Environmental Effects of In-House Windrow Composting of Poultry Litter

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Executive Summary

Land application to crop and pasture land is a commonly-applied and effective method of utilizing the resource value of poultry litter. In-house windrow composting of litter is an emerging management practice with the potential to mitigate water quality and nuisance odor concerns associated with land application, but few studies have demonstrated these effects. This project was designed to evaluate and demonstrate the effectiveness of in-house windrow composting to reduce litter bacteria concentrations, improve runoff water quality, and mitigate nuisance odors relative to untreated litter. Results related to bacterial reductions were not definitive due to extremely low *Escherichia coli* (*E. coli*) counts in untreated litter prior to performing in-house windrow composting. This is attributed to dry litter conditions. Low litter moisture and less than full heating of the windrowed litter likely led to few differences in litter properties or in runoff water quality being observed. In terms of nuisance odor, human monitors reported higher odorant concentrations from the in-house windrow composted litter site, but they noted that the untreated litter application site had a more offensive “manure” smell than the in-house windrow composted litter site. Analysis of sorbent tube air samples also produced inconclusive results related to odor mitigation. Alternatively, laboratory-based assessment demonstrated that the odor detection threshold was almost twice as high (odors were twice as strong) for untreated litter compared to in-house windrow composted litter. In spite of the low moisture content of litter in this project, in-house windrowing of litter prior to land application exhibits potential to be an effective litter management practice; especially reduction of nuisance odors in the subtropical to semi-arid climate of Central Texas. This potential benefit complements additional benefits such as reduction in food borne pathogens and poultry disease.

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List of Acronyms

BAEN	Texas A&M University Department of Biological and Agricultural Engineering
BMP	Best Management Practice
CFU	Colony Forming Unit
D/T	Detection Threshold
EMC	Event Mean Concentration
EPA	Environmental Protection Agency
GC/MS	Gas Chromatography-Mass Spectrometry
ICP	Inductively Coupled Plasma
IWC	In-House Windrow Composting
OAV	Odor Activity Values
TAMU	Texas A&M University
TWRI	Texas Water Resources Institute
USDA	United States Department of Agriculture
USDA-ARS	United States Department of Agriculture-Agriculture Research Service

Introduction

Land application is the most common, and usually most desirable, method of utilizing the nutrient and organic matter resources in animal manure and litter (USDA-USEPA, 1999). On a national scale, more than 90% of poultry litter is land applied as a soil amendment and nutrient source (Moore et al., 1995). Poultry litter consists of many different organic materials including manure, spilled feed, bedding material, and feathers and contains valuable N, P, K, and trace minerals (Kelleher et al., 2002; Bolan et al., 2010). Although land application of poultry litter can be a beneficial resource utilization technique, it can also create water quality and odor concerns. Excessive application rates increase potential for nutrient and pathogen runoff (Vervoort et al., 1998; Vories et al., 2001; Harmel et al., 2009a). Terzich et al. (2000) reported that *Staphylococcus*, *E. coli*, *Salmonella*, and *Campylobacter* are some of the pathogens commonly found in poultry litter. Terzich et al. (2000) reported that *E. coli* concentrations ranged from as low as 1.22×10^5 CFU/g in the Carolinas to 8.8×10^{10} CFU/g in Texas. Conversely, other researchers have found no *E. coli* in litter samples acquired from outer portions of litter compost piles or in inner portions of the same piles (Martin et al., 1998). In addition to potential water quality problems, almost half of the agricultural odor complaints originate from the spreading of animal manure or litter and the subsequent microbial degradation of feces and uric acid (Ullman et al., 2004).

A possible best management practice (BMP) to address water quality and odor concerns associated with poultry litter is heat treatment through in-house windrow composting (IWC) prior to its removal from the house and ensuing land application. IWC is a relatively simple technique that utilizes natural bacterial metabolism to generate heat within piles formed lengthwise down a broiler house. IWC is completed within the broiler house and requires a shorter time span than traditional composting (about 10 days compared to several months) (Bautista et al., 2008; Timmons, 2009). IWC is more accurately referred to as a “pasteurization” process instead of composting because although it uses heat from bacterial metabolism to destroy pathogens, it does not completely convert the litter to a humic-like material as does traditional composting (Timmons, 2009). According to the time-temperature criteria for composting set by the United States Environmental Protection Agency (EPA), a compost pile must maintain a temperature greater than 55°C for a minimum of 3 days for pathogen inactivation to occur (Wichuk and McCartney, 2007). IWC generates an internal temperature that ranges from 55°C to 65°C over a time period of 9 to 10 days.

IWC bacterial reduction effectiveness in poultry litter has been the subject of several evaluations. Hartel et al. (2000) found that windrowed litter contained fewer bacteria than non-composted litter, and Macklin et al. (2006, 2008) reported significant reductions in *Salmonella* and other food borne pathogens with IWC. Another evaluation reported that *E. coli* and *Clostridium perfringens* were completely eradicated after windrow composting (Bautista et al., 2008). In a laboratory evaluation where poultry litter was inoculated with *E. coli*, Wilkinson et al. (2011) found that *E. coli* was reduced by more than 99% after 1 hr at 55 °C under laboratory conditions.

While such research has shown the potential for pathogen reduction, no studies have compared runoff water quality from sites receiving untreated (fresh) and IWC litter. Similarly little published research has evaluated the effects of the IWC process on litter odor. The objectives of this project were to evaluate the environmental impacts of IWC on broiler litter prior to land application under subtropical/semi-arid conditions in Central Texas. Specifically, litter *E. coli*, soil quality, runoff water quality, and odor concentration and characteristics were evaluated.

Methods

In-House Windrow Composting of Broiler Litter

In this demonstration, broiler litter was treated with IWC at commercial broiler farms and land applied in two evaluations (Evaluation 1 in October 2011, Evaluation 2 in May 2012). In both evaluations, a single commercial broiler house was divided in half lengthwise. The litter on one side of the house was formed into a windrow (IWC litter) and the litter in other half was not disturbed (untreated litter). This windrow was formed within 48 hours of broiler removal. A custom made windrowing implement designed by Texas A&M University Department of Biological and Agricultural Engineering (BAEN) students aerated the litter and formed it into a windrow pile approximately 0.6 m tall and 1.5 m wide. The windrow was turned on day 4 in Evaluation 1 and day 5 in Evaluation 2, and the IWC litter and untreated litter were transported to the land application site on day 9 in Evaluation 1 and day 10 in Evaluation 2.

Land Application Site

Eight pasture watersheds, located at the USDA-ARS Grassland, Soil and Water Research Laboratory's Riesel Watersheds near Riesel, TX (Figure 1), received either untreated or IWC litter or did not receive any litter for comparison in this demonstration. Pasture management generally consisted of litter application (surface applied), forage shredding (or grazing), and herbicide application. Specifically, one of the pastures (SW12), a native (remnant) prairie that has never received litter or inorganic fertilizer, served as a reference site. Another pasture (W10), received litter application from 2001-07 and has been rotationally grazed since then; thus, this pasture served as an additional reference site. Neither of these sites, nor the remaining six pasture sites received litter in 2010-2011. Then in 2011-12 (4-Oct-2011) and 2012-13 (14-May-2012), three pastures received IWC litter at 6.7 Mg/ha (3 tons/acre) (P2, P4, SW17), and three pastures received untreated litter at 6.7 Mg/ha (3 tons/acre) (P1, P3, Y14). The 2012-13 application was moved earlier in the year in an attempt to obtain litter with a higher moisture content and thus observe a greater impact of the IWC process. Litter was applied on a dry weight basis to ensure the IWC and untreated litter solids were applied at the same rate.

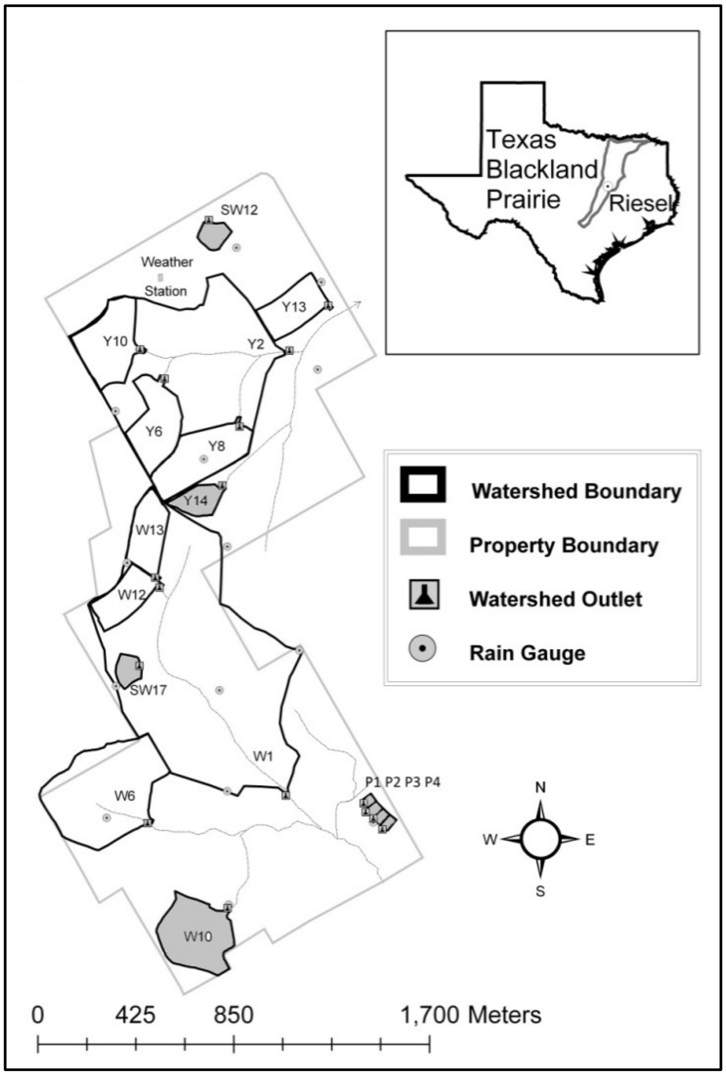

Figure 1: Pasture demonstration sites (shaded in gray) at the USDA-ARS Riesel Watersheds near Riesel, TX.

Litter Sample Collection and Analysis

In each demonstration cycle, samples of untreated and IWC broiler litter were collected at the time of windrow formation and again immediately before land application. These samples were analyzed for *E.*

coli levels with EPA Method 1603 (USEPA, 2006). Samples collected immediately prior to application were also analyzed for moisture content, organic carbon (C), total nitrogen (N), total phosphorous (P), and water soluble Nitrogen and Phosphorous (N and P).

Soil Sample Collection and Analysis

Soil samples were collected from each of the eight demonstration pastures the day prior to and the day of litter application. Five 7.6 cm depth soil cores were collected from three locations in each pasture resulting in three replications for each pasture. These samples were analyzed for *E. coli* concentrations with EPA Method 1603 (USEPA, 2006) to quantify the impact of litter application on soil *E. coli* levels. Additional soil samples were also collected from each pasture within one week of application and at least ten 7.6 cm depth soil cores were collected in each pasture. These samples were composited for each site and analyzed for organic C, as well as N and P concentrations.

