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# Performance of a plastic-wrapped composting system for biosecure emergency disposal of disease-related swine mortalities

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ABSTRACT

A passively-ventilated plastic-wrapped composting system initially developed for biosecure disposal of poultry mortalities caused by avian influenza was adapted and tested to assess its potential as an emergency disposal option for disease-related swine mortalities. Fresh air was supplied through perforated plastic tubing routed through the base of the compost pile. The combined air inlet and top vent area is $\leqslant \sim 1\%$ of the gas exchange surface of a conventional uncovered windrow. Parameters evaluated included: (1) spatial and temporal variations in matrix moisture content (m.c.), leachate production, and matrix $O_2$ concentrations; (2) extent of soft tissue decomposition; and (3) internal temperature and the success rate in achieving USEPA time/temperature ($T$) criteria for pathogen reduction. Six envelope materials (wood shavings, corn silage, ground cornstalks, ground oat straw, ground soybean straw, or ground alfalfa hay) and two initial m.c.'s (15–30% w.b. for materials stored indoors, and 45–65% w.b. to simulate materials exposed to precipitation) were tested to determine their effect on performance parameters (1–3). Results of triple-replicated field trials showed that the composting system did not accumulate moisture despite the 150 kg carcass water load (65% of 225 kg total carcass mass) released during decomposition. Mean compost m.c. in the carcass layer declined by ~7 percentage points during 8-week trials, and a leachate accumulation was rare. Matrix $O_2$ concentrations for all materials other than silage were $\geqslant 10\%$ using the equivalent of 2 m inlet/vent spacing. In silage $O_2$ dropped below 5% in some cases even when 0.5 m inlet/vent spacing was used. Eight week soft tissue decomposition ranged from 87% in cornstalks to 72% in silage. Success rates for achievement of USEPA Class B time/temperature criteria ranged from 91% for silage to 33–57% for other materials. Companion laboratory biodegradation studies suggest that Class B success rates can be improved by slightly increasing envelope material m.c. Moistening initially dry (15% m.c.) envelope materials to 35% m.c. nearly doubled their heat production potential, boosting it to levels $\geqslant$silage. The 'contradictory' silage test results showing high temperatures paired with slow soft tissue degradation are likely due to this material's high density, low gas permeability and low water vapor loss. While slow decomposition typically suggests low microbial activity and heat production, it does not rule out high internal temperatures if the heat produced is conserved. Occasional short-term odor releases during the first 2 weeks of composting were associated with top-to-bottom gas flow which is contrary to the typical bottom-to-top flow typically observed in conventional compost piles. In cases where biosecurity concerns are paramount, results of this study show the plastic-wrapped passively-ventilated composting method to have good potential for above-ground swine mortality disposal.


## 1. Introduction

In 2004, the Canadian Food Inspection Agency (CFIA) used a novel composting procedure to biologically decompose and heat treat poultry mortalities (Spencer et al., 2004) following an outbreak of highly pathogenic (H7N3) avian influenza (AI) in poultry flocks in British Columbia. In a significant departure from composting practices typically used for on-farm disposal of routine (non-disease-related) poultry mortalities, the CFIA wrapped the

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emergency composting piles in plastic sheeting to reduce the risk of AI virus being carried into the surrounding environment by bird and insect activity, wind, and precipitation. The plastic-wrapped composting matrix was passively aerated through 10-cm diameter slotted plastic drainage tubing passing through the base of the pile (perpendicular to the long axis) at 1.2-m spacing intervals, and penetrating the plastic biosecurity barrier on each side. Water vapor and gases produced by the composting process were vented through perforations in the plastic located along the ridge of the piles at 1.2-m spacing intervals. The CFIA plastic-wrapped emergency composting design has a total inlet/vent area for gas exchange that is about 0.25% of that provided by the surface area of a similarly sized conventional (unwrapped) composting windrow.

Successful implementation of the plastic-wrapped composting system for emergency disposal of chicken mortalities led CFIA to sponsor research to evaluate its feasibility as a biosecure emergency disposal option for swine or cattle. Because of its very limited ventilation area, the primary focus of the research was evaluation of the system's ability to sustain an adequate oxygen supply and remove large quantities of water and decomposition gases throughout long decomposition periods associated with large animal species. Chicken mortalities weighing 3–4 kg can be composted in 3–6 weeks (CAST, 2008), but market weight (110 kg) swine can take as long as 6 months (Alberta Agriculture and Rural Development, 2011), and decomposition of mature (450 kg) cattle carcasses in unturned piles can take 4–6 months during warm weather and 8–10 months during cold weather (Glanville et al., 2013).

