

Management of Bedded-Pack Manure From Swine Hoop Structures: 1998 Results

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Summary and Implications

Hoop structures are an increasingly popular alternative to conventional confinement facilities for swine production. Animals bed and dung on a bedded manure pack, which generates heat and contributes to animal comfort during winter months. As it comes directly out of the hoop structure, the high degree of variability in the bedded pack makes it difficult to predict manure nutrient contributions to crop fertilization needs. Although manure from the dunging area has clear fertilizer value, the high-carbon (C) low-nitrogen (N) status of the drier bedding may lead to nitrogen immobilization and crop stress if applied during or immediately prior to the growing season. This study examined the distribution of moisture, N, and temperature of the bedded pack inside a hoop, and evaluated the effect of 4 composting strategies on manure nutrient levels and uniformity, mass, volume, and moisture content. A simple loader built pile with no turning appeared to most effectively reduce nitrogen losses, but building piles with a manure spreader or frequent turning provided benefits in volume, mass, and moisture reduction. Composting did not consistently improve the nutrient variability of the manure, and additional studies are planned to address this concern.

Introduction

Hoop structures are an increasingly popular alternative to conventional confinement facilities for swine production in the high plains, midwestern United States, and western Canada. This system is attractive in part because of the low capital cost but also because of perceived advantages with respect to both odors and water quality impacts (2). A central feature of the system is that the animals bed and dung on a deep bedded-pack of cornstalks, straw, or other materials (1). Aerobic decomposition in the bedded-pack generates heat and raises the effective temperature in these unheated buildings, improving animal comfort under winter conditions. The bedded-pack is normally cleaned out after each group of pigs is sold, two to three times a year. At that time the manure-

bedding mixture is either directly spread on fields or stored for later use. Because this is a solid manure handling system, storage requirements are minimal, although there is some concern about nitrogen leaching from storage, especially during high-rainfall periods (4). The average characteristics of the manure-bedding mixture are ideal for composting, which provides volume reduction and nutrient stabilization prior to field application. Such composting will occur with minimal management if the material is piled in windrows about 1.5 to 2 meters in height and 3 to 4 meters in width (4).

As it comes directly out of the hoop structure, the high degree of variability in the bedded pack makes it difficult to predict manure nutrient contributions to crop fertilization needs. Although manure from the dunging area has clear fertilizer value, the high-carbon (C), low-nitrogen (N) status of the drier bedding may lead to nitrogen immobilization and crop stress if applied during or immediately prior to the growing season. Mixing the material to achieve a higher degree of uniformity would improve this situation, such as would occur if the bedded pack is piled or more intensively managed for composting prior to field application.

Because hoop structures are a relatively new technology, there is limited information available about the manure characteristics either inside the hoop or during subsequent manure management activities. The first objective of this study was to characterize the variability of moisture and nitrogen within the bedded pack inside a hoop structure, and the impact of those factors on bedding temperature. The second objective of this study was to evaluate four windrow composting strategies and their impact on mass, volume, moisture, and nutrient levels.

Materials and Methods

This study was performed at the Iowa State University Rhodes Research Farm in Rhodes, IA. Three hoop structures were built at the farm in the fall of 1997 for a series of studies characterizing swine finishing in hoops and comparing pig performance with swine finished in a power-ventilated finishing unit constructed at the same time. Two hundred approximately 50-lb. feeder pigs were placed in the each hoop on December 19, 1997, regrouped to approximately 150 pigs/hoop on January 10, and marketed in April 1998. Pigs were weighed in groups every 2 weeks, and that data used to calculate excreted manure nutrients using tables from the Agricultural Waste Management Field Handbook (6). Representative bales of corn stalk bedding also were weighed, and nitrogen inputs from the bedding estimated from analytical results. Bedding temperatures were recorded manually every 2 weeks in March and April. Temperatures were measured with a digital thermocouple probe at 3- and 6-inch depths at each of 24 interior grid locations (4). When the hoop bedding was removed for composting, samples

from six depths were composited at each of the same 24 grid points and analyzed for moisture, volatile solids (VS), TKN, ammonia, total P, and total K.

A 6-week comparative composting trial was initiated in mid-May and completed at the end of June 1998.

Composting treatments included two methods of windrow construction and two strategies of compost turning. Two windrows were constructed, one with a tractor-loader bucket and a second using a stationary manure spreader to unload into a pile. Each of these two windrows was divided into two sections, one of which was turned every time the temperature exceeded 65°C, and the other of which was left unturned until the end of the six week trial. Mixing took approximately 10 minutes for each windrow section.