Water Quality Sample Collection and Analysis

Data collection began in August 2010 and lasted three full years through July 2013. Runoff data and water quality samples were collected from a flow control structure (v-notch weir or a flume) located at the outlet of each watershed. During runoff events, water quality samples were collected with an ISCO 6700 (ISCO, Inc., Lincoln, NE) automated sampler. Each sampler was programmed to collect frequent flow-interval (1.32 mm volumetric depth) samples and composite them into a single 16 L bottle. Prior to collection of each sample, each sampler executed a rinse of the sample tubing with ambient water. Collected samples represent *E. coli* event mean concentrations (EMCs). Storm event samples were retrieved from the field as soon as possible after runoff events and processed using EPA method 1603 (USEPA, 2006) to enumerate *E. coli* within 6 hours of sample retrieval. Application of untreated and IWC litter produced no significant water quality differences; however, it should be noted that the limited number of runoff samples collected likely influenced this result. Within each sampling year, only 3, 4, and 0 runoff events occurred and is considerably lower than the average of 7 runoff events that occur annually at this location. The timing of runoff, specifically the long delay between litter application and the first runoff event, also reduced the likelihood of significant differences between the demonstrated litter treatment practices. During the first evaluation (2011-12), the first runoff event occurred more than 3 months following litter application and no runoff was recorded following litter application in the second evaluation.

Odor Data Collection and Analysis

Two methods (Nasal Rangers® and sorbent tubes for gas chromatography-mass spectrometry (GC/MS) analysis) were used to collect odor related data in Evaluation 1 and 2, and olfactometry analysis by trained panelists was also used in Evaluation 2. It is important to remember that odor is a person's olfactory perception, which may be either pleasant or offensive, of odorant compounds in the environment (Ullman et al., 2004; Millner, 2009).

Nasal Rangers

To assess ambient air odor concentrations, 18 human volunteers (referred to as monitors) were recruited from the local community. Monitors were screened for olfactory sensitivity to n-butanol "Sniffin" Sticks (St. Croix Sensory, Stillwater, MN). In addition to sensitivity testing, monitors participated in a training session involving odor observation techniques, data recording procedures, and proper technique for using Nasal Rangers. Nasal Rangers are portable devices that detect and measure odors, or olfactometers. Monitors were divided into groups of about four that remained together for all sampling days in an evaluation. Odor data were collected on three mornings during a 5-day period following litter application per evaluation. Monitors recorded dilution to threshold ratio (D/T) data using a Nasal Ranger every 5 min for 2.5 hr. Dilution to threshold ratios, a common method used to objectively determine and report the presence of odors, were determined by taking the volume of carbon filtered air divided by the volume of odorous air. On days of data collection, monitors were instructed to refrain from the use of perfume, aftershave, and cologne, as well as refraining from using tobacco or drinking alcohol as to not interfere with odor readings.

All Nasal Rangers used were calibrated by the manufacturer prior to use, and routine maintenance of the equipment, including changing O-rings and air filters, was conducted by the project managers. Data recorded by the monitors included: 1) date and time of the reading, 2) odor intensity (D/T), and 3) weather conditions. Monitors were stationed upwind of the litter application sites to assess ambient air and downwind at the edge of the application sites to determine the "worst case scenario" of odor perception following the land application of poultry litter.

Dilution to threshold ratio readings were taken by placing the Nasal Ranger over the nose, with the dial in the blank position, and breathing normally through the instrument. As the ambient air was drawn through the charcoal filter with the dial in the blank position, it allowed the monitors to "zero" their nose. They then turned the dial to the highest dilution ratio (60 D/T) and inhaled at the target inhalation rate (16 to 20 L/min as indicated by green LED lights). After inhalation, the dial was rotated to the next position, resumed normal breathing, and determined whether they had smelled an odor at that dilution or not. If they did experience an odor, the monitor recorded it on the data sheet along with the D/T and a descriptor (if applicable) for the odor. If the monitor did not smell an odor at that dilution, they turned the dial to the next lower dilution ratio and repeated the process until they either did or did not experience an odor at the lowest dilution ratio.

Sorbent tubes with GC/MS analysis

Volatile odorants were also collected into stainless steel sorbent tubes from wind tunnel flux chambers placed directly on litter piles in both evaluations. A total of 4 L of air was sampled in the 20 min time period. Three sorbent tube samples per litter type were collected from different locations on each litter pile. The sorbent tubes were analyzed using GC/MS to determine the concentrations of 13 selected odorants (acetic acid, propionic acid, butyric acid, isobutyric acid, valeric acid, isovaleric acid hexanoic acid, phenol, p-cresol, 4-ethylphenol, 2'-aminoacetophenone, indole, and skatole). Odor activity values (OAV) for each compound were determined by dividing the concentration of a compound by the detection threshold for that compound (Patton and Josephson, 1957; Friedrich and Acree, 1998; Trabue et al., 2006). Summed OAV values were also calculated as described by Parker et al. (2012).

Laboratory-based Olfactometric Analysis

In the second evaluation, air samples were also collected directly from the litter piles and in the middle of the untreated and IWC litter application sites on the day following application. Air samples (~ 10 L) were collected into Tedlar bags that were transported to the West Texas A&M University Commercial Core Laboratory. Duplicate samples for both the pile and application site for each type of litter were collected (8 total samples). The air samples were evaluated by trained panelists within 24 hr of collection using a commercial Forced Choice Triangular olfactometer. The panelists were qualified through training, sensory screening, following the code of conduct set forth by the laboratory, and continuous monitoring of their performance. The olfactometer presented the panelist with two air samples, which consisted of two non-odorous samples and one diluted sample to determine if the panelist could differentiate between the samples.

Results

Litter Results

Few differences in IWC and untreated litter composition were observed during both demonstrations and are likely attributed to the low moisture content of litter utilized. IWC litter did reach the desired 55°C threshold; however, the average moisture content ranged from only 18.5 to 21.3%, which is lower than other reported moisture levels in land applied poultry litters.

E. coli levels were typically below the detection limit (10 CFU/g of wet litter) in both untreated and IWC litter (detailed in Appendix I, page 26). Temperatures within IWC windrow cores typically exceeded the 55°C standard set by the EPA to deactivate pathogens, although the outer portions of the windrow did not. This data reiterates the necessity of turning the windrows to expose the maximum amount of litter to the required treatment temperature found in the core of the litter windrow.

Based on laboratory experiments performed by Wilkinson et al. (2011) studying the survival of E. coli in poultry litter under various conditions, it can be concluded that the warm, dry conditions in Central Texas would often produce conditions unfavorable for *E. coli* survival at the time litter is removed from the poultry houses and land applied. In Evaluation 1, *E. coli* counts in litter collected soon after flock removal were 20 CFU/g in the untreated litter and 55 CFU/g in the IWC litter and dropped below the detection limit for both by the end of the IWC period. In Evaluation 2, both litter types had *E. coli* levels < 10 CFU/g soon after flock removal and throughout the IWC cycle; however, untreated litter did have detectable levels (185 CFU/g) at day 10. These results suggest the potential for the IWC process to decrease *E. coli* levels.

In terms of IWC effects on litter nutrient levels, NH_4-N concentrations and moisture content were higher while total P concentrations were lower in IWC litter in the first demonstration. Generally speaking, differences in nutrient concentrations and moisture content observed in IWC and untreated litter were variable within and between demonstrations. It is assumed that wetter litter would likely experience greater change when subjected to the IWC process.

Soil Results

Application of untreated and IWC litter produced no significant differences in soil characteristics. This result is not surprising given the minimum effects of the IWC process on associated litter properties. Similarly, soils from untreated or IWC litter application sites exhibited non-detectable soil *E. coli* (<10 *E. coli*/g soil) following each litter application. This was attributed to low or non-detectable *E. coli* concentrations in the applied litter. Alternatively, soil organic C levels increased on all sites including the controls thus masking the effects of first litter application. Organic C levels recorded following the second litter application were variable regardless of litter type or if it received a litter application or not. Soil test P and soil N levels yielded similar results. Increases were observed following the 2011-12 applications on all sites regardless of litter type or whether they received litter (detailed in Appendix I, page 27) while both increases and decreases were seen in recorded levels following the second application.

Runoff Results

The demonstration produced *E. coli* runoff results that illustrated no significant impact from litter application. Instead, increasing *E. coli* concentrations were noted as land use changed from pasture with litter application to native prairie to grazed pasture (detailed in Appendix I, page 28). *E. coli* concentrations were observed following application of untreated and IWC litter, but increases were also observed in sites with no applied litter. As a result, these increases cannot be attributed directly to litter application. NO_3-N generally decreased in runoff samples while PO_4-P concentrations in runoff increased following application of untreated and IWC litter.

Odor Results

In both evaluations, most odor concentrations were well above their respective human detection thresholds. While results indicate more odor associated with the IWC application sites, the human monitors indicated an “earthy” odor for the IWC litter application site versus a more offensive “manure” odor originating from the untreated litter application site. Laboratory-based olfactometry that measure odor concentration but not odor offensiveness, indicated reductions in detection thresholds of 58-65% thus supporting the potential of IWC to reduce nuisance odor relative to untreated litter.

Cost of Implementing IWC

The cost of implementing IWC on a poultry farm for litter treatment prior to removal for land application will vary greatly depending on several factors including house size, amount of litter in the houses (depth), type and size of windrowing implement, type and size of tractor or skid steer loader utilized, skill of the operator, operator wages, and fuel cost. Total costs to the grower would also depend on whether the grower is performing IWC with on-farm equipment and labor or is paying a contractor with off-farm equipment to perform the work. Estimates obtained from growers and two IWC contractors in Texas for contract implementation of IWC ranged from $125 to $225 per house depending on house size. Costs for a poultry grower to implement IWC using on-farm labor and equipment may be less; however, this is highly dependent upon the specific approach and equipment utilized on the individual farm.

Technology Transfer

As a means to disseminate information on IWC effectiveness, a website (windrowlitter.tamu.edu) was developed that retains information from the demonstrations. The information includes progress reports, fact sheets, presentations and a poster. During the evaluation time period of November 2, 2009 through October 31, 2013, the webpage had a total of 2,143 views by 898 unique users.

Conclusions

Land application is a common and effective method of utilizing the nutrient and organic matter resources in poultry litter, thus many farm and ranch operations import litter as a soil amendment and nutrient source. When litter application is mismanaged, concerns regarding water quality degradation and nuisance odors can arise. In-house windrow composting of litter prior to land application has the potential to mitigate these concerns; however, few studies have evaluated the water quality and odor impacts.

This demonstration was designed to evaluate the effectiveness of IWC to reduce litter bacteria concentrations, improve runoff water quality, and mitigate nuisance odors. Results from this demonstration were largely inconclusive as results varied considerably from sites both receiving and not receiving litter. Fewer than normal runoff producing rain events further hampered the illustration of conclusive findings. Runoff samples illustrated no differences in *E. coli* levels between untreated litter or IWC sites but instead showed considerable variability both within and between demonstrations.

Human monitors noticed a higher concentration of odors when sampling at the edge of the field of IWC litter compared to untreated litter in both evaluations; however, they observed anecdotally that the odor from the untreated litter site had a more offensive “manure” smell than from the IWC site. Laboratory analysis of air samples from sites with untreated or IWC litter were also inconclusive, with apparent increases and decreases of various odorant compounds in the two evaluations; however, combined values were slightly lower indicating potential odor reduction in the IWC litter. Combining laboratory analysis with trained human panelists produced odor detection threshold values that were almost twice as high for untreated litter than IWC litter thus indicating that odors from untreated litter were twice as strong. In spite of the low moisture content of the litter used in this demonstration, in-house windrowing of litter prior to land application does appear to have the potential to be an effective BMP for litter treatment in terms of environmental impacts, especially reduction of nuisance odors.

