In-House Composting in High-Rise, Caged Layer Facilities

Richard T. Koenig
Washington State University, Pullman

F. Dean Miner, Jr.
Utah State University Extension, Provo

Bruce E. Miller
Utah State University, Logan

Matt D. Palmer
Utah State University Extension, Tooele

County Extension Agent Dean Miner sifts through composted poultry manure.
Photo by Gary Neuenswander

Inside this fact sheet:

SARE Agricultural Innovations are based on knowledge gained from SARE-funded projects. Written for farmers and agricultural educators, these peer reviewed fact sheets provide practical, hands-on information to integrate well-researched sustainable strategies into farming and ranching systems. The articles are written by project coordinators and published by SARE.

Geographic Range:

Continental U.S. and areas with similar climate and high -rise, caged layer poultry production systems. This SARE research was conducted in the western U.S., but similar research has been done in Pennsylvania, Maryland and Georgia.

Introduction

Manure handling, storage, and disposal are common problems facing poultry producers in the United States. Fly and odor control, urban encroachment, a limited nearby land base for manure disposal, and increased regulatory pressures necessitate the development of alternatives to traditional scrape and haul systems.

One alternative for high-rise layer facilities is to compost manure inside of the buildings housing laying hens. Research showed that the addition of a carbon source coupled with frequent aeration of compost in a layer house produced temperatures high enough to inhibit fly reproduction in the material.

In-house composting offers promising solutions to common problems faced by egg producers. Since manure can be treated within the layer facility, odors associated with manure disturbance and handling when cleaning out a building are reduced. Fly control is achieved with heat, thereby reducing the need for pesticides. In addition, a more uniform and marketable compost product is produced, which greatly reduces the need for a nearby agricultural land base for manure disposal. Research conducted by others [1] also has shown that the final weight and volume of material produced are at least 35% lower after in-house composting compared to traditional systems where poultry manure accumulates undisturbed.

This article summarizes the in-house composting process and relevant research findings from a Western SARE pro

(Introduction continued on page 2)

ject in Utah for producers interested in adopting the process on their farms. Additional information on in-house composting can be found on the Internet and in the publications cited in this article.

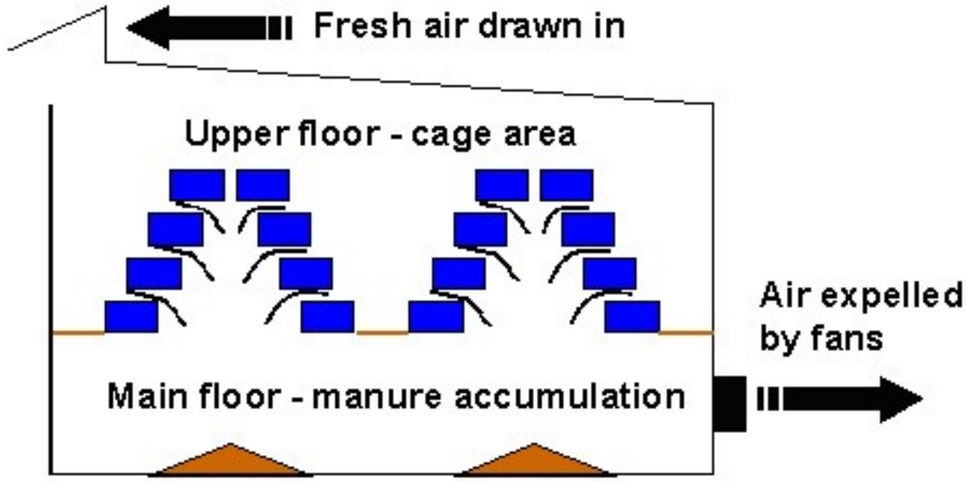

Figure 1. Schematic of a high-rise layer structure. Fans in the wall of the structure draw air out under negative pressure (suction). This pathway of air flow serves to vent ammonia and other gasses out of the structure, minimizing exposure of poultry.

High-Rise, Caged Layer Facilities

The standard structure design for high-rise, caged layer facilities involves housing poultry in offset-stacked cages in the upper floor of the structure. Manure from the cages is directed with plastic sheeting into the storage area below (Figure 1). Manure may accumulate for several months or more before buildings are cleaned out.

Automated fans housed in the lower portion of the structure control ambient temperatures in the cage area by drawing air in through evaporative cooling screens located in the roof and expelling it through the walls in the manure storage area. The fans also serve to vent ammonia and other gasses from the building, and to accelerate manure drying. Fly control is normally achieved by supplying a feed-based larvicide to laying hens coupled with topical applications of insecticides on the manure as needed to control outbreaks. Odor and fly complaints are commonly associated with the clean-out process when accumulated manure is disturbed for loading and transport.

