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Degradation of morphine in opium poppy processing waste composting

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HIGHLIGHTS

- Opium poppy processing waste has good biodegradable characteristics for composting.
- The residual morphine was completely removed after day 30 of composting.
- The compost was 55.3% of OM, 3.3% of total nutrients and 7.6 of pH.
- A turning frequency of every 10 days for composting of the waste is recommended.

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ABSTRACT

To investigate morphine degradation and optimize turning frequency in opium poppy processing waste composting, a pilot scale windrow composting trial was run for 55 days. Four treatments were designed as without turning (A1), every 5 days turning (A2), every 10 days turning (A3) and every 15 days turning (A4). During composting, a range of physicochemical parameters including the residual morphine degradation, temperature, pH, and the contents of total C, total N, total P and total K were investigated. For all treatments, the residual morphine content decreased below the detection limit and reached the safety standards after day 30 of composting, the longest duration of high temperature ($\geqslant$50 °C) was observed in A3, pH increased 16.9–17.54%, total carbon content decreased 15.5–22.5%, C/N ratio reduced from 46 to 26, and the content of total phosphorus and total potassium increased slightly. The final compost obtained by a mixture of all four piles was up to 55.3% of organic matter, 3.3% of total nutrient (N, P_2O_5 and K_2O) and 7.6 of pH. A turning frequency of every ten days for a windrow composting of opium poppy processing waste is recommended to produce homogenous compost.

1. Introduction

Opium poppy (*Papaver somniferum*) is a medicinally important plant, because it is the only commercial source for producing several benzylisoquinoline alkaloids (BIAs) with pharmaceutical importance, including the pain reliever morphine, the cough suppressant codeine and the antitumor agent noscapine (Frick et al., 2007; Wijekoon and Facchini, 2012). Morphine is the predominant alkaloid found in the varieties of opium poppy plants cultivated in most producing countries (Bural et al., 2010), usually accounting for 45–90% of alkaloid content (Stranska et al., 2013). According to International Narcotics Control Board (INCB) reports, the manufacture of morphine has followed a rising trend over the past two decades, standing at 416 tons in the year 2010, in which the United Kingdom, the United States, France, Australia and Iran were the leading manufacturers of natural alkaloids, accounting for 74% of global manufacture. Four other countries reported the manufacture of morphine in quantities of more than 10 tons: China (18.5 tons), Japan (12.5 tons), Slovakia (11.5 tons) and Hungary (10.5 tons) (INCB, 2011). In most countries including China, the pharmaceutical alkaloids are extracted mainly from the crushed dried capsules emptied of seeds (Mahdavi-Damghani et al., 2010). A large quantity of solid opium poppy processing waste is consequentially generated yearly as a by-product from raw materials. The waste is a valuable resource for organic fertilizer because it has a high content of organic matter and it is free of any impurities. Moreover, the waste still remains a certain amount of morphine, which can cause serious hygiene hazards, odour pollution, or even potentially drug-related crimes, if it is directly applied to agricultural land as fertilizer or indiscriminately discarded as an industrial waste (Suthar and Singh, 2012).

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Composting has been identified as an effective and economical method for the treatment of solid organic waste prior to land application. During the composting process, microorganisms transform the highly heterogeneous solid state organic matter to a usable, and value added compost product with beneficial physical, chemical and biological characteristics for application to soil systems (Ogunwande et al., 2008; Ramaswamy et al., 2010; Guo et al., 2012). Also, composting process destroys most parasites (pathogens and viruses contained in the waste) and considerably reduces odour emissions by reducing the levels of biodegradable hydrocarbons (Barrington et al., 2002). The windrow/pile composting is the most common method of composting of organic waste in most countries (Sykes et al., 2007). The windrows are turned regularly to allow air to blend into the waste, improving oxygen content, microbiological activity, removing excessive heat, water vapour and compost odours trapped and commonly believed to be a factor that affects the rate of decomposition as well as compost quality (Getahun et al., 2012). Turning frequency significantly affects temperature, moisture content, dry matter, pH, total carbon, total nitrogen, C/N ratio of composting piles (Tiquia et al., 1997; Wong et al., 2001; Ogunwande et al., 2008; Getahun et al., 2012). However, the high turning frequency will adversely increase the composting cost, and will be postponed the release of ammonia that has accumulated in the internal void space of compost (Parkinson et al., 2004).

