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Development of a bioprocess for fast production of enriched biocompost from municipal solid wastes

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ABSTRACT

The objective of the present study was to develop a bioprocess for fast production of enriched biocompost from municipal solid wastes using a native microbial cocktail and cheap lignocellulosic biomass i.e. wood chips. The open-windrow composting experiments included (1) only municipal solid waste (C), (2) municipal solid waste + wood chips at 3:1 ratio (CW), and (3) municipal solid waste + wood chips + a microbial cocktail (10^8 cells/kg), containing 11 native mesophilic and thermophilic bacterial strains (CWM).The microbial cocktail led to the fastest rise in the starting temperature (up to 73 °C after two weeks) and maximum carbon/nitrogen ratio decrease (40%) and organic matter reduction in the CWM compost. The CWM compost contained the minimum concentrations of the heavy and trace elements (i.e. zinc, copper, manganese, lead, nickel, chromium and cadmium) as well as *Salmonella* sp. and *E. coli* populations, whereas the control (C) contained the maximum contents of the heavy metals and human pathogens. . The maximum and minimum germination of the garden cress seeds were observed for the CWM (97.5%) and the control (73.3%) composts, respectively. Moreover, in comparison with the control, 60–70% increase was achieved in growth parameters i.e. wheat dry weight, wet weight, stem height and root long when 10% CWM compost was used.

1. Introduction

Among various municipal solid waste management systems, composting appears to be a safe form of treating wastes and the reclamation of the nutrients contained in them (Sulaiman et al., 2014). Composting is known as an environmentally friendly method of aerobic biological decomposition of organic matter. It is an effective biochemical process for resource recovery and to treat and transform the organic fraction of municipal solid waste (MSW) into a value-added product. Compost can be used in agriculture to meet crop nitrogen requirements; and to increase soil stabilized organic matter (Gu et al., 2011; Mingyan et al., 2013). Moreover, converting MSW into compost would also lead to controlling pathogens (during the thermophilic phase), decreasing germination of weeds and prevention of malodorous compounds production (Hargreaves et al., 2008). It has been confirmed that repeated application of MSW compost increases soil organic matter content and soil carbon/nitrogen ratio (C/N) to levels more than those of unamended soils (Montemurro et al., 2006).

Despite of all these advantages, there are still some problems, such as long composting time, odorous gas emissions and low quality and efficiency, associated with the conventional composting process of MSW which could jeopardize the economic viability of the process (Mingyan et al., 2013). Maturity of compost is very important, and has to be achieved prior to use in farms to avoid harmful effects on crops (Kato et al., 2005). The stability of compost is an index showing the degree of stability of organic fraction during the decomposition process. Unstable compost has a high potential for odor generation and pathogen regrowth (Shammas and Wang, 2009).

The quality of MSW compost is highly dependent on many factors, including the composting facility design, feedstock source and proportions used, composting procedure, and length of

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List of abbreviations:

CFU	colony forming unit
MSW	municipal solid waste
C	control
C/N	carbon/nitrogen ratio
CW	treatment containing municipal solid waste and wood chips
CWM	treatment containing municipal solid waste, wood chips and microbial cocktail
GI	germination index
NB	nutrient broth medium
TSA	tryptic soy agar
W/W	weight/weight
V/V	volume/volume
VVM	volume per volume per minute

maturation (Soumare et al., 2003; Shabani et al., 2011). Strategies to overcome the above mentioned challenges include developing new facilities, optimizing the composition of MSW and the other parameters affecting the process and finally addition of microbial bioactivators.

Generally, the overall efficiency of organic material breakdown depends on microbes and their activities. The enzymes released by the microorganisms during composting breakdown several organic compounds characterized by a complex structure, finally leading to the solubilization of simple water soluble compounds (Benitez et al., 1999; Raut et al., 2008). During the composting process, the microbial community is continuously changing. In the mesophilic phase, total counts and enzymatic activities are at the maximum, then they decrease during the thermophilic phase, and increase again when the temperature declines (Ryckeboer et al., 2003). As microorganisms play an important role during decomposition of municipal waste, one of the possible ways of increasing the nutrient content of the final compost product is microbial enrichment. This can be achieved either by introducing beneficial microorganisms by directed inoculation or by increasing the microbial activity through the application of amendments (Rao and Tak, 2001). Enrichment of MSW by specific microbiota during different stages of composting could boost the decomposition potential in order to obtain good quality composts in shorter time spans (Taiwo and Oso, 2004; Ghaffari et al., 2011). On such basis, different microbial inoculants have been used to reduce the process time and enhance compost quality (Thompson et al., 2002; Xi et al., 2002; Xiao et al., 2009; Parveen, 2010; Ghaffari et al., 2011; Mingyan et al., 2013). We previously isolated and characterized many mesophilic and thermophilic bacterial strains possessing a wide range of cellulase, xylanase, amylase, protease and lipase activities from composting process in Iran (Pourmazaheri et al., 2013). As the selected strains showed high hydrolase activities, and also were naturally coexistent in MSWs, hence, they could have high potential to enhance degradation of MSW (commonly, containing cellulosic, starchy, protein and oily compounds) during the composting process (Pourmazaheri et al., 2013). In the present study, addition of these native microbial strains to the composting process was investigated for accelerating composting in conjunction with wood chips in an open-system composting plant.