An Overview of In-House Composting

Composting is possible inside high-rise facilities using equipment sized to fit in the manure accumulation area of the structure. Cooperators at the sites where this SARE research was conducted used a Brown Bear model 24C compost turner [2] fitted to a skid-steer drive unit to aerate the materials (photo A). The skid-steer is the same power unit that, when fitted with a loader bucket, is used to remove material from the buildings. To prepare for a compost cycle, a carbon source such as straw or sawdust is spread on the floor after cleaning out a building. Manure is allowed to accumulate on the carbon bed for 2 to 4 days before forming the material into windrows with the turner. The material is turned (aerated) every two to four days, depending on the size of windrows and material temperature.

Aerating promotes rapid decomposition by microorganisms. The metabolic heat produced by the microorganisms is capable of generating temperatures in the compost above the lethal limit for fly larvae (110 ºF). Aerating also rotates fresh manure into the center of the pile where high temperatures kill new fly larvae. Material is removed when the volume exceeds the operational capacity of the turner.

In-house composting differs from traditional composting. Since manure is being added continuously, the product at the end of a cycle is not finished compost. However, as a result of frequent mixing and partial decomposition, the material is more uniform and has a lower moisture content and less odor than fresh poultry manure. If desired, fin-

Photo A. A Brown Bear 24C compost turner [2] fitted to a skid-steer drive unit turns compost inside a high-rise layer structure.

ishing can occur outdoors in a conventional composting system, or partially composted material can be land-applied without finishing. Practitioners should check with state and local officials regarding regulations on composting facilities and compost quality standards before marketing the products of this process as compost.

An essential component of in-house composting is the negative pressure ventilation system that vents ammonia and other gasses from the composting area. This reduces the exposure of poultry and employees to potentially toxic gasses produced during composting. High concentrations of harmful gasses may still be present in the composting area, so employees working there should be equipped with appropriate monitoring and respiratory safety devices. Also, practitioners should be aware of impending air quality rules designed to regulate ammonia emissions from poultry farms. Careful attention to composting conditions, particularly the carbon to nitrogen (C:N) ratio of the material, can limit ammonia emissions. There is also some evidence (cited later) that chemical amendments can be used to reduce ammonia volatilized from composting manure.

Managing Compost Inside Poultry Facilities

Details on composting processes and methods are outside the scope of this article but are presented elsewhere in comprehensive manuals [3]. Two of the most important factors for successful in-house composting are the appropriate C:N ratio and moisture content of the material. Carbon to nitrogen ratio should be in the range of 20:1 to 40:1, with moisture contents in the range of 40 to 65% by weight. Practitioners are encouraged to purchase a comprehensive reference on composting methods, and to periodically have samples of material analyzed to compare results to desired ranges and make adjustments as necessary.

Carbon requirements

Initial research showed that high composting temperatures could be achieved in-house using relatively low rates of carbon material (200 to 600 lbs per 1,000 square feet of floor area, [4, 5]) (Figure 2). The resulting C:N ratio of the compost, however, was approximately 10:1, much lower than recommended for optimum composting. Composting with a low C:N ratio contributes to high rates of ammonia gas evolution and atmospheric ammonia concentrations inside the layer facility. While using less carbon extends the length of time compost can accumulate before the volume exceeds the capacity of the turner, the resulting high rates of ammonia volatilization are not sustainable from an air quality perspective.
Increasing the amount of carbon used to produce a target C:N ratio of 20:1 to 40:1 will reduce ammonia volatilization. Formulae are available to calculate the exact amount of carbon necessary to achieve a target C:N ratio, knowing the characteristics of the manure and carbon source material [3]. Higher C:N ratio carbon sources are desirable, as they reduce the total amount of carbon required. Depending on the source, from 1/3 to 2 pounds of carbon per pound of manure would be required for an optimum C:N ratio with in-house composting.