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Appendix I:

Applied Engineering in Agriculture Publication:

“Environmental Impacts of In-house Windrow Composting of Broiler Litter Prior to Land Application in Subtropical/Semi-Arid Conditions”

Accepted for publication in Applied Engineering in Agriculture

ENVIRONMENTAL IMPACTS OF IN-HOUSE WINDROW COMPOSTING OF BROILER LITTER PRIOR TO LAND APPLICATION IN SUBTROPICAL/SEMI-ARID CONDITIONS

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ABSTRACT

Land application to crop and pasture land is a commonly-applied and effective method of utilizing the resource value of poultry litter. In-house windrow composting of litter is an emerging management practice with the potential to mitigate water quality and nuisance odor concerns associated with land application, but few studies have evaluated these effects. The present study was designed to evaluate the effectiveness of in-house windrow composting to reduce litter bacteria concentrations, improve runoff water quality, and mitigate nuisance odors relative to fresh litter. Results related to bacterial reductions were not definitive due to extremely low Escherichia coli (E. coli) counts in fresh litter prior to in-house windrow composting, which is attributed to dry litter conditions. Likely due to low litter moisture and less than full heating of the windrowed litter, few differences in litter properties or in runoff water quality were observed. In terms of nuisance odor, human monitors reported higher odorant concentrations from the in-house windrow composted litter site, but they noted that the fresh litter application site had a more offensive "manure" smell. Analysis of sorbent tubes also produced inconclusive results related to odor mitigation. Laboratory-based olfactometry, however, determined that the odor detection threshold was almost twice as high (odors were twice as strong) for fresh litter compared to in-house windrow composted litter. In spite of the low moisture content of litter in this study, in-house windrowing of litter prior to land application does appear to have the potential to be an effective litter management practice in terms of environmental impacts, especially reduction of nuisance odors in the subtropical to semi-arid climate of Central Texas. This potential benefit complements other possible benefits such as reduction in food borne pathogens and poultry disease.

KEYWORDS

Compost, water quality, odor, olfactometry, poultry litter, waste management.

INTRODUCTION

In many areas land application is the most common, and usually most desirable, method of utilizing the nutrient and organic matter resources in animal manure and litter (USDA-USEPA, 1999). On a national scale, more than 90% of poultry litter is land applied as a soil amendment and nutrient source (Moore et al., 1995). Poultry litter consists of many different organic materials including manure, spilled feed, bedding material, and feathers and contains valuable N, P, K, and trace minerals (Kelleher et al., 2002; Bolan et al., 2010). Although land application of poultry litter can be a wise resource utilization technique, it can also create water quality and odor concerns. Excessive application rates increase the potential for nutrient and pathogen runoff (Vervoort et al., 1998; Vories et al., 2001; Harmel et al., 2009a). Pope and Cherry (2000) and Terzich et al. (2000) reported that *Staphylococcus*, *Escherichia coli* (*E. coli*), *Salmonella*, and *Campylobacter* are some of the pathogens commonly found in poultry litter. Terzich et al. (2000) reported that *E. coli* concentrations ranged from as low as 1.22×10^5 CFU/g in the Carolinas to 8.8×10^{10} CFU/g in Texas. Conversely, other researchers have found no *E. coli* in litter samples acquired from outer portions of litter compost piles or in inner portions of the same piles (Martin et al., 1998). In addition to potential water quality problems, almost half of the agricultural odor complaints originate from the spreading of animal manure or litter (Ullman et al., 2004). The majority of offensive odors related to poultry litter result from the microbial degradation of feces and uric acid (Ullman et al., 2004).

One possible best management practice (BMP) to reduce water quality and odors concerns associated with poultry litter is heat treatment with in-house windrow composting (IWC) of litter prior to removal from the house and land application. IWC is a relatively simple technique that utilizes natural bacterial metabolism to generate heat within piles formed lengthwise down a broiler house. It can be successfully completed within the broiler house and requires a shorter time span than traditional composting (about 10 days compared to several months) (Bautista et al., 2008; Timmons, 2009). IWC is more accurately referred to as a "pasteurization" process instead of composting because although it uses heat from bacterial metabolism to destroy pathogens, it does not completely convert the litter to a humic-like material as does traditional composting (Timmons, 2009). According to the time-temperature criteria for composting set by the United States Environmental Protection Agency (EPA), a compost pile must maintain a temperature greater than 55°C for a minimum of 3 days for pathogen inactivation to occur (Wichuk and McCartney, 2007).

Several researchers have evaluated the effectiveness of IWC on reducing bacteria in poultry litter. Hartel et al. (2000) found that windrowed litter contained fewer bacteria than non-composted litter, and Macklin et al. (2006, 2008) reported significant reductions in *Salmonella* and other food borne pathogens with IWC. Another study reported that *E. coli* and *C. perfringens* were completely eradicated after windrow composting (Bautista et al., 2008). In a laboratory experiment in which poultry litter was inoculated with *E. coli*, Wilkinson et al. (2011) found that *E. coli* was reduced by more than 99% after 1 hr at 55 °C under laboratory conditions.

While such research has shown the potential for pathogen reduction, no studies have compared runoff water quality from sites receiving fresh (untreated) and IWC litter. Similarly little published research has evaluated the effects of the IWC process on litter odor, although Penn et al. (2011) reported that 60 day litter storage in piles under semipermeable tarps can eliminate malodors and reduce litter volume. Therefore, the objectives of this research were to evaluate the environmental impacts of IWC on broiler litter prior to land application under subtropical/semi-arid conditions in Central Texas. Specifically, litter *E. coli*, soil quality, runoff water quality, and odor concentration and characteristics were evaluated.

MATERIALS AND METHODS

IN-HOUSE WINDROW COMPOSTING OF BROILER LITTER

In this study, broiler litter was in-house windrow composted at commercial broiler farms and land applied in two trials (Trial 1 in October 2011, Trial 2 in May 2012). Both trials were conducted using the same methods except odor collection, which was expanded in Trial 2 based on results from Trial 1. In both trials, a single commercial broiler house was divided in half lengthwise. The litter on one side of the house was formed into a windrow (IWC litter) and the litter in other half was not disturbed (fresh litter). A custom made windrowing implement designed by Texas A&M University Department of Biological and Agricultural Engineering students aerated the litter and formed it into a windrow pile approximately 0.6 m tall and 1.5 m wide. The windrow was turned on day 4 in Trial 1 and day 5 in Trial 2, and the IWC litter and fresh litter were transported to the land application site on day 9 in Trial 1 and day 10 in Trial 2.

LAND APPLICATION SITES

Eight pasture watersheds, located at the USDA-ARS Grassland, Soil and Water Research Laboratory's Riesel Watersheds near Riesel, TX, received either fresh or in-house windrow composted litter or served as control sites for this study (Table 1, Figure 1). The Riesel Watersheds are dominated by Houston Black clay soil (fine, smectitic, thermic, udic Haplustert), which is recognized throughout the world as the classic Vertisol. These highly expansive clays, which shrink and swell with changes in moisture content, have a typical particle size distribution of 17% sand, 28% silt, and 55% clay. These soils are slowly permeable when wet (saturated hydraulic conductivity ≈ 1.5 mm/hr); however, preferential flow associated with soil cracks contributes to high infiltration rates when the soil is dry (Arnold et al., 2005; Allen et al., 2005; Harmel et al., 2006c).

Table 1: Land management and pasture watershed characteristics.

	Watershed Characteristics							
	P1 (fresh)	**P3 (fresh)**	**Y14 (fresh)**	**P2 (IWC)**	**P4 (IWC)**	**SW17 (IWC)**	**SW12 (native)**	**W10 (grazed)**
Area, ha	0.1	0.1	2.3	0.1	0.1	1.2	1.2	8.0
Slope, %	2.8	3.0	1.6	3.0	2.8	1.8	3.8	2.6
	---------- Land Management ----------							
2010-11	renovated[a]	renovated	renovated	renovated	renovated	renovated	hayed[c]	grazed[d]
Litter rate, Mg $ha^{-1}yr^{-1}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2011-12	shredded[b]	shredded	shredded	shredded	shredded	shredded	shredded	grazed
Litter rate, Mg $ha^{-1}yr^{-1}$	6.7	6.7	6.7	6.7	6.7	6.7	0.0	0.0
2012-13	shredded	shredded	shredded	shredded	shredded	shredded	shredded	grazed
Litter rate, Mg $ha^{-1}yr^{-1}$	6.7	6.7	6.7	6.7	6.7	6.7	0.0	0.0

[a] These pastures were renovated by plowing and smoothing, and then they were sewn with oats to reduce soil erosion until the coastal bermuda grass re-established.

[b] The standing vegetation was shredded but not removed.

[c] The standing vegetation was cut and removed for hay.

[d] This pasture was grazed by cattle.

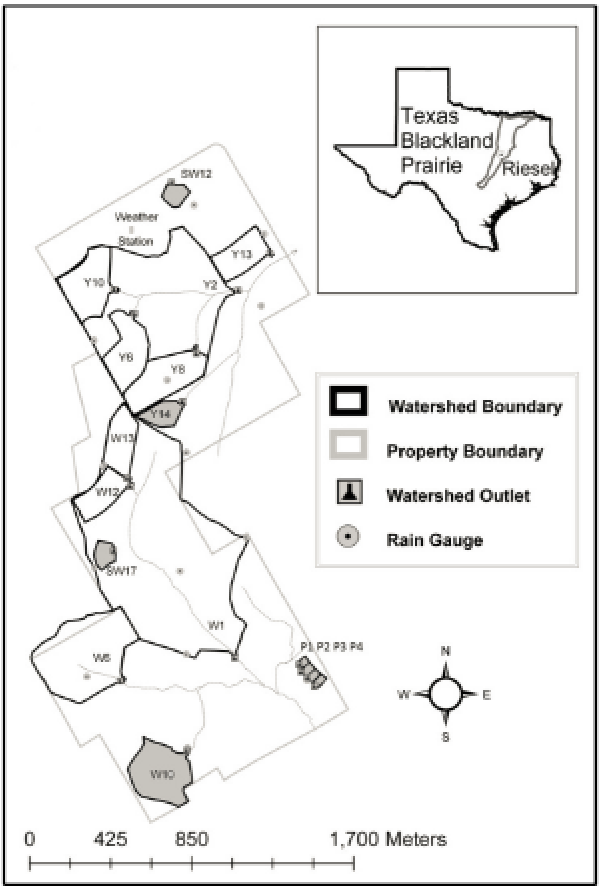

Figure 1: Pasture study sites (shaded in gray) at the USDA-ARS Riesel Watersheds near Riesel, TX.