The opium poppy processing waste possess high pectins, cellulose and hemicelluloses, and moisture leading to a reduced porosity and compact texture, thereby puts severe constraints on its biological degradation for composting. Current literature concerning the degradation of morphine in opium poppy processing waste composting is very limited because the cultivation of opium poppy and production of opium is strictly controlled to prevent making of illegal and highly addictive drugs such as heroin and illegal flavouring use. Thus, a pilot scale pile composting trial was performed to investigate morphine degradation and optimize turning frequency during composting of opium poppy processing waste.

2. Methods

2.1. Description of the study area

Composting experiment was carried out for 55 days between March and June, 2010 at the official opium poppy processing factory located at an elevation of approximately 1750 m above sea level and is 250 km northwest of Lanzhou, the provincial capital of Gansu, China. Its geographical coordinates are approximately 37°40′N latitude and 102°51′E longitude.

During this study, the maximum and the minimum temperature of the area were observed to be 7 °C and 22 °C, respectively while the maximum and the minimum precipitation were 6.1 mm and 8.4 mm, respectively.

2.2. Experimental set-up

The opium poppy processing waste was generated after extraction of the medicinal alkaloids. Composting methods adopted in this experiment was the windrow/pile composting. Each pile was a typical trapezoid shape, being approximately 1.2 m high; 2.5 m across at the base and 10 m long, so as to keep high temperature level within the pile and also allow oxygen flow into the core of the pile. Each windrow was covered with black shading net with 95% shade rate on the top for retaining moisture and protecting it from heavy rains. The initial properties of the opium poppy processing waste are summarized in Table 1.

Four turning frequencies were applied: Pile A1 without turning, pile A2, A3 and A4 were turned every 5 days, every 10 days and every 15 days, respectively. The total dry weight of each pile was approximately 2500 kg. The piles were turned using a truck with front-end loader until the end of the composting period. The initial moisture content of each windrow was adjusted to 60% (w/v) at the beginning of composting by sprinkling water. No further moisture adjustment was done thereafter. During the composting process, the ambient temperature and the temperature within each windrow at a depth of 60 cm under the pile surface in the front, central and hind part of the pile were measured daily.

2.3. Sample collection and analytical methods

A representative composite sample of approximately 6 kg was collected from five subsamples after mixing homogenizing and partitioning by quartering. Triplicate composite samples were obtained from each pile at the beginning and then 10 days until the end of the composting. The samples were air-dried, ground to pass through 0.5 mm-sieve, mixed thoroughly to make them homogeneous and then stored in polythene re-sealable bags in a refrigerator for analysis.

Morphine was determined by HPLC (1100 series HPLC system, Agilent Technologies, USA) and separated at 25 °C using an SUPELCOSIL LC-Si column (250 mm × 4.6 mm i.d., 5 mm). HPLC conditions were as follows: mobile phase, acetonitrile (0.01 mol/L) – KH_2PO_4 (0.005 mol/L) – $C_7H_{15}NaO_3S$ (20:40:40), flow rate, 1.0 mL/min, the detection wavelength was 220 nm. The sample was extracted by 20% methanol containing 5% acetic acid with ultrasonic for 30 min. The injection volume was 10 μL (Pharmacopoeia Commission of PRC, 2010). Moisture content was obtained by drying at 105 °C for 24 h in a hot-air oven, pH was determined using double distilled water suspension of each compost in a ratio of 1:5 (w/v) using pH meter (Sartorius, PB-10 Standard a meter) (Nishanth and Biswas, 2008). Total carbon (C) and total nitrogen (N) were analyzed with the Dumas combustion method (Flash EA-1112, Thermo Scientific, Waltham, Massachusetts, USA) (Bao, 2000). After H_2SO_4–H_2O_2 digest, the contents of total N, total P, total K of compost were determined by spectrophotometry, and flame photometry respectively (Tiquia et al., 1997).

2.4. Statistical analysis

The results reported are the means of three replicates. Basic statistical analyses were carried out using SPSS for Windows. Analysis of variances (ANOVA) was analyzed and Duncan test was used for determining any significant differences among the parameters analyzed with time. The significant level was set at $P < 0.05$.

Table 1
The initial properties of opium poppy processing waste.[a]

Total C (g/kg)	Total N (g/kg)	Total P (g/kg)	Total K (g/kg)	Morphine content (mg/kg)	C/N ratio	pH
369 ± 2	8.04 ± 0.03	4.60 ± 0.42	9.42 ± 0.12	1132 ± 31	46 ± 2.24	6.44 ± 0.02

Mean and standard error are shown (n = 3).
[a] Measured based on dry matter.

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