The duration of the mortality composting process is of concern due to associated changes in physical characteristics of the organic envelope material that provides the environment for microbial activity and animal tissue decay. Loss of mechanical strength is of particular concern and excess moisture caused by inadequate venting of carcass water is a primary cause. Weakened envelope material surrounding the carcasses causes compaction, reduced matrix porosity and gas permeability, and inadequate transport of $O_2$ throughout the compost pile. This fosters development of anaerobic zones, slow animal tissue decomposition, and increased production of odorous volatile organic compounds. Reduced matrix permeability also hinders water vapor transport, an important function because animal tissue – which is approximately 65% water by weight – releases considerable water during decomposition. Failure to vent excess water vapor from the pile can cause saturation and further weakening of the matrix. Ahn et al. (2008a,b) reported that at 80% of their water-holding capacity, the mechanical strength and gas permeability of ground cornstalks were only 22% and 46%, respectively, of the strength and permeability of cornstalks at 20% of their water-holding capacity.

While compaction and impeded gas/vapor transport occurs to some extent in all composting operations, the primary question driving the CFIA research was whether addition of the plastic biosecurity barrier would significantly exacerbate these problems during the lengthy composting periods associated with large animals. In addition to possible internal $O_2$ and moisture transport problems associated with envelope material compaction, there were questions regarding the long-term functionality of the passive aeration/ventilation system. The CFIA plastic-wrapped composting design provides a combined inlet/vent area available for gas exchange with the ambient environment that is only about 0.25% of that available with a similarly sized conventional (unwrapped) composting windrow. If long-term internal gas transport declines, it seemed likely that the number and/or size of aeration tubes and vents may need to be increased.

To answer the questions described above, the CFIA sponsored field and laboratory studies at Iowa State University to evaluate the performance of the CFIA emergency poultry mortality composting system when applied to swine and, if needed, to propose appropriate adaptations to the system design. Project objectives included documentation of:

1. Spatial and temporal (including seasonal) variations in matrix moisture content (m.c.), leachate production, and matrix $O_2$ concentrations.
2. Time required for decomposition of swine carcasses.
3. Achievement of USEPA time/temperature (*T*) criteria for pathogen reduction; and
4. The effect of envelope material type and initial m.c. on items 1–3.

## 2. Materials and methods

### 2.1. Treatment variables

Replicated ($N = 3$) field trials were carried out during cool- and warm-season trials lasting 8 weeks. Warm-season trials (#2 and 3) were begun in June and August; cool-season trials (#1 and 4) in November and April. Average daily *T* during the first 30 d of warm season trails were 22.4 °C and 20.5 °C; and 4.4 °C and 13.7 °C during cool seasons.

To test the effects of envelope material type on the performance of plastic-wrapped composting systems, 6 materials (wood shavings; corn silage; ground cornstalks; ground oat straw; ground soybean straw; and ground alfalfa hay) were included in the study. These were selected in consultation with the project sponsor and chosen because they are commonly used in poultry and livestock operations and are generally available in large quantities in the event of a disease emergency. Three materials were tested during each warm and cold season trial, and each was triple-replicated (9 test units per seasonal trial).

Initial m.c. of envelope materials varies depending on whether they are exposed to precipitation or stored in protected piles. To evaluate performance impacts associated with differing initial m.c., trial #1 and #3 were conducted with envelope materials that had been stored indoors (initial m.c. 15–30% w.b.). Prior to trial #'s 2 and 4, the envelope materials were moistened (45–65% w.b.) to simulate materials that have been exposed to seasonal precipitation. The exception was corn silage which is an inherently moist material and was tested only in its as-received (m.c. ranging from 52% to 82% w.b.) condition.

Testing all combinations of envelope material type and initial m.c. during single warm and cold seasons would have been preferable as this would have exposed all experimental treatments to identical ambient *T* conditions. This was impractical, however, due to the large quantities of swine carcasses, envelope material, experimental space, instrumentation, and personnel necessary for simultaneous replicated testing of all treatments.

### 2.2. Test bins

Field composting trials were conducted in 2 m × 2 m × 1.2 m (high) wooden test bins (Fig. 1A and B). Floors and sidewalls were insulated with 5 cm thick Styrofoam insulation to aid heat retention and simulate operating *T* likely to occur in larger piles. Bins were lined with rubber membrane to facilitate capture and quantification of leachate, and the tops and sidewalls were wrapped in sheet plastic to simulate the CFIA biosecure emergency composting procedure. Three lengths of 10 cm diameter plastic drainage tubing were embedded in envelope material placed in the bottom of each bin. These were extended vertically, through the sheet plastic and over the sidewalls, to carry ambient air to the base of the compost matrix (Fig. 1B and C). Using all 3 of the air inlet tubes was equivalent to 0.5 m inlet spacing in a full scale