Bioresource Technology 227 (2017) 171–178

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Co-composting of vegetable wastes and carton: Effect of carton composition and parameter variations

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HIGHLIGHTS

- Temperature data followed typical composting temperature variation trends.
- Carton and paper containing high lignocellulosic content slowed the composting rate.
- All composting mixes yielded phytotoxic-free composts.
- Key process parameters were within the relevant compost standards.

ARTICLE INFO

Article history:
Received 18 October 2016
Received in revised form 2 December 2016
Accepted 4 December 2016
Available online 10 December 2016

Keywords:
Reactor composting
Vegetable wastes
Carton
Temperature

ABSTRACT

The aim of the study was to investigate the effects of carton in the composting process of mixed vegetable wastes using an experimental composter of capacity 80 L. Three different mixes were set-up (Mixes 1, 2 and 3) which consisted of vegetable wastes, 2.0 kg paper and bulking agents, vegetable wastes, 1.5 kg carton and bulking agents, vegetable wastes, 4.5 kg carton and bulking agents, respectively. Temperature evolution, pH trends, moisture levels, respiration rates, percentage volatile solids and electrical conductivity were monitored for a period of 50 days. The system remained under thermophilic conditions for a very short period due to the small size of the reactor. The three mixes did not exceed a temperature of 55 °C, where sanitization takes place by the destruction of pathogens. The highest peak of CO_2 evolution was observed in Mix 2 indicating that maximum microbial degradation took place in that mix.

1. Introduction

Composting is an environmental-friendly process involving the destruction of pathogens and the recycling of nutrients (Karnchanawong and Suriyanon, 2011; González et al., 2015) to give a final stable product commonly used as soil amendment. The composting process kinetics is highly dependent on the basic physical properties of the substrates used as well as other factors, such as temperature, pH, moisture content, C:N ratio, bulk density, respiration rate and the volatile solids. Bulking agents play a crucial role in the process and have a bearing on the biodegradation kinetics. A very important factor to be considered prior to starting the composting process is the nature of the substrate itself. The substrate used is the only food source provided to the microorganisms and carbon dioxide is released from the degradation of carbohydrates.

Carton is heavy-duty paper of numerous variable strengths and ranges from a simple compilation of single-sheet thick of paper to more complex and compact structures comprising multiple corrugated or uncorrugated layers. Printing papers and carton originate from wood pulp fibers and consisting primarily of cellulose, hemicellulose, lignin (Wang et al., 2015) and also ash (Zhou et al., 2013). Cellulose is a biopolymer which guarantees high porosity in a material due to its properties as a natural fiber (Asdrubali et al., 2016). Cellulose-based cartons are widely used for packaging purposes and discarded afterwards. Lela et al. (2015) reported that paper and carton make up 40–45% of municipal solid waste by mass and this represents a high proportion being discarded otherwise than in a sustainable manner. Composting is an appropriate cost-effective technique which is very commonly applied to significantly reduce the amounts of paper sent otherwise to landfills. However, it appears that scanty work has been reported on the composting dynamics of carton in the presence of other more readily biodegradable substrates. The novelty of this work resides in that it has addressed the co-composting of carton with a complex

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http://dx.doi.org/10.1016/j.biortech.2016.12.019
0960-8524/© 2016 Published by Elsevier Ltd.

mixture of yard wastes, bagasse, waste office paper, chicken manure, beetroot tops and cabbage leaves in a new design of a vertical in-vessel batch bioreactor. The substrates selected in the study for batch composting experiments were vegetable wastes, paper, carton with bagasse, poultry manure and dry leaves as bulking agents. The aim of the study was to investigate, analyze and evaluate the effects of addition of carton on the overall macroscopic composting dynamics of vegetable wastes. The objectives entailed the design of an experimental composting vessel, regular monitoring of temperature, pH, moisture content, volatile solids, respiration rate and electrical conductivity.

2. Materials and methods

2.1. Selection and preparation of substrates

In this study, the selected substrates were vegetable wastes, yard wastes, bagasse, waste paper and carton and chicken manure. The vegetable wastes consisted of beetroot tops and cabbage leaves. Samples of all the selected substrates were pre-examined to determine their respective individual moisture content. Vegetable wastes were collected from a local market and were manually sorted and shredded prior to characterization. Carton, collected from local supermarkets, are mostly used as packaging materials and generally discarded in large amounts and waste printed office paper was obtained from the administrative sections. These were cut to an average size of 3 by 3 cm and 3 samples of 100 g were taken to measure the moisture content. Yard waste was collected from the surroundings premises of the University of Mauritius, bagasse was obtained from the Sugar Tech lab of the University of Mauritius and chicken manure was collected from the University of Mauritius farm.