2. Materials and methods

2.1. Strains and culture conditions

Eleven native thermophilic and mesophilic bacterial strains, including *Thermoactinomyces intermedius*, *Geobacillus thermodenitrificans*, *Geobacillus* sp., *Bacillus licheniformis*, *Brevibacillus parabrevis*, *Brevibacillus formosus*, *Brevibacillus agri*, *Bordetella petrii*, *Aneurinibacillus migulanus*, and *Pseudoxanthomonas* sp. were used in this study (Pourmazaheri et al., 2013). These bacteria were previously isolated from composting process in Isfahan Compost manufacture, and showed a wide range of cellulase, xylanase, amylase, protease and lipase activities (Pourmazaheri et al., 2013). The bacterial strains were routinely maintained on Nutrient Broth (NB), Nutrient Agar (NA), or Tryptic Soy Broth (TSB), Tryptic Soy Agar (TSA), and stored in glycerol (10% volume/volume (v/v)) at −80 °C.

2.2. Temperature and pH optimization

Two hundred ml of sterile NB or TSB media in three replicates were inoculated with 3% (v/v) of the strains biomass to obtain the pre-culture media. Five temperature values, including 25, 30, 35, 37 and 40 °C were considered for mesophilic bacteria. The temperature values used to find the optimum growth condition of the thermophilic bacteria included 50, 55, 60, 65, and 70 °C. The pH was adjusted in the range of 5–8 with 0.1 intervals using 1 M HCl and 1 M NaOH. Bacterial growth was evaluated on a shaker at 150 rpm after 24 h incubation using serial dilution and CFU counting.

2.3. . Fermentation conditions

To use all the 11 selected bacterial strains in the composting process as a microbial cocktail, all the strains were separately produced in a 10 L batch fermentor (BIOFLO 2000, New Brunswick Scientific, USA) containing 8 L of the selected culture medium. For each strain, fermentation was performed under optimum growth temperature and pH (Table 1), using 3% primary inoculation and 70% oxygen saturation. For adjusting oxygen concentration, an automatic control was used through setting the mixer speed in the range of 300–1200 rpm and aeration rate at 1 VVM. Growth kinetics in the fermentor were investigated with continuous and online measurements of the medium turbidity at 660 nm by a turbidity meter equipped with a fiber optic sensor (Turbidity transmitter, Trb 8300, Mettler–Toledo), and CFU number was also measured for each strain. To prepare the final microbial cocktail containing all the 11 bacterial strains, the concentration of each strain was adjusted at the CFU of 10^7 cells/ml after harvesting. The final strain cocktail was obtained by adding together aliquots of equal volumes of the individual strain preparations.

2.4. MSW preparation and composting experimental setup

MSW was collected from different municipality regions of Isfahan city, and transferred to the Isfahan municipality compost plant (Isfahan, Iran). After initial mechanical and manual sorting and separation of the inorganic fraction, the organic waste materials were air dried (organic matter: 59%, C/N: 20, pH: 5.8, EC: 6 ds/m). Composting experiments were designed and performed in an open windrow system (each windrow: height: 1.2 m, width: 2.5 m and length: 15 m). The composting experiments were performed using three raw materials/mixtures, including: 1) MSW (Treatment C); 2) MSW + wood chips at 3:1 (w:w) ratio (Treatment CW); and 3) MSW + wood chips + microbial cocktail preparation (10^8 cells/kg MSW) (Treatment CWM) in three replicates. The final weight of the raw materials in each windrow was about 5 tons. The raw materials in each windrow were sprinkled with water to adjust moisture content to about 60%, which was kept constant by watering during the process. Aeration was performed every three days using a turner system till the end of the 28 d experiment (Fig. 1).