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Research article

Waste recycling by vermicomposting: Maturity and quality assessment via dehydrogenase enzyme activity, lignin, water soluble carbon, nitrogen, phosphorous and other indicators

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ABSTRACT

Present study aims to examine the dynamics of maturation and qualification indicators in various vermicompost treatments and selection of the best treatment along with best maturation time in this regard. In this empirical study, dynamics of chemical (pH, electrical conductivity (EC), total nitrogen (TN), phosphorous, lignin, water soluble carbon (WSC), C/N, NH_4/NO_3) and biological (dehydrogenase enzyme (DEH) and DEH/WSC) properties were investigated in four various treatments, including various ratios of compost produced from municipal solid waste (MSW) and carbonaceous materials (50:50, 70:30, 85:15 and 100:0) over 100 days.

Results showed a significant fluctuation in EC, DEH and DEH/WSC proportions over the process. In addition, a noticeable increase was observed for the dynamics of TN, phosphorous and lignin. In contrast, the C/N, NH_4/NO_3 and WSC values gradually decreased during the process. Moreover, it was observed that the length of 75 days for the process is an appropriate time for maturation of all treatments. However, the first and second treatments resulted in better outcomes compared with the other types of treatments. From the point of view of quality obtained vermicompost was nitrogen enriched product in all treatments. Whereas, for the phosphorous elements this method is appropriate for the first treatment only.

1. Introduction

At present, owing to ever increasing population and anthropogenic activities, Municipal Solid Waste (MSW) generation shows a noticeable increase with varying characteristics. MSW management therefore has become an important issue, especially when it comes to safe disposal. In most cities and towns, however, there is an unscientific and nonsystematic MSW management involved in dumping of solid waste in the outskirts of cities. Landfill and incineration are the most widely used types of waste management options, which in comparison to stabilization by composting and vermicomposting, have minimum utilization. One of the most important MSW recycling technologies is their bioconversion to organic fertilizers that is referred to as composting and vermicomposting. MSW compost and vermicompost are increasingly applied in agriculture as a soil conditioner and fertilizer (Paul et al., 2011). Whereas, in contrast to vermicompost, two of the most important drawbacks of MSW compost are less macro and micronutrients and much higher levels of electrical conductivity (EC) than agricultural soils, which in its application in agriculture, can potentially cause the prevention of seed germination (Hargreaves et al., 2008; Iqbal et al., 2010). Additionally, according to the properties of MSW compost produced and valid guidelines, the produced MSW compost does not meet the appropriate conditions for the amendment of soils. MSW compost, therefore, is

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considered more as a soil conditioner than a soil fertilizer and it is even introduced as a secondary waste by some scientists (Gomez, 1998; Gray and Biddlestone, 2013; Hargreaves et al., 2008; Stonehouse, 2013). So for successful use of MSW compost as a fertilizer, all the existent problems should be solved. Vermicomposting is a thought–provoking process in this regard. Vermicomposting is able to not only enrich the final product from the aspect of both macro and micro nutrients and improve the other important parameters such as Carbon to Nitrogen (C/N), NO_4/NO_3, EC and proportion of its cellulose component decomposition, but also, augment the diversity of soil microbial communities after permanent applications (Aira et al., 2006; Alidadi et al., 2007; Alidadi et al., 2005; Doan et al., 2014; Fornes et al., 2012). On the other hand, the greater the diversity of soil microbial community structure, the more recycling of soil nutrients and other chemical and physical processes of the soil will occur. Therefore, for maintaining soil fertility and also providing an appropriate and healthy web of soil food, existence of different microbial species in soil is necessary (Wang et al., 2014). Furthermore, the produced vermicompost will be perfectly organic, important to provide soil health and therefore the product health (Lohani et al., 2011). Additionally, the degree of maturity and stability of compost and vermicompost are key parameters affecting the successful use for agricultural practices. Utilization of immature and unstable vermicompost may create an anaerobic condition for soil microorganisms. This is due to microorganisms taking advantage of available O_2 for breaking down materials and production of organic acids during the early stages of this process. Phytotoxicity may also be another drawback for using immature and unstable vermicompost. Although there are some conceptual differences amongst maturity and stability, these two terms are both frequently used in order to determine the organic matter decomposition degree over the vermicomposting process. Stability of vermicompost is defined as the microbial biomass activity level which can be determined with the rate of CO_2 production and O_2 uptake or with the released heat proportion resulting from microbial activity. Maturity of vermicompost is the level of phytotoxic organic substance degradation created over the active stage of this process (Benito et al., 2003). In describing maturity, a single criterion is not sufficient; thus, it is best evaluated with the measurement of two or more properties of vermicompost. There are some criteria and parameters for evaluating the vermicompost maturity which are based on different properties. These include physical (colour, odour, temperature, particle size and inert materials etc), chemical (C/N, Cation Exchange Capacity (CEC), pH, EC, NH_4/NO_3, Water Soluble Carbon (WSC), lignin, complex carbohydrates, humification index etc) and biological (microbial activity, enzyme activity etc) (Bernal et al., 2009). Chemical components of vermicompost feedstocks along with their decomposition stage are effective on maturity, stability and quality of vermicompost (Benitez et al., 1999; Bernal et al., 2009). So in the present study, conversions of MSW compost and agricultural wastes (carbonaceous materials), a main part of MSW into vermicompost, as an organic fertilizer have been studied. The specific objective of the present study was to investigate the effect of various materials (MSW compost and carbonaceous materials) on chemical (pH, EC, Total Nitrogen (TN), C/N, NH_4/NO_3, lignin, phosphorous and WSC) and biological (dehydrogenase enzyme activity (DEH) and DEH/WSC) properties during the vermicomposting process over 100 days and determine the quality, stabilization degree and maturation time of the produced vermicompost coupled with selection of the best treatment in this regard.