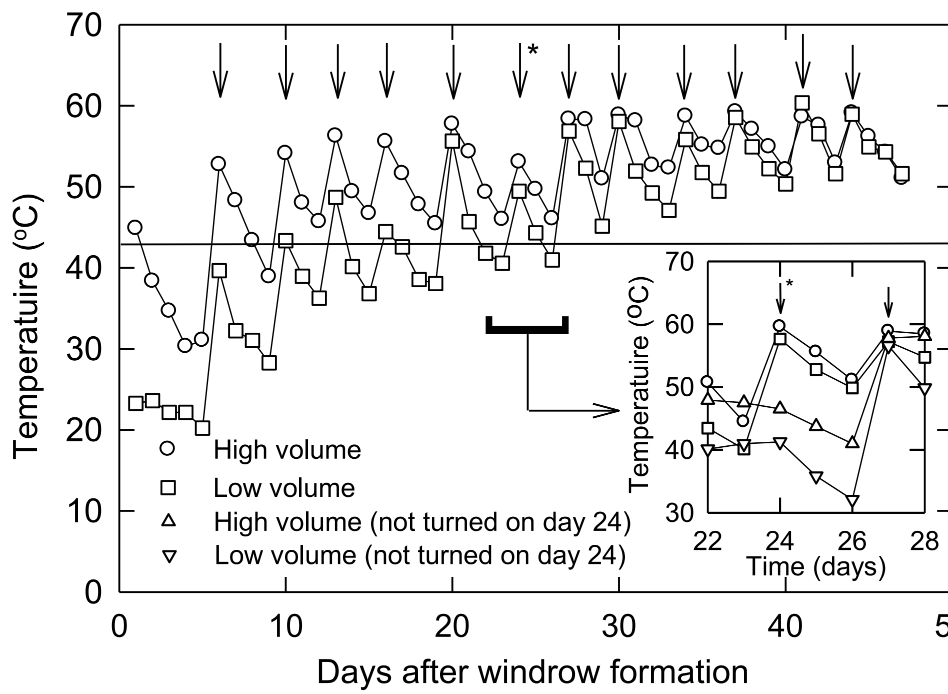

Figure 2. Daily compost temperatures measured during a seven-week in-house cycle. The treatments consisted of high and low initial volumes of composting material. Arrows indicate when compost was turned. The horizontal line represents the lethal limit for fly larvae (43 oC = approximately 110° F). The * indicates when certain replications of the treatments were not turned on day 24. Data from Miner et al. (2001) [5].

Research demonstrated the importance of turning frequency to maintain high compost temperatures.

According to published research, a single laying hen produces approximately 0.058 lb manure per day (41% moisture equivalent) [6]. The C:N ratio of layer manure averages 8.5 [4, 5]. Using this information, together with data on the carbon source and the formulae cited above, the total amount of carbon needed for a given number of birds and length of time composting will occur can be calculated. Research [1] also suggests that as much as 35% of the manure decomposes during in-house composting, so some adjustment in the amount of manure may be warranted when forecasting carbon requirements.

Since manure is added continuously over time, all of the carbon should not be added at the beginning of an in-house composting cycle. Divide the carbon into three or more separate applications made at regular intervals during a cycle. For example, in a six-week cycle, add approximately 33% of the carbon at the beginning of the cycle, 33% after two weeks, and the final 33% after four weeks.

Turning frequency

Research demonstrated the importance of turning frequency on maintaining compost temperatures above the lethal limit for fly larvae. Results showed that critical temperatures could be achieved by turning the material once every 2 to 3 days (Figure 2). Missed turning events resulted in a rapid drop in temperatures below the critical value (see insert graph in Figure 2). Regular monitoring of compost temperatures is critical to determine when to aerate the materials. An inexpensive compost thermometer should be purchased to monitor windrow temperatures. Temperature monitoring also can be used as a troubleshooting tool. If temperatures do not reach critical values for fly control after a turning event, check compost moisture content and C:N ratio and compare to desired ranges cited above or in handbook references [3].

Average compost temperatures increased over time as the total volume and insulating capacity of the material increased (Figure 2). However, frequent turning is still necessary to ensure that fresh material deposited on top of the windrows is rotated into the pile and heated to kill fly larvae. Flies develop from egg to adult stages in as little as nine days under ideal conditions. Therefore, ensuring that all manure is rotated into compost piles at least once every nine days is critical for successful fly control.

Composting manure from young poultry (pullets)

Composting manure from pullets was less successful in research. Compost failed to reach critical temperatures for fly control despite more frequent turning and supplemental carbon additions. The failure of composting with pullet manure was attributed to a higher moisture content compared to layer manure. Additional research on pullet manure composting is warranted. Increasing the rate of carbon may further promote successful pullet manure composting.

Moisture content

In the arid climate where this research was conducted, the moisture content of in-house compost declined to as low as 30% by weight during summer months [4, 5], well below the acceptable range of 40 to 65% [3]. Critical temperatures for fly control were still achieved with this low moisture content. Although studies in which water was added to composting materials were not conducted, supplemental water may increase composting temperatures in situations where the moisture content of material declines below critical levels.

