BSF for treating various organic waste (OW) has been thoroughly studied and discussed in detail. The salient observations on the factors affecting the growth of BSF larvae as well as comprehensive analysis of patents on breeding and utilization of BSF are also presented in this paper. The present review also assesses the potential of various rapid composting techniques and advocates about the planning and development of real-scale treatment systems by the researchers, environmental planners and policy makers to eradicate the problem of solid wastes.

1. Introduction

The sky-scraping "ick factor" of solid waste is a major cause for the requirement of more landfill sites. The situation is getting more problematic with the rapidly rising worldwide population, which is likely to surge from 7300 million in 2015–9700 million in 2050 (UN DESA, 2015). About 33% of the food waste (FW) generated from the total food consumption resulted in the generation of 1179 million tonnes in the year 2010–11 (Gustavsson et al., 2011). The escalation in population growth from 2005 to 2050 might result in the rise of global food demand by 100% while merely 60% increase in agricultural production was estimated (Tilman et al., 2011). The total agricultural residue wastes are expected to be 92 million tonnes per year in India (Cardoen et al., 2015). In India, about 23% of rice straw (RS) is burnt in the farms which contributed about 0.05% to greenhouse gases (GHG) emissions (Gadde et al., 2009).

Many of the metropolitan cities in the developing countries have their existing SWM system; however, these systems need to be well systematized. The major portion of MSW is comprised of organic wastes (OWs) (MSWM manual, 2016). With low calorific value, i.e., about 800–1000 kcaL/kg of MSW in Indian cities, the thermal processing of MSW is not an economical and technically feasible option (Sharholy et al., 2008). Biodegradation of OWs is another option for treatment which comprises many processes, such as anaerobic digestion, composting and vermicomposting, etc. Due to the low bioconversion rate and various other environmental elements affecting the worm's activity, the process of vermicomposting is inhibited. Anaerobic digestion needs control conditions which are difficult to cultivate at large-scale, and thus, it does not gain large popularity on the commercial scale (Kumar, 2011).

Composting is a method of treating the biodegradable waste using specific microbes (Bohacz, 2018) to obtain the end product as a soil

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conditioner. Due to the significant portion of biodegradable waste present in the MSW, composting can be the most favorable method of treatment (Guidoni et al., 2018). Composting has been practiced in many municipalities because of its economic and technical feasibility (Soobhany, 2018). Composting of OW is a technique of rerouting discarded materials from dumping sites while obtaining a product at a low cost which is appropriate for the agrarian purpose. By the process of composting, the huge volume of wastes is reduced significantly.

Moreover, it destroys pathogens, reduces germination of weeds and obliterates malodorous compounds (Bernal et al., 2009). In the recent years, several changes had been observed in the composting technologies (vermicomposting, windrow composting, co-composting, in-vessel composting) to develop a cost-effective and a rapid method of composting. The positive effect of compost on physical, chemical and biological soil properties led to a rise in the usage of compost for agricultural processes. The agricultural waste has a high amount of lignocellulosic component which makes the degradation process intrinsic (Manyapu et al., 2018; Negi et al., 2018). Lignin is enormously resistant to biodegradation due to its strong linkages hampering the degradability of RS. The lignocellulosic content present in the RS affects the composting period. Lack of active lignocellulases and recalcitrant nature of lignocelluloses hinders the degradation of lignocellulosic material (Kong et al., 2018). Black soldier fly (BSF) can unravel this problem.

The present review attempts to highlight different problems causing hindrances in current practices of the composting system in the Indian context and the effect of BSF for efficient biodegradation of various OWs in the sub-tropical conditions. The main areas of emphasis include different types of composting practices adopted in Indian Scenario, i.e., co-composting of various biodegradable wastes; gaps identified in the composting process and perspectives for its effective implementation; various aspects associated with BSF; utilization of BSF in the diverse field and its effective application in the decomposition of biodegradable wastes. The summary of patents filed and granted in the US in the domain of BSF utilization is also presented in this review.

2. Current practices adopted for composting of organic wastes in Indian Scenario

The waste produced in India has high organic content, i.e., about 50% in comparison to 30% produced by developed nations (Joshi and Ahmed, 2016). Due to improper segregation of solid waste at source, a meager amount of waste is processed through the composting (Lou and Nair, 2009; MSWM Manual, 2016). Some of the practices of composting adopted across India are described in this section.