Initial mass of the windrows was estimated by multiplying the weight of measured loads of manure representative of the wet, dry, and intermediate regions of the hoop by the number of loads from each region. Both manure spreader loads and tractor-bucket loads were weighed for this part of the analysis. Each windrow section was entirely weighed at the end of the trial. Although there was some migration of material from the windrows, especially during turning, this effect appeared relatively small. Initial and final volumes were calculated from the windrow dimensions assuming a parabolic cross section (5).

Temperature, oxygen, and carbon dioxide concentrations were recorded daily for the first 2 weeks and twice a week thereafter. Temperature was recorded at 30-, 60-, and 90-cm depths at 12 locations in each section, and O₂ and CO₂ were recorded at two locations in each section. Initial and final moisture, C, and N were analyzed from 12 grab samples were taken from each of the four sections. These samples were collected from approximately 30-, 60-, and 90-cm depths at each of four locations in each sections. Samples from the same depth also were composited from the four sampling locations in each section at the end of the trial for analysis of ammonia, VS, P, and K. Moisture analysis was by oven drying at 105°C until constant weight. Samples for total C and N were air-dried at 37°C, ground and analyzed by dry combustion in a Carlo Erba CN analyzer. Ammonia, VS, and total P and K were analyzed by the Iowa State University Analytical Services Laboratory.

Results and Discussion

Each group of pigs that populates a hoop house quickly settles on a dunging area and a sleeping area, and the sleeping or resting area remains relatively dry and free of manure. Weather conditions during the first few days appear to strongly influence the resulting pattern. Groups started under warm conditions tend to dung in the middle of the hoop and sleep near the cooler sides, whereas many groups started under colder fall and winter conditions dung at the north end of the hoop and along the east and west wall. This later pattern was observed in the hoop observed in this study, as indicated by Figures 1 and 2, which show the distribution of moisture and N, respectively.

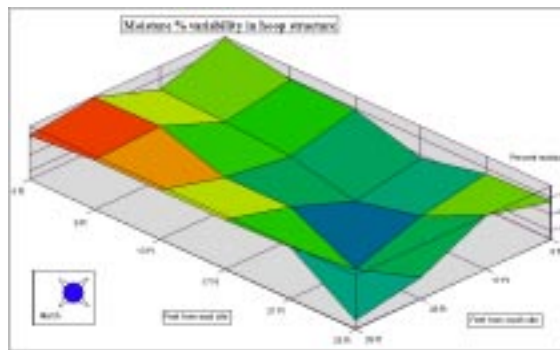


Figure 1. Bedding moisture content in east hoop, ISU Rhodes Research Farm, Spring 1998.

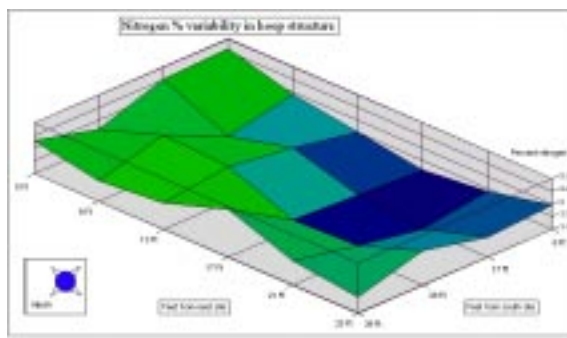


Figure 2. Bedding nitrogen levels in east hoop, ISU Rhodes Research Farm, Spring 1998.

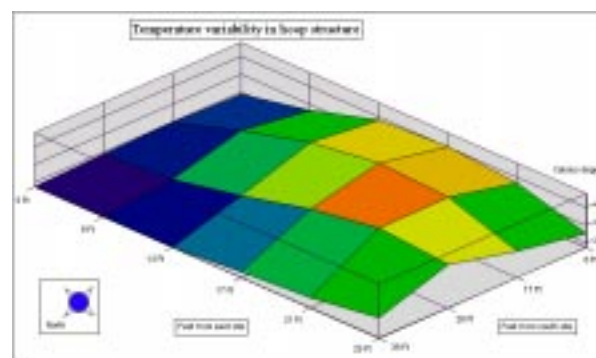


Figure 3. Distribution of average bedded pack temperatures in the east hoop of the ISU Rhodes Research Farm, Spring 1998.

Bedding temperature in the hoop was highest in the sleeping resting area, and lowest along the east and north walls of the hoop, as indicated in Figure 3. The sleeping-resting area had a moisture content of approximately 50% (wet basis), which was adequate to support rapid decomposition but porous enough to remain largely aerobic. Lower temperatures in the wetter regions correspond with

moisture levels in the range of 60 to over 70%. Throughout this region we observed the pig traffic on moist or dung-filled bedding caused severe packing and greatly reduced porosity. We hypothesize this translated into anaerobic conditions in this area, so that decomposer microorganisms were unable to fully oxidize carbon sources and thus did not generate much heat.