Utah egg producer Mike Shepherd holds composted poultry manure. *Photo by Gary Neuenswander*

Compost moisture content was higher in winter than in summer due to higher relative humidity, lower ambient temperatures and reduced operation of ventilation/cooling fans in the buildings during winter. More frequent turning and the addition of higher rates of carbon during winter are recommended to accelerate drying and promote higher material temperatures.

Fly control

The farmer cooperators on this SARE research project were able to discontinue using a feed-based larvicide and shift to topical applications of an insecticide when needed as long as the material was managed appropriately to maintain high temperatures. Fly outbreaks, though infrequent, did occur when equipment broke down and turning schedules could not be maintained.

Similar success in controlling flies with in-house composting has been reported by other researchers [7].

Ammonia volatilization and control

One of the main challenges with in-house composting is the accumulation of high levels of ammonia and other gasses inside layer houses and venting of these gasses from the facility. Active biological decomposition coupled with the low carbon to nitrogen ratio and frequent turning of the material contributes to higher ammonia levels than in high-rise layer facilities where manure accumulates in static beds. Monitoring showed that atmospheric ammonia in the composting area peaked well above safe levels for humans and poultry when the compost was being turned (Figure 3). Atmospheric ammonia was also higher in winter when fan use to cool buildings was reduced. Ammonia concentrations in the cage area were less than 50% of the concentrations in the composting area due to air flow patterns created by operation of the ventilation system [8].

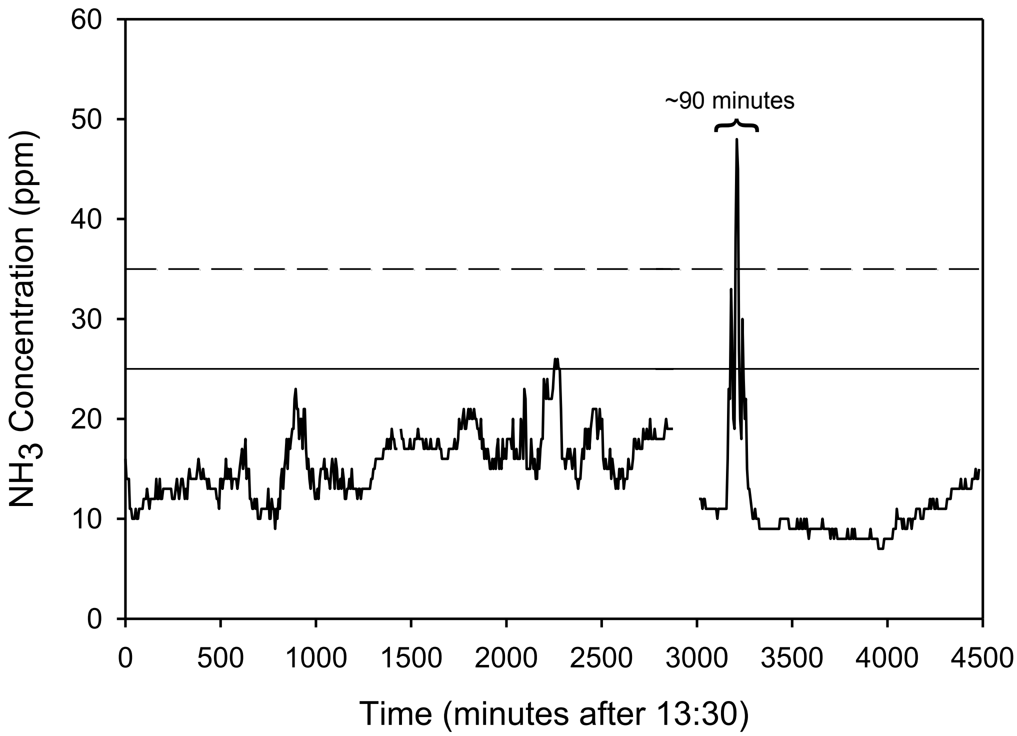

Figure 3. Ammonia concentrations over time in the manure storage area of a high-rise layer structure during in-house composting. The peak concentration occurred during a compost turning event. The —— line indicates the 8 hour human health exposure limit. The — — line indicates the 10 minute human health exposure limit. Data are from Koenig et al. (in press) [9].