2.1. Aerobic composting

Composting is a technique in which microbes degrade organic matter (OM) of the waste into bio-fertilizer in the presence of air under specific temperature and pH. Aeration is the primary parameter affecting the rate of composting process (Raut et al., 2008). In aerobic composting, specific aerobic microbes in the presence of air degrade OM into fertilizer. Li et al., 2015a designed a factorial method in combination with controlled experimentation, which evaluated the amount of inoculum and the aeration rate which mainly contributes to the maturity of FW composting. The optimum aeration can resolve the problem of odour faced during the composting process. High concentration of methane (CH_4) and carbon dioxide (CO_2) was observed at a low aeration rate (Bernal et al., 2009). Li et al., 2008 recommended 0.25 L/min/kg volatile solids aeration rate to achieve the less odour. During aerobic composting of sewage sludge, heavy metals like lead, zinc, and cadmium were significantly reduced (Liu et al., 2007). Parkinson et al., 2004 experimented with aerobic composting of cattle manure and observed that there were 30.4% and 28.2% losses in total nitrogen and total phosphorus, respectively. Jeong and Hwang, 2005 confirmed the development of struvite crystals during aerobic composting of FW.

2.2. Windrow system

In a windrow system, a heap of waste is left for decomposition and aeration purposes; it is flipped around. The turning of waste lowers the temperature of the compost and thus provides air circulation to the system. Cekmecelioglu et al., 2005 examined an in-vessel composter treating soil to discover the relevance of windrow system. The cost of a windrow system is comparatively low as no mechanical equipment is used for the aeration purpose. The nature of material and equipment used for turning purpose decides the total height of the window. Periodic turning is essential to maintain an optimum temperature (Ogunwande et al., 2008). The occasional turning of olive mill waste can reduce OM by 40–50% (Cayuela et al., 2008). The optimized mixture (50% FW, 10% bulking agent, 40% manure) in an in-vessel composting experiment showed improvement over the results during windrow composting (Cekmecelioglu et al., 2005). In windrow composting of oil refinery sludge and green waste, the amount of CH_4 produced was found to be decreased by 65% after addition of 25% of green waste (Fountoulakis et al., 2009). In windrow composting for 75% drained olive cake and 25% poultry manure, total organic carbon (TOC) was reduced from 36.70% to 23.43% (Hachicha et al., 2006).

2.3. Aerated static pile composting

It is a system in which OM is degraded without any physical operation during primary composting. Aeration to the mixture of wastes is done using perforated pipes. It can be open, covered, windrows or even in a closed container. Aeration rate is the crucial factor in this method of composting. The intensity of aeration creates the vertical temperature difference amid the top and bottom of the pile. Luo et al., 2008 demonstrated an experiment on sewage sludge using aerated static pile composting method. With 0.6 and 0.9 L/min/kg rate of aeration, the thermophilic stage lasted for nine and four weeks, respectively (Rasapoor et al., 2009). Zhang and He, 2006 have investigated aerated static pile co-composting of pine sawdust and solid pig manure. In aerated static bin system, pH and TOC were significantly affected by an increase in moisture content above 80% (Zhu, 2006). González et al., 2016 used an aerated stagnant windrow with semi-permeable film technology to shorten the composting period to 30 days. Robledo-Mahón et al., 2018 and González et al., 2016 conducted experiments and observed the influence of semi-permeable film on the bacteriological variety.

2.4. In-vessel composting

These are the closed system of composting with controlled temperature for treating the biodegradable waste. Different systems of in-vessel composting include tunnels, containers, agitated bags, rotating drums and enclosed halls. An et al., 2012 experimented with in-vessel composting of FW with uric acid and coal ash. The results indicated a significant drop in the pH. Involuntary aeration and motorized agitation were used to improve the condition and encourage rapid composting. Mechanical agitation can break up particles, which provides better contact of the microbe with the carbon. The high temperature in the vessel can destroy pathogenic activities. Aeration can remove odour, though some systems have separate odour control system. Kalamdhad et al., 2009 used 3500 L rotating drum for processing the vegetable waste (VW) and tree leaves. During in-vessel composting of feedstock materials, change in particle density was observed from 1097 to 2325 kg/m^3 (Mohee and Mudhoo, 2005). A significant reduction from 62% to 40% in TOC was observed in the course of in-vessel composting of polluted soil and green waste (Antizar-Ladislao et al., 2008). Jain and Kalamdhad, 2018 conducted a study on the