Pasture watershed management generally consisted of litter application (surface applied), shredding (or grazing), and herbicide application. Specifically, one of the watersheds (SW12), a native (remnant) prairie that has never received litter or inorganic fertilizer, served as a reference and control site. Another watershed (W10), received litter application from 2001-07 and has been rotationally grazed since then; and thus served as an additional control. Neither of these watersheds, nor the remaining six watersheds received litter in 2010-2011, which served as a background year. Then in 2011-12 (4-Oct-2011) and 2012-13 (14-May-2012), three watersheds received IWC litter at 6.7 Mg/ha (P2, P4, SW17), and three watersheds received fresh litter at 6.7 Mg/ha (P1, P3, Y14). The 2012-13 application was moved earlier in the year in an attempt to obtained wetter litter and thus increase the likelihood of observing a greater impact of the IWC process. Litter was applied on a dry weight basis to ensure the IWC and fresh litter solids were applied at the same rate.

LITTER SAMPLE COLLECTION AND ANALYSIS

In each trial, samples of fresh and IWC broiler litter were collected within 24 hr of flock removal. For fresh litter, grab samples were collected from the top 5 cm of the litter using a clean glove at 15 m intervals (resulting in 5-6 sampling locations). The sub samples were composited in a sterile Whirl–Pak bag (NASCO Inc., Fort Atkinson, WI), and the bag was shaken to thoroughly mix the sample. The same procedure was used to sample litter from the windrow piles within 30 min of windrow formation. After transportation from the houses to the application site, litter was sampled again immediately prior to land application by collecting 6-8 composite samples (replications) each composed of 10-12 samples from random locations within the pile. All of these samples were analyzed for *E. coli* levels with EPA Method 1603 (USEPA, 2006). The samples collected immediately prior to application were also analyzed for moisture content, organic C, total N, total P, and water soluble N and P. Moisture content was determined by drying at 65 °C for 16 hr. Organic C was determined using a total C analyzer with the primary sample ignition furnace temperature reduced to 650 °C (McGeehan and Naylor, 1988; Schulte and Hopkins, 1996). Total N was also determined with a combustion process (McGeehan and Naylor, 1988), and total P was determined with a nitric acid digestion and inductively coupled plasma spectrometry (Havlin and Soltanpour, 1989). Water extractable nitrate plus nitrite N (NO_3+NO_2-N), ammonium N (NH_4-N), and orthophosphate P (PO_4-P) concentrations were determined with extraction methodology described in Self-Davis and Moore (2000) and subsequent colorimetric analysis.

SOIL SAMPLE COLLECTION AND ANALYSIS

Soil samples were collected from each of the eight study watersheds the day prior to and the day of litter application. Five 7.6 cm depth soil cores were collected from three locations in each watershed resulting in three replications for each. These samples were analyzed for *E. coli* concentrations with EPA Method 1603 (USEPA, 2006) to quantify to impact of litter application on soil *E. coli* levels.

Additional soil samples were also collected for each watershed within one week of application. At least ten 7.6 cm depth soil cores were collected in each watershed. These samples were composited for each site and analyzed for organic C, as well as N and P concentrations. Soil organic C was determined using a total C analyzer with the primary sample ignition furnace temperature reduced to 650 °C based on McGeehan and Naylor (1988) and Schulte and Hopkins (1996) and by the combustion method at 600 °C and gas chromatograph analysis (Elementar Instruments, 2013). Water soluble organic C was determined by the method of Haney et al. (2012). Soil test P was determined with the Mehlich 3 (Mehlich, 1984) and H3A extractants (Haney et al., 2006) followed by inductively coupled plasma (ICP) analysis. Soil N levels were determined with the methods of Keeney and Nelson (1982), Haney et al. (2006, 2012), and by the combustion method at 900 °C and gas chromatograph analysis (Elementar Instruments, 2013).

WATER QUALITY SAMPLE COLLECTION AND ANALYSIS

Data collection began in August 2010 and lasted three years through July 2013. For each watershed, runoff data and water quality samples were collected from a flow control structure (v-notch weir or a flume) located at the watershed outlet. For runoff events, water quality samples were collected with an ISCO 6700 (ISCO, Inc., Lincoln, NE) automated sampler. Each sampler was programmed to collect frequent flow-interval (1.32 mm volumetric depth) samples and composite them into a single 16 L bottle as discussed in Harmel et al. (2006a, b). Prior to collection of each sample, each sampler executed a rinse of the sample tubing with ambient water. Because the samples were collected on equal flow intervals and composited into a single bottle, the resulting *E. coli* concentrations represent event mean concentrations (EMCs).

Storm event samples were retrieved from the field as soon as possible after runoff events. For *E. coli* analysis, a thoroughly mixed subsample was poured into a 0.7 L sterile, polyethylene Whirl–Pak bag (NASCO Inc., Fort Atkinson, WI). Once the sample bag was approximately ¾ full, it was twirled, securely closed, and checked for leaks by gently squeezing. Samples were stored in a cooler on ice during transport to the laboratory. All water quality samples were stored at 4°C prior to analysis.

Determination of the *E. coli* concentration in each water sample with EPA method 1603 (USEPA, 2006) was initiated within 6 hr of sample retrieval. Four dilutions (10, 1, 0.1, and 0.01 mL) were filtered using 0.45 µm membrane filters. The filters were then placed in petri dishes containing modified mTEC agar and incubated at 35°C ± 0.5°C for 2 ± 0.5 hr to resuscitate injured or stressed bacteria and then incubated at 44.5°C ± 0.2°C for 22 ± 2 hr. Finally, the number of red or magenta colonies were counted and recorded. Ideally, between 20 and 80 colonies appeared on the petri dishes. For quality control, 100 mL of phosphate buffered saline was processed as a blank with each batch of samples, and a lab duplicate was evaluated with each batch.

Samples were also analyzed for dissolved NO_3+NO_2-N and PO_4-P concentrations using colorimetric methods (Technicon 1973a; 1973b) with a Technicon Autoanalyzer IIC (Bran-Luebbe, Roselle, IL) or a Flow IV Rapid Flow Analyzer (O.I. Analytical, College Station, TX). Results for NO_3+NO_2-N in runoff are reported as nitrate N (NO_3-N) because the NO_3-N form dominates.

ODOR DATA COLLECTION AND ANALYSIS

Two methods (Nasal Rangers® and sorbent tubes for gas chromatography-mass spectrometry (GC/MS) analysis) were used to collect odor related data in Trial 1, and olfactometry analysis by trained panelists was also used in Trial 2. It is important to remember that odor is a person's olfactory perception of odorant compounds in the environment, *which may be either pleasant or offensive* (Ullman et al., 2004; Millner, 2009).

Nasal Rangers

To assess ambient air odor concentrations, 18 human volunteers (referred to as monitors) were recruited from the local community. Monitors were screened for olfactory sensitivity to n-butanol "Sniffin" Sticks (St. Croix Sensory, Stillwater, MN). In addition to sensitivity testing, monitors participated in a training session involving odor observation techniques, data recording procedures, and proper technique for using Nasal Rangers (described subsequently). Monitors were divided into groups of about four that remained together for all sampling days in a trial. Odor data were collected on three mornings during a 5-day period per trial. Monitors recorded dilution to threshold ratio (D/T) data using a Nasal Ranger every 5 min for 2.5 hr. Dilution to threshold ratios, a common method used to objectively determine and report the presence of odors, were determined by taking the volume of carbon filtered air divided by the volume of odorous air. On days of data collection, monitors were instructed to refrain from the use of perfume, aftershave, and cologne, as well as refraining from drinking alcohol and tobacco use to not interfere with odor readings.

All Nasal Rangers used were calibrated by the manufacturer prior to use, and routine maintenance of the equipment, including changing O-rings and air filters, was conducted by the project managers. Data recorded by the monitors included: 1) date and time of the reading, 2) odor intensity (D/T), and 3) weather conditions. Monitors were stationed upwind of the litter application sites to assess ambient air and downwind at the edge of the application sites to determine the "worst case scenario" of odor perception following the land application of poultry litter.

Dilution to threshold ratio readings were taken by placing the Nasal Ranger over the nose, with the dial in the blank position, and breathing normally through the instrument. As the ambient air was drawn through the charcoal filter with the dial in the blank position, it allowed the monitors to "zero" their nose. They then turned the dial to the highest dilution ratio (60 D/T) and inhaled at the target inhalation rate (16 to 20 L/min as indicated by green LED lights). After inhalation, the dial was rotated to the next position, resumed normal breathing, and determined whether they had smelled an odor at that dilution or not. If they did experience an odor, the monitor recorded it on the data sheet along with the D/T and a descriptor (if applicable) for the odor. If the monitor did not smell an odor at that dilution, they turned the dial to the next lower dilution ratio and repeated the process until they either did or did not experience an odor at the lowest dilution ratio.

Sorbent tubes with GC/MS analysis

Volatile odorants were also collected into stainless steel sorbent tubes from wind tunnel flux chambers placed directly on litter piles in both trials. The top of the lateral flow wind tunnel was a 0.6 cm thick piece of plexiglass with four 0.9 cm outlet holes from which air samples were collected. The flush gas inlet was a 5.08 x 5.08 cm steel tube with ten 0.3 cm holes spaced 2.5 cm apart. Compressed breathing air was used as the flush gas at a flow rate of 8 L/min. Following the flushing of the chamber, pocket pumps pulled air at a rate of 200 mL/min for 20 min through the stainless steel tubes, and odorants (volatile organic compounds) were absorbed onto the packing material. A total of 4 L of air was sampled in the 20 min time period. Three sorbent tube samples per litter type were collected from different locations on each litter pile. The sorbent tubes were analyzed using GC/MS to determine the concentrations of 13 selected odorants (acetic acid, propionic acid, butyric acid, isobutyric acid, valeric acid, isovaleric acid hexanoic acid, phenol, p-cresol, 4-ethylphenol, 2'-aminoacetophenone, indole, and skatole). These odorants were selected based on previous research (e.g., Wright et al., 2005) and previous experience. P-cresol, which is a naturally occurring metabolic product formed by bacteria under anaerobic conditions (Jones et al., 1993), has received considerable attention because such conditions exist in the rumen or in the digestive tract of non-ruminants; therefore, substantial amounts of p-cresol are excreted by animals (Martin, 1982). Odor activity values (OAV) for each compound were determined by dividing the concentration of a compound by the detection threshold for that compound [as described by Patton and Josephson (1957), Friedrich and Acree (1998), and Trabue et al. (2006)]. Summed OAV values were also calculated as described by Parker et al. (2012).

Laboratory-based olfactometric analysis

In Trial 2, air samples were also collected directly from the litter piles and in the middle of the fresh and IWC litter application sites on the day following application. Pocket pumps collected air samples (~ 10 L) into Tedlar bags that were transported to the West Texas A&M University Commercial Core Laboratory. Duplicate samples for both the pile and application site for each type of litter were collected (8 total samples); additional samples were not collected due to high analysis cost. The air samples were evaluated by trained odor panelists within 24 hr of collection using a commercial Forced Choice Triangular olfactometer. The panelists were qualified through training and sensory screening, and they followed the laboratory code of conduct and had their performance continuously monitored. The olfactometer presented each panelist with two air samples which consisted of two non-odorous blanks and one diluted sample to determine if the panelist could differentiate between them. Results were reported as detection threshold values (odor units/m^3) for each air sample.

STATISTICAL ANALYSIS

One-way analysis of variance (ANOVA) followed by Tukey's pairwise mean comparison (family error rate, α = 0.05) was used to examine whether the IWC process produced significant changes in litter properties, soil C, N, and P levels, water quality constituents, and odor activity values. These statistical tests were conducted with Minitab software (Minitab, 2000) according to procedures described in Helsel and Hirsch (1993) or Haan (2002).