There are several options to manage atmospheric ammonia during in-house composting. Practices that conserve nitrogen and reduce ammonia volatilization are the most desirable and environmentally sustainable solutions. Using rates of carbon calculated to maintain optimum C:N ratios will increase ammonia assimilation by microorganisms and reduce ammonia volatilization. Chemical amendments such as aluminum sulfate also have the potential to reduce ammonia volatilization from in-house compost [9], but more research remains to be done in this area. To reduce exposure in the short term, facility personnel where this research was conducted would over-ride the automated fan system for 15 to 30 minutes to vent ammonia when compost was being turned. It is recommended that facilities using in-house composting invest in ammonia gas sensors to prevent exposure of workers and poultry to high levels of atmospheric ammonia. In light of impending air quality regulations, practitioners of in-house composting also are cautioned to adopt practices that reduce ammonia emissions from poultry facilities.

Economic Evaluation

Cooperators on this project reported cost savings associated with reduced pesticide use for fly control, removal of less material from the buildings at cleanout, and the production of a higher value and saleable product. Additional costs were incurred for turning the compost. Based on partial budget analysis including these costs, annual savings equaled $6,000 per building per year. Total annual savings at a 330,000 laying hen facility was approximately $30,000. This was equivalent to a 65% reduction in costs associated with pesticides and manure removal and disposal. Overall, the greatest cost reduction was realized from reducing the amount of pesticide used. The savings offset the costs of new compost turners and other equipment required for in-house composting in less than three years. Additional opportunities were created to use waste cardboard and egg shells from a cracking operation as a carbon source and amendment, respectively, to the compost.

SARE Research Synopsis

The goal of SARE research project In-house composting in high-rise, caged layer facilities was to develop operational parameters for in-house composting. Specific objectives were to: 1) evaluate carbon source, rate, and turning frequency variables for their effects on compost temperatures; 2) evaluate amendments and process controls to reduce ammonia volatilization from composting manure; and 3) conduct a partial budget economic analysis of in-house composting relative to traditional methods of handling and disposing of poultry manure.

Researchers found annual savings of $6,000 per hen house per year.
Ohio State University Photo Library

The research was initiated in 1998 at a 330,000-layer egg farm and later expanded to a second facility of similar size. Both farms were located in central Utah and featured high-rise, caged layer buildings. Each building housed approximately 65,000 laying hens. The manure accumulation area in each building was divided into multiple quadrants and treatments applied to separate quadrants in a randomized complete block experiment design. Each treatment was replicated three times within a building.

Two trials were conducted to evaluate the effect of carbon rate and turning frequency on compost temperatures. Trials indicated that initial carbon rates of 200 to 600 lbs per 1,000 square feet of floor area were adequate to achieve critical temperatures for fly control as long as material was turned at least once every three days during early stages of composting. Wheat straw and sawdust were equally effective as carbon sources.

Trials demonstrated the importance of turning frequency to maintain high compost temperatures. Temperatures peaked on the day of turning and declined rapidly thereafter. A turning frequency of once every two to three days was essential to maintain high in-house compost temperatures in layer manure. We also found that rotating fresh manure with live larvae from the surface to the interior of the pile enabled heat to kill the larvae. Longer intervals between turning events could be used later in the composting cycle when higher volumes of compost were present.

In-house composting with manure from young birds (pullets) was generally unsuccessful due to the higher moisture content of pullet compared to layer manure. Two additional trials were completed evaluating the effects of turning frequency (three or six days per week) and carbon rate (400 or 800 lbs/1,000 square feet of floor area) on composting pullet manure. Results indicated that increasing the turning frequency could accelerate pullet manure drying and increase compost temperatures. Doubling the rate of carbon was less effective than increasing turning frequency.

In all of these studies, the C:N ratio of composting material was in the range of 10 to 12:1 throughout a cycle. Composting with low C:N ratios generated high levels of atmospheric ammonia within the poultry facilities. While no reductions in egg production or increases in bird mortality were noted, high ammonia levels were a health concern for workers and poultry.

Initial efforts to control atmospheric ammonia were focused on documenting the spatial and temporal variability of ammonia inside high-rise facilities during composting. Atmospheric ammonia levels were shown to vary spatially within the buildings, with higher concentrations found near the center of the building away from ventilation fans. Concentrations frequently exceed 25 ppm ammonia (the upper limit for eight-hour exposure of workers) in the manure storage area. Atmospheric ammonia concentrations were approximately 50% lower in the cage area. Spikes in atmospheric ammonia exceeding 35 ppm (the upper limit for 10-minute exposure) occurred immediately after a compost turning event and lasted for less than 60 minutes. Ammonia levels also increased over time as compost volumes increased. In a series of laboratory and limited in-house trials, process controls and chemical amendments such as aluminum sulfate showed potential to reduce ammonia volatilization from composting poultry manure.

This fact sheet is based on a SARE-funded project. For more information, please visit www.sare.org > Project Reports > Search the database for project # SW00-040

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