The composting trials demonstrated the relative ease with which hoop manure can be composted. Table 1 provides the key to our abbreviations of these strategies. All four strategies rapidly achieved thermophilic temperatures, as indicated in Figure 4. The two turned sections were turned daily for the first 2 weeks, and then cooled rapidly below the 65°C trigger temperature and were not turned during the last 2 weeks. The manure spreader built, unturned section generated similar temperatures to the two turned sections, which may have been a result of high porosity and adequate oxygen. Oxygen concentrations in this section were similar to the O₂ concentration of the turned sections and consistently higher than in the loader built, unturned section (4). Carbon dioxide concentrations were generally higher in the loader built piles, again suggesting enhanced air movement in the spreader built piles (4).

Table 1. Composting strategies.

Composting Strategy	Key
Manure spreader built, turned @ 65°C	MST
Manure spreader built, not turned	MSNT
Loader built, not turned	LNT
Loader built, turned @ 65°C	LT

Table 2. Mass and volume reductions from hoop manure composting strategies.

Key	% Mass Reduction	% Volume Reduction
MST	63	45
MSNT	57	36
LNT	16	23
LT	42	31

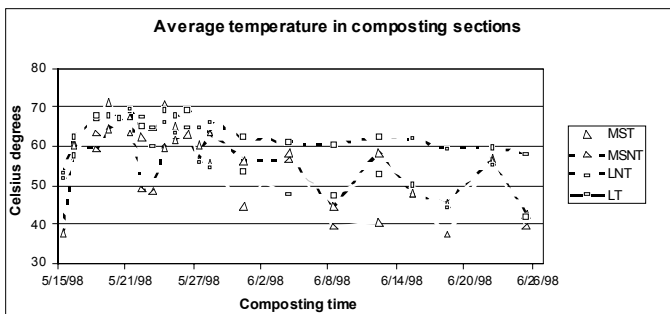


Figure 4. Average compost temperatures during the six week composting trials.

During the last 2 weeks of the composting trials temperatures, O₂ and CO₂ trended toward ambient concentrations, with the loader built, unturned pile showing less of this effect.

The composting trials occurred during an extremely wet period, with approximately 16 inches of precipitation falling during the course of the experiment. Some of this precipitation was absorbed by the uncovered piles, and moisture content increased during the initial 3 weeks in both of the unturned piles (Figure 5). The turned piles both lost moisture even during this wet period, due to both release of saturated air during the turning process as well as subsequent exposure of the moist interior surfaces to occasional drier conditions. Both unturned piles did lose significant amounts of moisture when the wet weather abated in the fourth week, but additional rainfall in weeks 5 and 6 reversed this effect.

One of the more important practical issues in manure management is the number of trips needed to move manure to crop fields. The significant mass and volume reduction results reported in Table 2 thus provide one important potential justification for composting. Mass reductions were greatest with the manure-spreader-built piles (63% for the turned section and 57% for the unturned section). The loader-built piles experienced mass reductions of 42% for the turned section and 16% for the unturned section. These mass reductions are calculated on a wet-weight basis and are thus influenced by both biodegradation of solids and by inputs and outputs of water, so even greater reductions could be expected if precipitation were reduced. Volume reductions were also substantial and followed a similar trend, with the greatest reductions from the spreader built turned section (45%) and the smallest reduction from the loader-built, unturned section (23%). One should note that part of the apparent volume reduction resulted from an artificially high initial volume, due to the fluffing action of the manure spreader while the pile was being built.

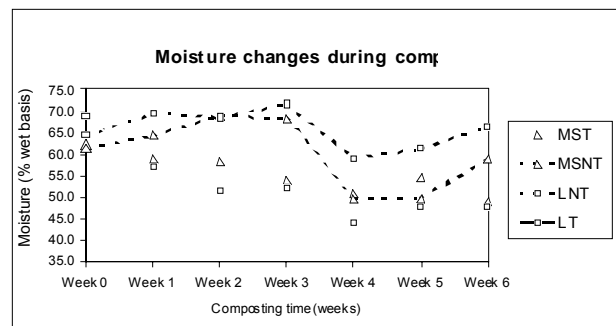


Figure 5. Average moisture content during the 6-week composting trials.