RESULTS AND DISCUSSION

LITTER RESULTS

Data loggers within IWC litter pile indicated that the temperature of the windrow core typically exceeded the 55°C standard set by the EPA to deactivate pathogens, although the outer portions of the windrow did not (these data and related discussion are presented in Winkler, 2013). This result, although surprising because of the low moisture content (Table 2), reiterates the necessity of turning the windrows to expose the maximum amount of litter to the required treatment temperature found in the windrow core.

Few statistically significant differences in IWC and fresh litter were observed in Trial 1 and none in Trial 2 even though the "age" of the litter varied from only four flocks in Trial 1 to 16 flocks in Trial 2. The minimal impacts of the IWC process in this study is attributed to the low moisture content of litter studied, although much of the IWC litter did reach the desired 55°C threshold. The average moisture contents ranged from only 18.5-21.3% (Table 2), which is lower than the range 22-29% reported by Edwards and Daniel (1992) and lower than typical moisture contents of turkey and broiler litter from Central Texas and applied at Riesel from 2001-2010 (avg. = 25.1%) (Harmel et al., 2011).

E. coli levels were typically below the detection limit (10 CFU/g of wet litter) in both fresh and IWC litter (Table 2). As reported in Harmel et al. (2013), warm, dry conditions in Central Texas often produce conditions unfavorable for *E. coli* survival at the time that litter is removed from the poultry houses and land applied (Wilkinson et al., 2011). In Trial 1, *E. coli* counts immediately after flock removal were 20 CFU/g in the fresh litter and 55 CFU/g in the IWC litter, but *E. coli* counts were below the detection limit at the end of the IWC period. In Trial 2, both litter types had *E. coli* levels < 10 CFU/g immediately after flock removal; however, fresh litter did have detectable levels (185 CFU/g) at day 10, whereas IWC litter had levels < 10 CFU/g. Although these levels are quite low, these results suggest the potential for the IWC process to decrease *E. coli* levels.

In terms of IWC effects on litter nutrient levels, NH_4-N concentrations and moisture content were significantly higher and total P concentrations were significantly lower in IWC litter in Trial 1 (Table 2). Tiquia and Tam (2000) reported dramatic decreases in NH_4-N concentrations during the first 35 days of litter composting, but the litter was much wetter (50-60%) in that study, which likely led to much higher microbial activity. The rest of the effects of the IWC process on litter were minimal and not statistically significant. It is assumed that wetter litter would likely experience greater change when subjected to the IWC process.

Table 2: Litter properties presented "as-is" not on a dry-weight basis as means with standard deviations in parentheses.

							Water extractable nutrients		
Applied	**Samples**	**Moisture**	**Organic C**	***E. coli***	**Total N**	**Total P**	**NO_3-N**	**NH_4-N**	**SRP**
	(n)	**(%)**	**(%)**	**(CFU/g)**	**(%)**	**(%)**	-------------(mg/kg)------------		
Trial 1[a]									
IWC	8[c]	21.3 A	28.9 A	< 10[d] A	2.79 A	1.37 A	818 A	3781 A	464 A
		(0.9)	(2.6)	(0)	(0.12)	(0.15)	(310)	(433)	(19)
Fresh	8	19.7 B	29.5 A	< 10 A	2.82 A	1.55 B	1071 A	2148 B	442 A
		(1.0)	(1.8)	(0)	(0.08)	(0.09)	(291)	(878)	(25)
Trial 2[b]									
IWC	6	18.5 A	30.3 A	< 10 A	2.91 A	1.49 A	282 A	3507 A	566 A
		(0.9)	(1.0)	(0)	(0.11)	(0.05)	(62)	(170)	(32)
Fresh	6	19.6 A	30.6 A	185 A	2.77 A	1.43 A	324 A	3831 A	542 A
		(0.9)	(0.7)	(311)	(0.16)	(0.08)	(24)	(1066)	(18)

[a] Trial 1 was initiated in October 2011. The "age" of the litter in Trial 1 was approximately four flocks. The IWC windrow was turned on day 4, and the IWC litter and fresh litter were transported to the land application site on day 9.

[b] Trial 2 was initiated in May 2012. The "age" of the litter in Trial 2 was approximately sixteen flocks. The IWC windrow was turned on day 5, and the IWC litter and fresh litter were transported to the land application site on day 10.

[c] Within each trial, mean values for IWC and fresh litter properties followed by the same letter are not significantly different (α= 0.05).

[d] *E. coli* values below method detection limit of 10 CFU/g of wet litter.

Soil Results

As expected based on the minimal effects of the IWC process on litter properties associated with soil characteristics, application of fresh and IWC litter produced no significant differences in soil characteristics. The very low to non-detectable *E. coli* concentrations in litter contributed to non-detectable soil *E. coli* (< 10 CFU/g soil) for watersheds with application of fresh or IWC litter (data not shown). Similarly, soils in the native prairie (SW12) and the grazed pasture (W10) had non- detectable *E. coli* levels (< 10 CFU/g soil).

Although soil organic C levels did increase on all watersheds that received litter, similar increases were observed for SW12 and W10 that did not receive litter (Table 3); therefore, it is unclear how much litter application and how much interannual variability contributed to these increases. The water soluble organic C method of Haney et al. (2012) seemed to be able to better separate the impact of litter application in Trial 1. All watersheds with litter increased > 83 mg/kg following application, whereas the grazed pasture (W10) increased 37 mg/kg and native prairie (SW12) decreased. Following the initial increase, organic C and water soluble organic C decreased on all watersheds in Trial 2, regardless of litter type or whether or not the watershed received litter application.

Similar to organic C levels, soil test P and soil N levels increased in 2011-12 on all watersheds regardless of litter type or whether they received litter (Table 4, 5). The most dramatic differences were not related to fresh versus IWC litter but to differences in previous litter application rates. All of the 0.1 ha plots (P1, P2, P3, P4) along with SW12 and SW17 had never received litter application. In contrast, W10 received 6.7 Mg/ha and Y14 received 13.4 Mg/ha from 2001-2007; therefore, these watersheds have higher initial soil test P values (Table 4). This influence of previous litter application was also apparent in NO_3-N and water soluble organic N levels on Y14 (Table 5).

Table 3: Soil organic C data from watersheds with fresh and IWC litter application presented along with data from a native prairie and a grazed pasture. No significant differences were observed in mean values between the fresh and IWC treatments.

Year	P1 (fresh)	P3 (fresh)	Y14 (fresh)	P2 (IWC)	P4 (IWC)	SW17 (IWC)	SW12 (native)	W10 (grazed)
	organic C[a] (%)							
2010-11	2.10	1.97	2.56	2.00	1.88	2.08	3.39	2.59
2011-12	2.66	2.46	3.09	2.74	2.53	2.45	4.38	3.26
2012-13	2.89	2.34	3.61	2.57	2.34	2.73	4.67	4.20
	organic C[b] (%)							
2010-11	1.57	1.57	2.44	1.58	1.53	2.04	2.90	2.47
2011-12	2.01	1.99	2.84	2.14	2.08	2.43	4.22	3.11
2012-13	2.43	1.70	3.22	2.08	1.87	2.29	4.18	3.68
	water soluble organic C[c] (mg/kg)							
2010-11	241	254	375	241	272	292	377	368
2011-12	418	393	462	563	369	375	362	405
2012-13	324	268	347	249	246	300	268	323

[a] McGeehan and Naylor (1988) and Schulte and Hopkins (1996).
[b] Elementar Instruments (2013).
[c] Haney et al. (2012).

Table 4: Soil P data from watersheds with fresh and IWC litter application presented along with data from a native prairie and a grazed pasture. No significant differences were observed in mean values between the fresh and IWC treatments.

Year	P1 (fresh)	P3 (fresh)	Y14 (fresh)	P2 (IWC)	P4 (IWC)	SW17 (IWC)	SW12 (native)	W10 (grazed)
	Mehlich3-ICP[a] (mg/kg)							
2010-11	5	5	87	4	5	7	6	26
2011-12	32	26	135	59	34	35	12	73
2012-13	64	41	162	38	44	43	6	62
	H3A-ICP[b] (mg/kg)							
2010-11	2	2	16	2	2	3	4	6
2011-12	8	9	30	19	9	13	4	14
2012-13	18	12	44	15	14	18	5	16

[a] Mehlich (1984).
[b] Haney et al. (2006).

Table 5: Soil N data from watersheds with fresh and IWC litter application presented along with data from a native prairie and a grazed pasture. No significant differences were observed in mean values between the fresh and IWC treatments.

Year	P1 (fresh)	P3 (fresh)	Y14 (fresh)	P2 (IWC)	P4 (IWC)	SW17 (IWC)	SW12 (native)	W10 (grazed)
NO$_3$-N[a] (mg/kg)								
2010-11	2	3	22	2	2	7	5	7
2011-12	20	17	37	21	15	18	25	31
2012-13	21	15	38	20	20	22	3	3
NO$_3$-N[b] (mg/kg)								
2010-11	3	3	15	2	3	6	9	3
2011-12	18	15	36	17	12	18	22	29
2012-13	28	19	45	27	24	26	7	8
NH$_4$-N[b] (mg/kg)								
2010-11	0.3	0.5	2	0.4	0.3	4	3	4
2011-12	3.5	3.9	3.6	12.9	5.5	2.7	0.7	1.3
2012-13	8.5	7.0	4.1	8.7	9.0	4.9	2.7	3.3
water soluble organic N[c] (mg/kg)								
2010-11	15	15	32	14	17	20	19	24
2011-12	58	56	41	102	61	45	31	41
2012-13	44	35	46	36	25	25	20	29
total N[d] (%)								
2010-11	0.12	0.10	0.19	0.10	0.09	0.14	0.22	0.22
2011-12	0.16	0.17	0.27	0.16	0.17	0.19	0.32	0.26
2012-13	0.17	0.12	0.24	0.14	0.13	0.20	0.30	0.28

[a] Keeney and Nelson (1982).
[b] Haney et al. (2006).
[c] Haney et al. (2012).
[d] Elementar Instruments (2013).

WATER QUALITY RESULTS

As expected based on the minimal effects of the IWC process on litter properties associated with water quality, application of fresh and IWC litter produced no significant water quality differences (Table 6). This result was affected by the limited amount of runoff. The years in this study produced only 3, 4, and 0 runoff events, which is considerably lower than the more than seven runoff sampling events per year on average in the period 2000-2008 reported by Harmel et al. (2009a). The timing of runoff, specifically the long delay between litter application and the first runoff event, also reduced the likelihood of significant differences between the treatments. In the Trial 1 period (2011-12), the first runoff event occurred more than 3 months following litter application. Following litter application in Trial 2, runoff did not occur for the remaining study duration.

The present study produced similar *E. coli* runoff results as those presented in Harmel et al. (2013). Both studies demonstrated no significant impact of litter application, and both reported increasing *E. coli* concentrations as land use changed from pasture with litter application to native prairie to grazed pasture (Table 6). As stated in Harmel et al. (2013), improved wildlife habitat and presumably wildlife abundance and biodiversity likely contributed to increased *E. coli* runoff from the native prairie (Aschwanden et al., 2007). Similarly, Harmel et al. (2010, 2013) demonstrated the potential for increased *E. coli* runoff for grazed pastures relative to litter or compost applied pastures.

