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The effect of composting on the degradation of a veterinary pharmaceutical

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ABSTRACT

Composting has been identified as a viable means of reducing the environmental impact of antibiotics in manure. The focus of the present study is the potential use of composting on the degradation of salinomycin in manure prior to its field application. Manure contaminated with salinomycin was collected from a poultry farm and adjusted to a C:N ratio of 25:1 with hay material. The manure was composted in three identical 120 L plastic containers, 0.95 m height × 0.40 m in diameter. The degradation potential for salinomycin was also ascertained under open heap conditions for comparison (control). Salinomycin was quantified on HPLC with a Charged Aerosol Detector, at an interval of every 3 days. The salinomycin level in the compost treatment decreased from 22 mg kg^{-1} to 2×10^{-5} μg kg^{-1} over 38 days. The corresponding decrease in the control was from 27.5 mg kg^{-1} to 24 μg kg^{-1}. The changes in pH, EC (dS m^{-1}), temperature, total kjeldahl nitrogen (TKN), total potassium (TK), total phosphorus (TP) and carbon content in both the composting and the control samples were monitored and found to be different in compost as compared to the control. During the composting process, the loss of TKN was 36%, which was substantially lower than corresponding loss of 60% in the control. The loss of carbon was 10% during composting, whereas the loss in the control was 2%. In composting, the temperature modulated from 27 °C (initially) to a high of 62.8 °C (after 4 days), and then declined to 27.8 °C at the end of 38 days. On the basis of the results obtained in this study, it appears that the composting technique is effective in reducing salinomycin in manure.

1. Introduction

The use of antibiotics in the veterinarian sector can be divided in two main categories: therapeutic and prophylactic or as growth promoters. It is estimated that in the United States alone more than 12.0 thousand tonnes of antibiotics were sold for animal use in 2006, 4.6% of which was used for growth promotion (Animal Health Institute, 2007). Approximately 75% of the antibiotics administered to animals are not absorbed and are excreted (Chee-Sanford et al., 2009). Although antibiotic concentrations in manures can range from trace levels to >200 mg kg^{-1} or mg L^{-1}, typical concentrations are in the 1–10 mg kg^{-1} or mg L^{-1} range (Kumar et al., 2005; Dolliver et al., 2008). It is estimated that the total manure produced from cattle, swine, and poultry operations in the USA is more than 130 million tonnes annually (Dolliver and Gupta, 2008). Canadian livestock have been documented as producing an estimated 177.5 million tonnes of manure annually (Hofmann and Beaulieu, 2006).

In the United States, land application is the most common method for manure disposal following its storage in lagoons or pits (Chee-Sanford et al., 2009). As a result of this disposal method, soil and water contamination may occur. Antimicrobials used in the livestock industry have been detected in surface water in Canada (Forrest et al., 2006; Lissemore et al., 2006), the USA (Kolpin et al., 2002; Watkinson et al., 2009), Europe (Hirsch et al., 1999; Christian et al., 2003), and Asia (Managaki et al., 2007). A recent survey of treated drinking water across the United States indicated that antibiotics were present in over half of the water supplies (AP, 2008). There is growing evidence of antibiotics reaching surface and ground water from Concentrated Animal Farming Operations (CAFOs) and from manure applied on agricultural soils (Kemper et al., 2007; Watanabe et al., 2008; Davis et al., 2006; Thiele-Bruhn, 2003). Moreover, the possibility of direct leaching/runoff from manure stockpiles has also been reported with very high concentrations of 210, 3175, and 2544 μg L^{-1}, for chlortetracycline, monensin, and tylosin, respectively (Dolliver et al., 2008).

Ionophores are the single, most widely-used group of antibiotics for veterinary purposes. According to a survey in 2001, 3520 metric tonnes of ionophoric compounds were administered to animals in the United States (AHI, 2003). Salinomycin, an ionophoric pharmaceutical, is commonly used as a feed additive (50–70 mg kg^{-1}) for fattening and for the prevention of coccidiosis caused by *Eimeria tenella*, *E. necatrix*, *E. acervulina*, *E. maxima*, *E. brunetti*, and *E. mivati* in poultry (EFSA, 2004). Although its use in Canada and United States is not all that well documented, data

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from other countries indicates its widespread usage (Hansen et al., 2009). A number of the relevant characteristics of salinomycin are provided in Table 1.

Due to hydrophobic inclination, salinomycin is likely to persist in environmental solid phases. In one study, the concentration of salinomycin was found to be approximately 500 times higher in sediment than in the water column (Kim and Carlson, 2006). The presence of these compounds in manure is also reported (Schlusener et al., 2006); a concentration of 11 $\mu g\, kg^{-1}$ of salinomycin was found in manure samples.

It has been reported that for manures kept in lagoons, the concentrations of some antibiotics can be stable for up to 150 days (Kuchta and Cessna, 2009). Moreover, relatively constant levels of antibiotics have been reported in soils for 5–9 months following the application of manure (Aga et al., 2005; Schlusener et al., 2003). Although these concentrations may be low, the effects of long-term exposure to such low concentrations of antibiotics are not yet clear. The potential danger to human and animal health cannot be ignored. Antibiotics could increase the threat of pesticide pollution; they can affect soil microorganisms and disrupt the degradation of pesticide residues.