Another issue of considerable importance in manure utilization is the extent of nutrient losses during storage and treatment. With hoop structures, some of the storage occurs within the hoop, and losses may thus occur before the manure

is collected. To estimate the extent of these losses for nitrogen we calculated the inputs to the bedded-pack from pigs (as described in the methods section). Subsequent N levels were calculated by multiplying the average concentration by the mass of the bedded pack or compost section. Figure 6 summarizes these results. They should be viewed as trends rather than absolute losses, both because the initial N inputs were estimated and because there was a high degree of variability in the N data from each treatment (discussed below).

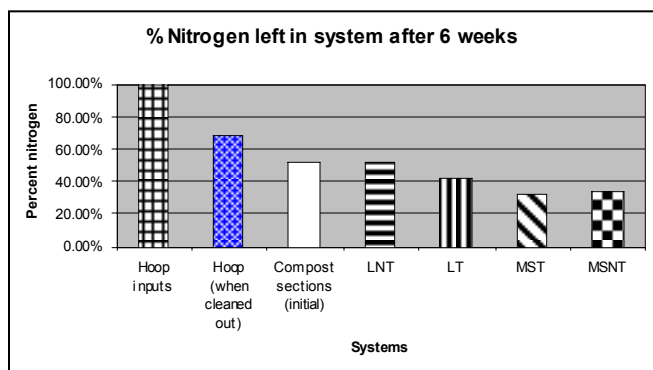


Figure 6. Estimated N retention during hoop manure management activities.

The results of this analysis suggest that approximately a third of the manure N is lost while the pigs are still in the hoop. We expect this loss is primarily through ammonia volatilization but it also may indicate leaching into the soil. There appears to be another significant loss (on the order of 10% of the original N) occurring when the manure is moved from the hoop to the field, and again we suspect this is due to ammonia volatilization as the bedded pack is broken apart. The composting strategies that were most effective in reducing the compost volume and mass also resulted in the greatest nitrogen losses, with the manure spreader-built-sections experiencing cumulative losses of greater than 60%. These losses are higher than typically reported for most other manure management systems (6) and warrant further investigation. From a nitrogen conservation perspective, the loader built, unturned pile appears to be the most effective composting strategy.

In addition to the cumulative N losses, two other issues are of considerable importance to achieve effective N utilization. The first has to do with N concentration, and like volume and mass reductions has an important impact on the number of required trips to the field. A related issue is the N variability, which effects the optimum application rate. Manure with highly variable nutrients is likely to be over-applied, because most farmers will select an application rate that ensures adequate nutrients to all plants. Table 3 illustrates the effect of these four composting treatments on nutrient concentration and variability.

Table 3. Concentration and variability of nitrogen from hoop manure.

Manure Source	Average N (% dry basis)	Standard Deviation (% dry basis)	Standard Error(%)
Hoop at cleanout	1.94	0.26	13
Manure spreader built, turned @ 65°C (MST)	1.63	0.40	24
Manure spreader built, not turned (MSNT)	2.22	0.63	28
Loader built, not turned (LNT)	1.94	0.22	11
Loader built, turned @ 65°C (LT)	1.35	0.12	9

From these results it appears that turning reduces the concentration of N in compost from that initially available in the hoop. This reduction is smaller than the equivalent mass loss of nitrogen illustrated in Figure 1 because there is a countervailing concentration effect from the shrinking mass of organic matter. The loader-built, unturned pile retained a constant N concentration, whereas the spreader built turned pile appears to have a slightly increased concentration. As with the cumulative N loss data, caution should be used in interpreting results because of the relatively high standard deviation. Similarly, the counterintuitive increased variability from the spreader built pile indicated by the higher standard errors may be due to inadequate sample homogenization. As with the previous N results, these values should be viewed as preliminary until the experiment can be replicated.

Summary and Conclusions

Hoop structures provide an opportunity for pigs to modify their environment through selective dunging and sleeping patterns. Variability in moisture and nutrients contributes to temperature differences that the animals exploit for comfort throughout the grow-finish cycle. This incidental in-situ composting may have beneficial effects, but appears to also be implicated in significant losses of N. The composting strategies that minimize further N losses are also those most easily accomplished: building piles with a tractor loader and minimizing handling and turning. More intensive composting, although contributing to N loss, has impacts that can be beneficial as well. Frequent turning reduces pile moisture levels, which can be critical during periods of heavy rain. Either frequent turning or building piles with a manure spreader appear to provide adequate oxygen to maintain generally aerobic conditions, which would be important for odor control at sensitive locations. The manure spreader construction technique maximized mass and volume reductions in the windrows, dramatically reducing the number of required trips to the field. Because of the high level of variability in this system and challenges with sampling and analysis, this first year study's results are

preliminary. We anticipate repeating these experiments with the current group of pigs over a winter composting cycle and will be reporting additional results in the coming year.

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