Runoff *E. coli* concentrations did increase following application of fresh and IWC litter, but increases were also observed in watersheds with no applied litter; therefore, it is doubtful that litter application produced these increases. Similarly, NO_3-N and PO_4-P concentrations did increase following application of fresh and IWC litter. This increase was expected as these watersheds had received no fertilizer nutrient additions in recent years.

Table 6: Average annual concentrations of selected water quality constituent data from watersheds with fresh and IWC litter application presented along with data from a native prairie and a grazed pasture. No significant differences were observed in mean values between the fresh and IWC treatments.

Year	P1 (fresh)	P3 (fresh)	Y14 (fresh)	P2 (IWC)	P4 (IWC)	SW17 (IWC)	SW12 (native)	W10 (grazed)
				NO_3-N (mg/L)[a]				
2010-11	1.52	0.89	0.00	1.11	0.60	0.38	0.61	0.51
2011-12	1.08	0.67	0.27	0.82	1.34	0.20	0.24	0.15
2012-13	-[b]	-	-	-	-	-	-	-
				PO_4-P (mg/L)[c]				
2010-11	0.25	0.24	0.50	0.24	0.26	0.24	0.22	0.77
2011-12	0.89	0.55	0.97	0.74	0.91	0.48	0.12	0.31
2012-13	-	-	-	-	-	-	-	-
				E. coli (CFU/100 mL)[d]				
2010-11	190	50	410	193	10	200	1200	6900
2011-12	3008	2037	2233	5186	861	860	3575	24,180
2012-13	-	-	-	-	-	-	-	-

[a] The uncertainty for average annual NO_3-N concentrations is estimated to be ±11% based on Harmel et al. (2009b).

[b] No runoff occurred during this year.

[c] The uncertainty for average annual PO_4-P concentrations is estimated to be ±10% based on Harmel et al. (2009b).

[d] The uncertainty for average annual *E. coli* concentrations is estimated to be ±45% based on McCarthy et al. (2008).

ODOR RESULTS

Nasal Rangers

In both trials, a majority of the Nasal Ranger readings (57% in Trial 1 and 89% in Trial 2) were non-detectable (these data and additional discussion are presented in Winkler, 2013). Many of the non-detectable readings occurred at the upwind site used to verify that the downwind odors originated from the application site, and the fresh litter site did have fewer odor detects than the IWC site. While these results indicate more odor associated with the IWC application sites, the human monitors were not able to accurately characterize the odor descriptors for either site. However, their anecdotal observations did indicate an "earthy" odor for the IWC litter application site versus a more offensive "manure" odor originating from the fresh litter application site. It is important to remember that the Nasal Rangers (as well as sorbent tubes with GC/MS analysis and laboratory-based olfactometry discussed subsequently) measure odor concentration but not odor offensiveness, also called "hedonic tone".

Sorbent tubes with GC/MS analysis

GC/MS analysis indicated several significant differences in odorants associated with fresh and IWC litter (Table 7). The only statistically significant change in Trial 1 was the increase in isobutyric acid, but several significant changes were observed in Trial 2. Concentrations of acetic acid, butyric acid, isobutyric acid, propionic acid, and valeric acid decreased, but concentrations of hexanoic acid, p-cresol, and phenol increased. The results from GC/MS analysis for isovaleric acid and skatole were removed from the analysis due to problems with analytical standards for these odorants and possible transcription errors in Trial 2. The summed OAV values for IWC litter were lower than for fresh litter in both trials, indicating a potential reduction in total odorant concentrations. Although some level of litter pasteurization occurred for the IWC litter in both trials as indicated by measured windrow temperatures, which likely prompted microbial decomposition, consistent reductions in odorant compounds were not observed.

In both trials, most of the odorant concentrations were well above their respective human detection thresholds. The exceptions were acetic acid, which occurred at concentrations near its detection threshold and 4-ethylphenone, which occurred at levels well below its detection threshold. Based on these results, 4-ethylphenone can likely be disregarded in future evaluations of poultry litter odor.

Table 7: Results of gas chromatography-mass spectrometry (GC/MS) analysis presented as odor activity values.

Compound	**Description**	**Detection Threshold (mg/m^3)**	**Fresh Trial 1**	**IWC Trial 1**	**Fresh Trial 2**	**IWC Trial 2**
			------------------ OAV[a] ------------------			
2'-aminoacetophenone	Bat cave; taco shell	0.514	3.4 ±2.8	0.7 ±0.06	7.0 ±4.4	12.0 ±2.1
4-ethylphenol	Spice; horse manure	13.0	0.4 ±0.4	0.1 ±0.05	0.3 ±0.1	0.2 ±0.04
Acetic Acid	Sour; vinegar	2.03	1.1 ±1.3	1.5 ±0.9	3.8 ±1.1	0.9 ±0.3*
Butyric Acid	Body odor; vomitus	0.034	72.8 ± 82.0	309.0 ±254.5	7.9 ±0.7	1.4 ±1.1*
Hexanoic Acid	Foul	0.18	39.6 ±7.1	71.8 ±57.1	3.3 ±5.6	118.3 ±53.8*
Indole	Piggy; musty	0.004	307.4 ±264.7	8.1 ±4.3	3,017.3 ±563.0	2,595.1 ±138.2
Isobutyric Acid	Rancid; butter	0.123	45.3 ±38.1	572.8 ±107.9[b]	32.6 ±21.6	1.02 ±0.9**
P-cresol	Barnyard	0.01	1,573.4 ±1595	725. 9 ±425	13.6 ±8.4	389.0 ±263.6**
Phenol	Medicinal; floral	0.734	56.9 ±56.5	24.6 ±0.8	8.8 ±0.9	12.9 ±1.0*
Propionic Acid	Body odor; vomitus	0.35	16.8 ±11.4	12.3 ±5.5	96.1 ±24.0	58.8 ±9.0**
Valeric Acid	Foul	0.036	53.2 ±42.8	59.5 ±44.07	222.57 ±17.6	91.1 ±56.2*
		Summed OAV	2170	1786	3416	3281

[a] Odor activity values (OAV) = concentration/detection threshold (mean ± standard deviation).
* Significant difference in odorant OAV in fresh and IWC litter at $\alpha = 0.05$.
** Significant difference in odorant OAV in fresh and IWC litter at $\alpha = 0.10$.

Laboratory-based olfactometric analysis

Whereas Nasal Ranger tests and sorbent tube with GC/MS analyses produced inconclusive results, laboratory-based olfactometry indicated definitive nuisance odor reduction in IWC litter. Detection threshold values (odor units/m^3)

as perceived by olfactometry panelists for air samples from IWC treatments were less than half of the values of those collected from fresh litter (Table 8). These empirical data with reductions in detection thresholds of 58-65% support the potential of IWC to reduce nuisance odor relative to fresh litter, even in subtropical/semi-arid climate in Central Texas and the resulting dry litter conditions.

Table 8: Detection threshold (DT) values (odor units/m^3) determined by olfactometry with human panelists for air samples collected from litter application sites and litter piles in Trial 2.

Location	Treatment	DT (odor units/m^3)	Average DT (odor units/m^3)	DT % reduction
Application site	Fresh	1,011	1,220	65%
	Fresh	1,429		
	IWC	602	428	
	IWC	254		
Litter pile	Fresh	4,082	4,082	58%
	Fresh	-[a]		
	IWC	2,030	1,731	
	IWC	1,432		

[a] The Tedlar bag for this sample was punctured in transport, thus it could not be analyzed.

CONCLUSIONS

Land application is a common and effective method of utilizing the nutrient and organic matter resources in poultry litter, thus many farm and ranch operations import litter as a soil amendment and nutrient source; however, concerns associated with mismanaged land application include contributions to water quality degradation and nuisance odors. Although one emerging BMP - in-house windrow composting of litter prior to land application - has the potential to mitigate these concerns, few studies have evaluated the water quality and odor impacts.

The present study was designed to evaluate the effectiveness of IWC to reduce litter bacteria concentrations, improve runoff water quality, and mitigate nuisance odors. Bacterial results were not definitive due to the extremely low counts in fresh litter prior to IWC treatment, which is attributed to the dry litter conditions present at the time of sampling. Although portions of the IWC litter did reach the EPA temperature standard for composting, which was surprising because of the low moisture content, the outer portions of the windrows did not. As a result of low litter moisture and less than full heating of the windrowed litter, few differences in fresh and IWC litter were observed. Although the experimental setup in this study justified lack of water addition, increasing the moisture content in IWC efforts would increase the potential for pathogen and odor reduction; however, the logistics and production impacts of adding water would have to be carefully weighed.

In addition, no significant differences were observed in runoff water quality from the watersheds that received fresh and IWC litter. However, this was not surprising as recently published research in Central Texas concluded that land application of litter had little impact on runoff *E. coli* concentrations. In that study, Harmel et al. (2013) attributed the lack of increase in *E. coli* runoff to the late summer target application date in which litter was produced and removed from poultry houses during hot, dry conditions unfavorable for *E. coli* survival.

In terms of nuisance odor mitigation, human monitors using Nasal Rangers noticed a higher concentration of odors when sampling at the edge of the field of IWC litter compared to fresh litter in both trials; however, they observed anecdotally that the odor from the fresh litter site, while low in concentration, had a more offensive "manure" smell than from the IWC site, which had an "earthy" smell. Laboratory GC/MS analysis of air samples from sites with fresh or IWC litter were also inconclusive, with apparent increases and decreases of various odorant compounds in the two trials; however, the summed OAV values were slightly lower indicating potential odor reduction in the IWC litter. The most conclusive support of the potential of IWC to reduce nuisance odor were the results from laboratory-based olfactometry with trained panelists. With this method the detection threshold values for air samples collected from IWC and fresh litter piles and land application sites were almost twice as high for fresh litter, which indicates odors from fresh litter were twice as strong.

In spite of the low moisture content of the litter used in this study, in-house windrowing of litter prior to land application does appear to have the potential to be an effective litter management BMP in terms of environmental impacts, especially reduction of nuisance odors in the subtropical to semi-arid climate of Central Texas. This potential benefit complements additional benefits such as reduction in food borne pathogens (Macklin et al., 2008) and poultry disease (Giambrone et al., 2008).

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Appendix II:

Poultry Litter Field Day Agenda

TEXAS A&M AGRILIFE
RESEARCH | EXTENSION

USDA ars Agricultural Research Service

POULTRY LITTER FIELD DAY

Wednesday, July 10, 8:00am – 1:00pm

Riesel High School
600 East Frederick Street, Riesel, TX 76682

Agenda:

8:00-8:30:	Registration, Coffee, and Donuts
8:30-8:55:	**Summary of Economic and Environmental Results 2001-2012** Dr. Daren Harmel, USDA-ARS
8:55-9:20	**In-House Windrow Composting** Dr. Craig Coufal, Texas AgriLife Extension
9:20-9:45	**Assessment of Bacteria in Litter** Dr. Terry Gentry, Texas AgriLife Research
9:45-10:00	Break
10:00-10:25	**Impact of Composting on Litter Nutrient Levels and Odor** Dr. Craig Coufal, Texas AgriLife Extension
10:25-10:50	**Litter Management, Application Rate/Process and Spreader Calibration** Dr. Saqib Mukhtar, Texas AgriLife Extension
10:50-11:00	Travel to Field Site
11:00-12:00pm	**Field Demonstration of Windrow Process** Project Team
12:00pm	Lunch Meal sponsored by the **Texas Poultry Federation**

TEXAS POULTRY FEDERATION

Texas Water Resources Institute
make every drop count

TSSWCB

Appendix III:

Poultry Litter Field Day Press Release

Poultry litter field day set for July 10 in Riesel

View all articles by Paul Schattenberg → June 13, 2013

RIESEL- Management of poultry litter will be the focus of a field day to be held July 10 at Riesel High School, 600 E. Frederick St. in Riesel.