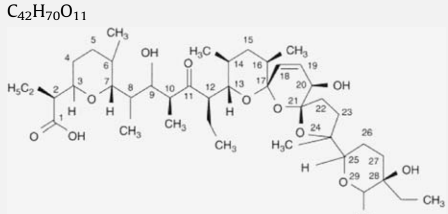
Instead of developing technologies to enhance the degradation of antibiotics in soil and to prevent them from contaminating surface and ground water, a more effective and practical solution might be found to reduce environmental contamination from veterinary antibiotics. It might be more effective to eliminate the antibiotics in the manure before it is applied to agricultural land as fertilizer (Wang et al., 2006). On-farm manure management strategies, such as composting, may provide a practical and economical option. The present study aims to evaluate the reduction of the amount of salinomycin remaining in manure after composting.

2. Methods

2.1. Chemicals and standards

Salinomycin (98% pure) was obtained from Sigma Aldrich Company. The characteristics of salinomycin are presented in Table 1.

Table 1
Physicochemical properties and characterization of salinomycin.

Compound/group	Salinomycin/ionophore
Use	Anticoccidial drug
CAS number	53003-10-4
Commercial/trade name in Canada/US	
Mw ($g\, mol^{-1}$)	751
Formula	$C_{42}H_{70}O_{11}$
Structure[a]	
Solubility in water[d] ($mg\, L^{-1}$)	17–905
pK_a	4.5–6.4
Stability	Unstable in acidic condition, stable in alkaline condition
Melting point (°C)	140–142
Log K_{ow}[c]	5.15
Soil DT^{50}	5[b]–16[c] days

[a] Kim and Carlson (2006).
[b] Schlusener and Bester (2006).
[c] EFSA (2004).
[d] Hansen et al. (2009).

The stock solution of salinomycin was prepared by dissolving 10 mg in 10 mL of methanol (MeOH). The standard solution was stored at 4 °C in a vial and it was freshly prepared every 2 months. Working standard solutions were prepared by diluting the stock solution with methanol. These standards were used for fortification in recovery experiments and for preparation of the calibration curves.

2.2. Cleaning and pretreatment of laboratory glassware

To avoid contamination, all glassware were prewashed with acetone, baked at 250 °C for at least 10 h, cooled, then rinsed with a saturated methanolic solution of Na_2EDTA, and finally air dried.

2.3. Equipment

The tests were conducted under laboratory conditions using three identical 120 L cylindrical plastic containers, 0.95 m height × 0.4 m in diameter. Each container was insulated with 100 mm of mineral wool with an RSI value of 2.5. For aeration purposes, an air plenum, 100 mm in height, was created at the bottom of each container using a supporting material wire mesh. The wall of the vessel at the level of plenum had one perforation for aeration purposes.

2.4. Experimental materials

The poultry manure was collected from a commercial poultry farm in Saint Sophie, Quebec. The manure was analyzed for moisture, carbon and nitrogen content from which a C:N ratio was calculated (Table 2). Water was added to the manure to produce a moisture content in the range of 50–60 $g\, kg^{-1}$. The initial C:N ratio was adjusted to 25 by adding hay, cut in 2.5 cm long pieces. The poultry manure and hay were thoroughly mixed manually in a plastic tray; three composting bins were filled with 10 kg mixture in each, and then compacted. Three open containers were filled with 10 kg of poultry manure without adding hay. The experiment was conducted at the mean ambient temperature of 20–25 °C in an open laboratory. The composting bins and open mounds were routinely monitored for temperature. For aeration, the composting mixes were turned and mixed with an iron rod 4 days after the initiation of the experiment. The moisture content was monitored at weekly intervals, and water was added to maintain moisture content at a predetermined level. The pH, EC, C, total N, P and K were measured at 6, 12 and 38 days. Three samples were taken from each bin/container, mixed thoroughly, and a composite sample was collected in a plastic bag. Samples were collected at three-day intervals. The samples were immediately brought to the laboratory and analyzed for their antibiotic content. The samples were then stored at 4 °C to determine other parameters (C, N, EC, pH, total P and K). All analyses were completed within one week of sampling.

Table 2
Characteristics of the experimental material.

Material	Characteristics				
	DM (%)	TN ($g\, kg^{-1}$)	pH	Ash (%)	C (%)
Hay	84.0 (0.28)	13.15 (1.3)	6.3 (0.08)	11.48 (1.92)	48.4 (1.05)
Manure	49.63 (0.11)	26.36 (1.1)	6.9 (0.9)	18.61 (0.86)	44.47 (0.47)

Note: all analyses are reported on a dry weight (dw) basis.
The C content was calculated using equation (100 – ash (%))/1.83.
The value in parenthesis is the standard deviation.
DM, dry matter; TN, total nitrogen.