2. Materials and methods

2.1. Experimental design

Feed materials used in this empirical study were composed of two main parts. This includes the compost produced from MSW in Mashhad's compost factory, where the length of composting process has been 45 days and carbonaceous organic materials (COM) include sawdust, boxwood leaves and cardboard. Firstly, the compost used was washed to reduce its electrical conductivity (EC). Four treatments with three replicates were prepared from compost and COM with varying proportions including A) 50%:50%, B) 70%:30%, C) 85%:15% and D) 100%:0% to provide appropriate conditions. In each replicate 1 kg of dry weight and 100 g of Eisenia Fetida earthworms was used so that, the mean weight of each earthworm was 2 g and the total number of earthworms used were fifty in each treatment (Ndegwa et al., 2000). The duration of the present study was 100 days and moisture content of the treatments was maintained at ~50–80% by spraying water on the surface. The experimental bins were kept in the laboratory at room temperature and covered with a mosquito net to prevent any intrusion of pests. During this process, sampling was conducted five times. These took place on the 0th, 25th, 50th, 75th and 100th days.

2.2. Analytical methods

Upon completion of mixing, the process samples were taken and analyzed. The moisture content was determined by drying the samples in an oven at 105 °C for 24 h until constant weight was obtained. The pH of samples was determined potentiometrically in a 1/10 suspension placed on a mechanical shaker at 230 rpm for 30 min. EC was measured in a 1:10 (w/v) water extract. Measurement of total carbon content was performed via combustion in ovens at 750 °C for 2 h (Tim Haug, 1980). Total Kjeldahl Nitrogen digestion method was used for determination of total nitrogen (Theroux et al., 1936). C/N ratio of samples was calculated by dividing the weight of total carbon by the total weight of nitrogen. The proportion of $NH_4^+$and NO_3^- was measured using the KCl extraction method (Eldridge et al., 1943). Dehydrogenase activity measurement was conducted by the methods described by Tabatabai. Based on this method, 0.5 g of vermicompost sample was completely mixed with 0.1 g of $CaCO_3$. Then, 1 mL of 3% aqueous solution of 2, 3, 5-triphenyltetrazolium chloride (TTC) along with 2.5 mL of distilled water were added. After incubation at 37 °C for 24 h, 10 mL of methanol was added. The obtained suspension was filtered and the proportion of triphenyl formazan (TPF) in the filtrate was measured using a spectrophotometer at 485 nm (UV/VIS T80/T80+, England). A control without the addition of TTC was included for each sample (Page, 1982). Water Soluble Carbon (WSC) of samples was extracted with distilled water (1/5 w/v), and the extracted carbon with pyrophosphate was measured by oxidation with potassium dichromate and measurement of absorbance at 590 nm (Sims and Haby, 1971). Ascorbic acid method was used for determination of total phosphorous. Firstly, samples were digested and then read at 880 nm on a Spectrophotometer (UV/VIS T80/T80+, England) (Way, 2012). The lignin samples were dried at 50 °C for 24 h prior to weighing into glass culture tubes. The weighed sample was placed in a vacuum desiccator over P_2O_5 with the caps off for at least 18 h before analyzing. The standard procedure involved eliminating the sample from the desiccator, adding 2.5 ml of fresh prepared acetyl bromide reagent, capping immediately, and heating at 70 °C. Then 100 μL of perchloric acid was added to samples. Heating time duration was 30 min. After heating, the samples were quantitatively transferred with the aid of acetic acid to 50 mL volumetric flasks that contained 10 mL of 2 M NaOH and