Located in McLellan County, Riesel is part of the Waco Metropolitan Statistical Area.

The field day is hosted by the Texas A&M AgriLife Extension Service, Texas Water Resources Institute, the U.S. Department of Agriculture's Agricultural Research Service and the Texas A&M University poultry science department.

There is no cost to attend, and lunch will be provided by the Texas Poultry Federation.

Registration begins at 8 a.m. with presentations to start at 8:30 a.m.

Poultry production has expanded significantly in Central in Texas in recent years, said Matt Brown, Texas Water Resources Institute program assistant.

Texas Water Resources Institute is part of Texas A&M AgriLife Research, AgriLife Extension and the College of Agriculture and Life Sciences at Texas A&M University.

"Poultry litter — the combination of bedding material and manure — is a great source of plant nutrients," Brown said. "However, if improperly managed, litter removed from these poultry facilities and applied to the land can represent a threat to water quality through bacterial and nutrient runoff from these fields."

Certain best management practices can reduce the environmental impacts of poultry litter, he said.

A program on poultry litter composting will be held July 10 in Riesel. In-house windrow composting is a cost-effective practice that reduces the amount of microorganisms in poultry litter before removal. (Texas A&M AgriLife Extension Service photo)

Brown said program attendees will learn about in-house windrow composting, a management strategy used by commercial poultry producers to reduce pathogenic microorganisms in litter.

Presentations also will address the economic and environmental impacts of poultry litter application, bacteria found in poultry litter, the effect of composting on litter nutrient levels and odor, spreader calibration and litter application, and various additional litter management practices.

"Attendees need to come prepared to travel, because following the presentations participants will see a demonstration of the windrow process at the Agricultural Research Service Grassland, Soil and Water Research Laboratory located a few miles from the high school," he said.

The group will return to the high school for lunch.

Holders of Texas Department of Agriculture private pesticide applicator licenses will be offered two continuing education units in the general category.

RSVP by July 8 to Shane McLellan, AgriLife Extension agent for McLennan County, at 254-757-5180 or s-mclellan@tamu.edu.

The In-House Windrow Composting of Poultry Litter project is managed by the Texas Water Resources Institute, part of AgriLife Research, AgriLife Extension and the College of Agriculture and Life Sciences. The project is funded through a Clean Water Act grant provided by the Texas State Soil and Water Conservation Board and U.S. Environmental Protection Agency.

An agenda and more information can be found at the project website, windrowlitter.tamu.edu.

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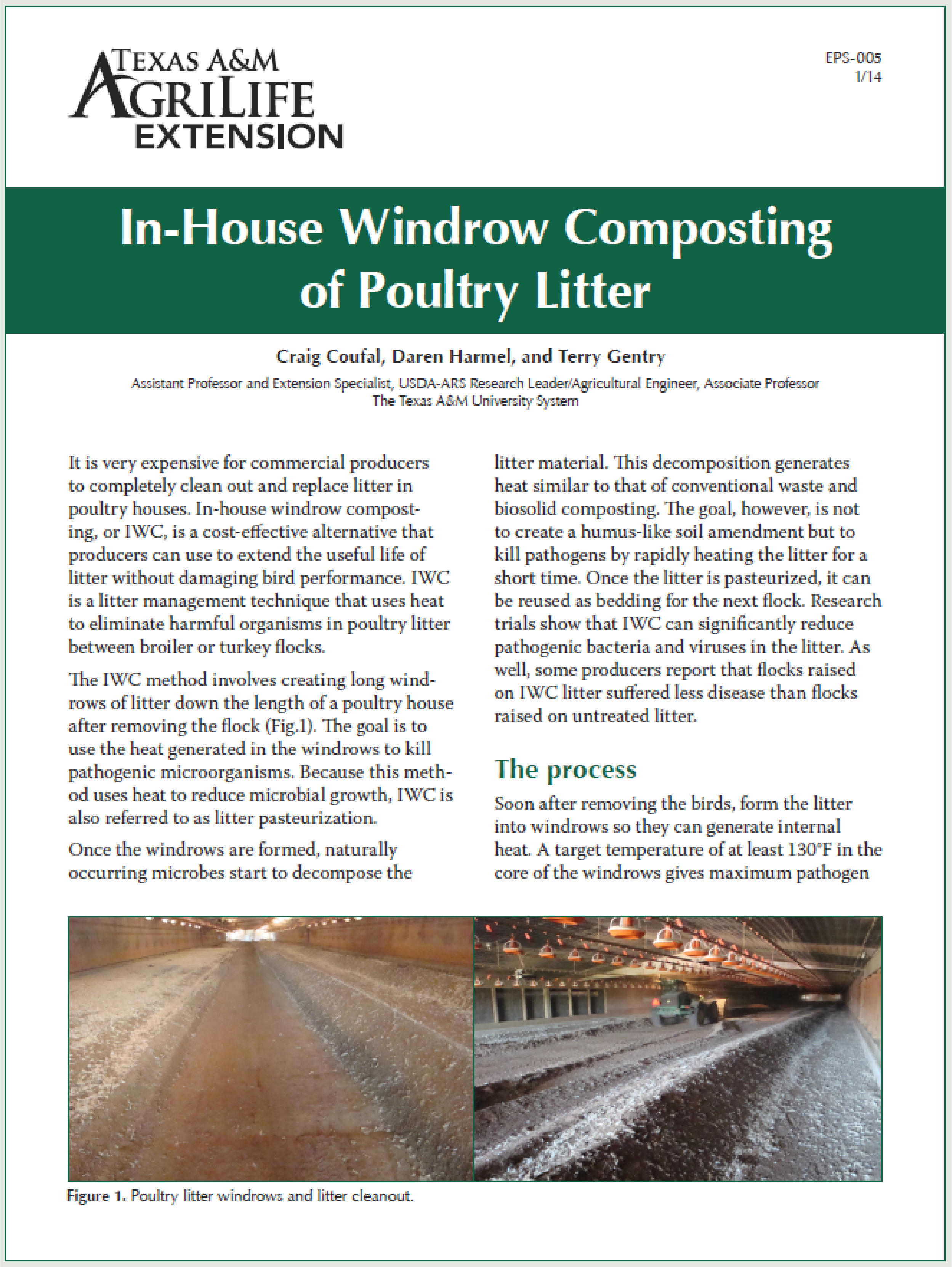
Appendix IV:

AgriLife Extension Fact Sheet:

In-House Windrow Composting of Poultry Litter



TEXAS A&M AGRILIFE EXTENSION

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In-House Windrow Composting of Poultry Litter

Craig Coufal, Daren Harmel, and Terry Gentry

Assistant Professor and Extension Specialist, USDA-ARS Research Leader/Agricultural Engineer, Associate Professor
The Texas A&M University System

It is very expensive for commercial producers to completely clean out and replace litter in poultry houses. In-house windrow composting, or IWC, is a cost-effective alternative that producers can use to extend the useful life of litter without damaging bird performance. IWC is a litter management technique that uses heat to eliminate harmful organisms in poultry litter between broiler or turkey flocks.

The IWC method involves creating long windrows of litter down the length of a poultry house after removing the flock (Fig.1). The goal is to use the heat generated in the windrows to kill pathogenic microorganisms. Because this method uses heat to reduce microbial growth, IWC is also referred to as litter pasteurization.

Once the windrows are formed, naturally occurring microbes start to decompose the litter material. This decomposition generates heat similar to that of conventional waste and biosolid composting. The goal, however, is not to create a humus-like soil amendment but to kill pathogens by rapidly heating the litter for a short time. Once the litter is pasteurized, it can be reused as bedding for the next flock. Research trials show that IWC can significantly reduce pathogenic bacteria and viruses in the litter. As well, some producers report that flocks raised on IWC litter suffered less disease than flocks raised on untreated litter.

The process

Soon after removing the birds, form the litter into windrows so they can generate internal heat. A target temperature of at least 130°F in the core of the windrows gives maximum pathogen

Figure 1. Poultry litter windrows and litter cleanout.

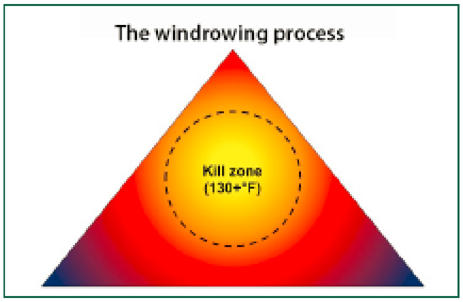

Figure 2. Target temperature in windrow core.

reduction (Fig. 2). The outer layers of the windrow will not reach temperatures high enough to kill pathogens, so the windrows must be turned after 3 or 4 days. This involves reforming the windrow so that litter from the outer edges of the pile moves into the center allowing the maximum amount of the litter to reach the target temperature. This also aerates the litter; aeration encourages heating in the reformed windrow.

Figure 3 shows temperatures recorded in the core of litter windrows during a Texas broiler farm trial. Windrows of the right size and moisture will typically heat to over 130°F in 24 to 36 hours. After 12 to 24 hours at peak temperature (often as high as 150°F) windrow temperatures will slowly decrease. Once they begin to cool, turn them. The sudden drop in temperature on day 4 is when the data loggers were removed and the windrows turned. Figure 3 also shows that the internal temperature of the windrows can vary greatly. This variability is influence by moisture, the amount of oxygen available in the windrow, its shape and size, and the placement of the temperature probes.

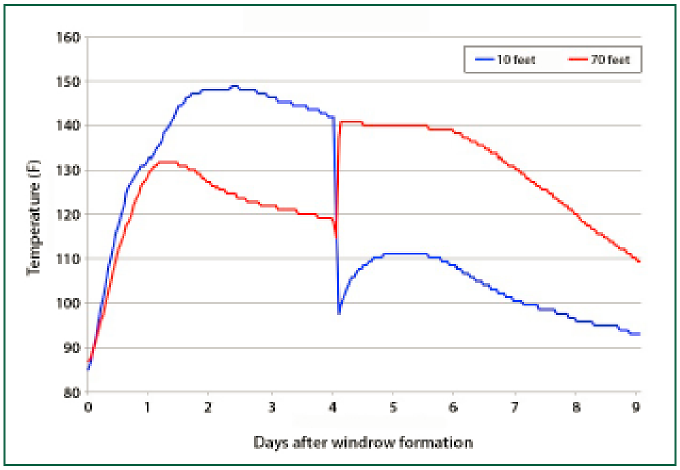

Figure 3. Core windrow temperatures recorded by data loggers at 10 feet and 70 feet from the end of a litter windrow on the cool pad end of a broiler house. Data loggers removed during turning on day 4.

Procedure

The following are generally accepted procedures for IWC in poultry houses. For optimum results, customize these operations according to litter conditions, scheduling, and operator experience.