2.2. Experimental design of compost reactor

Six 80-L high density polyethylene bins were designed to be used as the vertical cylindrical composters (Fig. 1). The vessels were 60 cm high, had an internal diameter of 52 cm at the top and 40 cm at the base. According to Adhikari et al. (2013), the side of the reactor was perforated since it gives optimum conductive aeration. The top lid of the composter was perforated with three holes of diameter 10 mm, located within a radius of 100 mm from the centre of the lid and 60° apart, to fit the size of the temperature probe. The holes were labelled as P1, P2 and P3 and temperature readings were taken at these three positions. Four perforations of diameter 6.5 mm were made at the base of the vessel to allow for the evacuation of leachate formed during the decomposition of easily degradable organic substrates as mentioned by Yang et al. (2013). A 50 mm diameter and 1 m long perforated PVC pipe was vertically passed through the vessel to allow for passive airflow in the system. The perforations on the pipe were estimated based on the study carried out by Karnchanawong and Suriyanon (2011). Two rectangular bars of concrete were placed beneath each composter and a 200 mm diameter aluminium tray was placed for the collection of leachate.

2.3. Experimental composting procedure

Three different mixes were set-up for the composting experiments and they were conducted in duplicate set-ups. The first mix (Mix 1) consisted of finely shredded vegetable wastes, dry leaves, bagasse, chicken manure and paper. The second (Mix 2) and the third (Mix 3) mixes consisted of carton instead of paper, and they differed in quantity. Table 1 presents the amount of each substrate used in each mix. All substrates of Mix 1 were spread on the floor and 3.5 ± 0.2 kg of water was sprayed to adjust the moisture content. After a homogeneous mixing of the substrates, each of the two composters was filled with 20 ± 2 kg of the mixture. The same technique was used for the second and the third mixes. The compost mixtures were turned and mixed once on a two-week basis to ensure adequate aeration in the system and break any lumps formed. The six composting vessels were monitored for a period of 50 days.

2.4. Analytical procedures

All the parameters were monitored and tests were conducted in accordance to the TMECC 2001 (Test Method for the Examination of Composting and Compost). The temperature was measured on a daily basis with a temperature probe (Reotemp Compost Thermometer-FR tip) of 0.6 m. Temperature readings were taken at three different positions namely P1, P2 and P3 and at each position, the temperature was noted at three different heights; at H = 15 cm, H = 30 cm and H = 50 cm, respectively. The moisture content and volatile solids of each pile were tested twice a week. Samples were taken from the bottom, surface and centre of the pile and mixed thoroughly by composite sampling. The samples were then divided in three; each of 100 g and oven-dried (Forced convection oven-Lab Companion) at 105 °C for the moisture content experiment, while for the determination of volatile solids; the samples were heated in a muffle furnace (Carbolite Furnace) at 550 °C.

20 g of fresh compost sample was mixed with 200 ml of 0.011 mol/L calcium chloride and stirred for 60 min. The pH was recorded using a calibrated pH meter. 200 ml of distilled water was poured into a beaker and 20.0 g of compost sample was added. The mixture was thoroughly stirred for 2 h. The mixture was then filtered and analysed using a properly checked and calibrated electrical conductivity meter (Mettler Toledo Seven Compact, Inc. Lab 731 ISM). The evolution of carbon dioxide was monitored through the Jar test. Similar methods were adopted by Francou et al. (2008). 25 g of fresh compost sample was deposited in a jar and 25 ml of 1.0 mol/L NaOH was pipetted into a small beaker which was then carefully placed in the jar. After 24 h of incubation, the NaOH was titrated with 1.0 mol/L HCl. All the experiments were performed in triplicates.

For the water holding capacity test, a cylinder with a closed-meshed plastic bottom was used for the experiment. Fresh sample, screened through the 9.4 in. sieve tray, was filled into the cylinder and the mass was noted. The cylinders were placed into a large container and water was poured such that the material absorb the water from the bottom and water penetrates through the sample and rise to the top by capillary action. The set-up was left to stand for 24 h. The cylinders were taken out and placed on a water-saturated base essentially composed of cellulose base and covered with a watch glass and were allowed to drain for two hours after which the masses of each cylinder were measured. Pak-choi seeds (*Brassica rapa* var. *chinensis*) were used in the germination index experiment to assess the phytotoxicity of the compost (Yang et al., 2013). Using a basis of 100 g of dry compost, the exact amount of compost sample to be used for each mix was calculated and the amount of water to be added was determined accordingly. The calculated amount of sample was weighted into a beaker followed by water and the mixture was well stirred. The mixture was allowed to settle for a time period of 20 min after which it was filtered. A dilution factor of 10 was used by mixing 10 ml of the extract with 90 ml of distilled water. 5.0 cm of filter paper was placed in 5.5 cm of petri dishes. For each mix, 5 dishes were labelled as "control", another five "10 × dilution" (i.e. dilution made for a dilution factor of 10) and the remaining five as "full strength". 1 ml of the appropriate test solution was added to the corresponding labelled petri dishes and eight seeds were evenly