1. Construct windrows within 2 days of removing the birds. Run the windrows the length of the house at 18 to 24 inches tall. If caked litter is excessive, remove some (e.g., from under the drinker lines) before forming the windrows. This will reduce excess moisture and possible ammonia problems when the litter is spread for chick placement.
2. Monitor windrow temperatures. Temperature can be measured with any type of thermometer as long as the stem or probe can reach the center of the pile—approximate 12 inches. If 130°F is not reached within 48 hours, successful composting is not likely. Try again by turning litter or level it out.
3. Turn the windrows 3 or 4 days after first forming them. Work the rows so that litter moves from the outside to the inside of the newly formed windrow. If there is enough time between flocks and the litter is sufficiently moist, turn the litter a second time and take advantage of a 3rd heat cycle.
4. Level the litter out 3 or 4 days after reforming windrows. Level the litter bed at least 4 days before placing the next flock to give moisture and ammonia enough time to purge from the litter.

IWC considerations

Equipment: Producers have been most successful with equipment that is specially designed for IWC. This equipment does the job more quickly and gives the windrows a more consistent size and shape. However, windrows can be formed with standard equipment such as a 3-point mounted angle blade or skid loader with a bucket.

Litter moisture: IWC is a microbial-driven process. For it to work, the litter must be moist enough to support microbial growth. The minimum recommended moisture content is approximately 25 percent. The optimum moisture content is 30 to 35 percent. If there is too little moisture (less than 25 percent) core windrow temperatures will likely not reach 130°F. If the litter is too moist (more than 35 percent) leveled litter will not be dry enough to avoid volatilizing excessive ammonia at chick placement.

Layout time: Proper IWC and litter purging takes at least 12 days, especially if initial litter moisture is high. IWC is not recommended if the layout time between flocks is less than 12 days. Trying to treat litter in windrows too quickly will likely not reduce microbes sufficiently. As well, purging litter for too short a time after windrow leveling will result in ammonia problems from litter that is not dry enough.

Litter depth: Keep the litter in the houses between 4 and 6 inches thick. Litter that is too deep takes longer to work and is more difficult, if not impossible, to form into windrows. Four to 6 inches of litter in a typical broiler house makes 2 windrows per house. Litter that is more than 6 inches deep will likely require 3 windrows.

Cost: The cost of implementing IWC depends on whether to work is done in house or contracted out. Rates vary by region and house size, but contractor rates of $125 to $300 per house have been reported. IWC using on-farm labor and equipment requires 1 to 1.5 hours forming the windrows, 0.5 to 1 hour turning the windrows, and 1 to 2 hours leveling the litter back out for a total of 3 to 4 hours per house. This is comparable to the time it takes to decake an entire house with a traditional decaking machine.

Ammonia concerns: Some producers have observed high ammonia volatilization after the litter is leveled out, particularly after the first time litter is windrowed. Managing litter moisture before forming windrows is essential to preventing this problem. After the windrows are leveled out and before placing new chicks, ventilate the house completely to remove ammonia and moisture from the litter. Producers have reported fewer ammonia problems after performing IWC for several consecutive flocks.

IWC as litter treatment for land application

When planning a partial house cleanout, it can be beneficial to use IWC before removing the litter. Traditional composting reduces pathogens and offensive odors and stabilizes the decomposition of organic materials. Texas A&M University and USDA-ARS have evaluated IWC for treating litter before applying it to land. The project showed that treatment reduced offensive odors without changing the nutrient content of the litter. In addition, the litter that remained in a partial cleanout benefitted from the pasteurization effects of IWC.

For more information, contact Dr. Craig Coufal (ccoufal@poultry.tamu.edu), Assistant Professor and Extension Specialist, Department of Poultry Science.

Texas A&M AgriLife Extension Service
AgriLifeExtension.tamu.edu

More Extension publications can be found at *AgriLifeBookstore.org*

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The Texas A&M University System, U.S. Department of Agriculture, and the County Commissioners Courts of Texas Cooperating.

Appendix V:

Student Poster:

Effect of In-House Windrow Composting on Odors During Land Application

Effect of In-house Windrow Composting on Odors During Land Application

Scott Winkler[1], Craig Coufal[1], Daren Harmel[2] and Edward Caraway[3]

[1]Poultry Science Department, Texas A&M University, [2]USDA-ARS, Temple, TX, [3]West Texas A&M University, Canyon, TX.

ABSTRACT

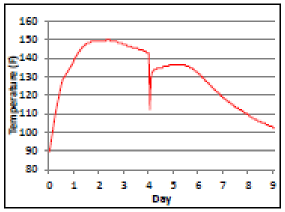
Managing odors associated with livestock feeding operations can be difficult, especially as urban growth expands into traditionally agricultural areas. A frequent cause of nuisance odor complaints is the land application of poultry litter. Composting is an aerobic process known to stabilize organic wastes and reduce the potential for offensive odors. In-house windrow composting (IWC) of poultry litter has become a common litter management practice in the poultry industry. An experiment was conducted to determine if IWC could influence odors during the land application of poultry litter. A commercial broiler house was divided in half length-wise. The litter on one side of the house was formed into a windrow (treated litter) and the other half of the house was not disturbed (raw litter). The windrow was turned on day 4, and both types of litter were removed from the house and hauled to the litter application site on day 9. Both types of litter were land applied to separate, nonadjacent fields the following day. Volatile gases were collected onto sorbent tubes from wind tunnel flux chambers placed directly on litter piles prior to application. The concentrations of 13 compounds commonly associated with animal manure were then determined by GC/MS. Concentrations were converted to odor activity values (OAV) by dividing the concentration of each compound by a detection threshold value. Human panelists also assessed odor concentration by taking edge-of-field measurements using Nasal Ranger® Field Olfactometers. Results of GC/MS analysis indicated that OAV values for butyric, isobutyric, isovaleric and hexanoic acids were greater in the treated litter compared to the raw litter by 325, 1164, 58 and 82%, respectively. However, phenol, P-cresol, 4-ethylphenol, 2-aminoacetophenone, and indole OAV values for the treated litter were 57, 54, 74, 79, and 97%, respectively, lower than the raw litter. Panelist data indicated higher odor concentrations at the treated litter field. These data indicate that IWC treatment of litter can alter the odor profile, but may not reduce the total amount of volatiles released during land application.

OBJECTIVE AND HYPOTHESIS

- The objective of this experiment is to determine the effectiveness of IWC as a litter treatment process to influence odors during the land application of poultry litter.
- Our hypothesis is that IWC will reduce offensive odors associated with poultry litter at the time of and application.

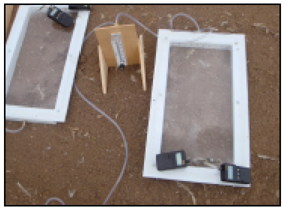
MATERIALS AND METHODS

Litter on the left side of a commercial broiler house was left undisturbed and litter on the right side was windrowed the day after broilers were removed.



The core temperature of windrows was monitored with iButton data loggers. Windrows were turned on day 4, and litter was removed on day 9.

Raw litter and IWC litter was transported to the USDA-ARS Riesel Watersheds Facility at Riesel, Texas on separate trucks. The two types of litter were applied to two separate, non-adjacent fields at a rate of 3 tons/acre.



Odor characterization was performed by GC/MS analysis of volatiles collect by sorbent tubes from wind tunnel chambers placed on litter piles prior to land application.

Human panelists also assessed odor concentration by taking edge-of-field measurements using Nasal Ranger® Field Olfactometers (St. Croix Sensory, Stillwater, MN).

RESULTS

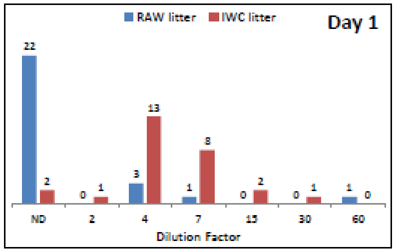
GC/MS analysis of volatile organic compounds collected by sorbent tubes from raw and IWC litter piles at the time of land application.

Compound	Description	Detection Threshold (mg/m^3)	Treatment [1]	Concentration (ng/L)	OAV[2]	Percent Reduction	P-Value
Acetic acid	Sour; vinegar	2.030	Raw litter	2.14	1.05	-41.92	0.65
			IWC	3.04	1.50		
Propionic acid	Body odor; vomitus	0.350	Raw litter	5.86	16.76	26.51	0.57
			IWC	4.31	12.32		
Butyric acid	Body odor; vomitus	0.034	Raw litter	2.47	72.77	-324.63	0.13
			IWC	10.48	308.99		
Isobutyric acid	Rancid; butter;	0.123	Raw litter	5.55	45.32	-1163.96	0.00
			IWC	70.16	572.77		
Valeric acid	Foul	0.036	Raw litter	1.93	53.19	-11.83	0.86
			IWC	2.16	59.49		
Isovaleric acid	Foul/sweat; buttery	0.007	Raw litter	3.61	555.36	-57.89	0.69
			IWC	5.70	876.88		
Hexanoic acid	Foul	0.180	Raw litter	7.14	39.57	-81.51	0.30
			IWC	12.96	71.82		
Phenol	Medicinal; floral	0.734	Raw litter	41.73	56.85	56.76	0.38
			IWC	18.05	24.58		
P-cresol	Barnyard	0.010	Raw litter	15.26	1573.44	53.87	0.42
			IWC	7.04	725.89		
4-ethylphenol	Spice; horse manure	13.000	Raw litter	4.83	0.37	73.76	0.30
			IWC	1.27	0.10		
2'-aminoaceto-phenone	Bat cave; taco shell	0.514	Raw litter	1.75	3.41	78.66	0.17
			IWC	0.37	0.73		
Indole	Piggy; musty	0.004	Raw litter	1.18	307.43	97.38	0.11
			IWC	0.03	8.05		
Skatole	Outhouse; fecal	0.002	Raw litter	0.33	146.66	-18.83	0.76
			IWC	0.39	174.27		

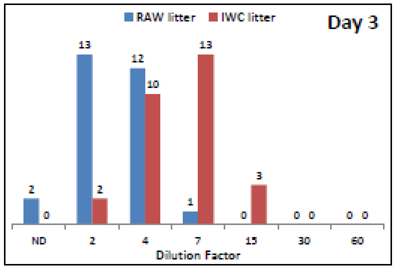
[1] Raw litter n = 4; IWC n = 3

[2] OAV = Odor Activity Value (concentration/detection threshold)

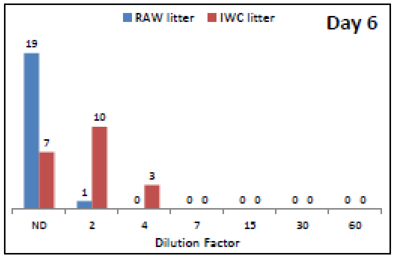
Frequency of dilution to detection threshold values determined by odor panelists at edge of application field.



n = 27 observations/treatment



n = 28 observations/treatment



n = 20 observations/treatment

CONCLUSIONS

- While the use of IWC did not result in a reduction in the overall amount of odors volatilized from litter during land application, it did alter the concentrations of individual odorant compounds, particularly those with a manure-like descriptor.
- These data indicate that IWC may be a useful best management practice to alter the odor characteristics of poultry litter, thus reducing the potential for nuisance odor complaints resulting from the land application of poultry litter.

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