In-house Pasteurization of Broiler Litter

LSU AgCenter
Research & Extension

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Introduction

Poultry production is the largest animal agricultural industry in Louisiana, second only to forestry production in total generated income. The Louisiana broiler industry produces almost 1 billion pounds of meat each year. In current management systems, used poultry bedding material called litter is typically land applied on pastures or hay fields after removal from poultry houses. Investigations in midwestern states and more recently in Louisiana have determined that mismanagement and misuse of animal manures from animal feeding operations (AFOs) such as feedlots, dairy farms or poultry farms can contribute to nonpoint source water pollution. The potentially large quantity of litter generated from the poultry industry in Louisiana has raised concerns with environmental regulators and poultry industry integrators about proper use and management of poultry litter. As a result, poultry growers are becoming more environmentally conscious about how poultry litter is used and handled and have developed "environmentally friendly" alternatives to conventional litter management. Many poultry producers re-use the litter from previous flocks to help reduce the amount of litter for disposal and to help defray production costs.

Poultry litter contains uric acid. When exposed to moisture, air and microbiological degradation, the uric acid is converted to volatile ammonia that increases pH in poultry litter (near pH 8.5). As poultry litter dries, the pH becomes more neutral (near pH 7). The highest concentration of ammonia in a poultry house is experienced within a few inches above the litter surface where chicks are susceptible to its detrimental effects on eyes and lungs. Coupled with elevated relative humidity levels in houses and the high moisture contents of litter in houses cleaned after a previous flock, ammonia can have a devastating affect on the health of chicks. Most poultry losses occur soon after chicks are introduced to the houses because of respiratory tract damages or illnesses, such as pneumonia, that may result in death.

To reduce the potential effect of ammonia on chick health when re-using poultry litter, poultry producers have depended on chemical litter treatments that reduce the ammonia loss from litter when chicks are most vulnerable to high ammonia concentrations. Poultry litter treatments acidify litter, a condition under which ammonia is not volatile, and chemically bind some ammonia. This condition, however, is short-lived but can reduce losses of chicks in early growth stages. The two commonly used chemical treatments in Louisiana are Al+Clear and PLT.

Salmonella spp., Escherichia coli, Clostridium spp., Campylobacter spp., Staphylococcus aureus and other microorganisms are pathogenic to humans and also may be pathogenic to poultry, causing serious infections that may lead to death. Most pathogenic microorganisms cannot withstand the high pH and high ammonia concentrations common in poultry litter. However, *Salmonella spp.* and *Clostridium spp.* are two examples of organisms able to survive the adverse environments of poultry litter. These bacteria are able to endure for long periods under adverse conditions and can repopulate. Chemical poultry litter treatments make claims that the acidic conditions created after application to litter can reduce pathogenic microorganism populations in addition to reducing ammonia concentrations. Some microorganisms, however, can survive the chemical poultry litter treatments and, in the absence of competition from other microorganisms, may more easily re-infest poultry litter following chemical treatment. Composting is a term often used to identify the process of using elevated temperatures to kill microorganisms by destroying or denaturing proteins, including genetic materials. Another term is thermal treatment or thermal inactivation. Heat generated during composting (self-heating) is the energy released when microorganisms degrade materials that contain carbon (organic matter). Self-heating and aeration that occurs during composting has been known for many years to kill pathogenic microorganisms. The United States Environmental Protection Agency (U.S. EPA) recognizes composting as a "process to further reduce pathogens" (PFRP) in pre-treated biosolids (Class B) under the 40CFR.503 regulations (503 or Biosolids Rule). The PFRP relies on a time/temperature relationship under which composting materials are required to exist above 131 F for various periods of time; 72 hours in static piles and invessel composting technologies or 15 days (with five turnings) for turned windrow composting.

Moisture loss during the early stage of composting can be significant, and the odor potential of composting materials often decreases significantly as drying occurs. Additionally, chemical changes that occur during composting also enhance emissions of odor-causing chemicals such as sulfide gasses and ammonia, and neutralization of acidic chemicals such as volatile fatty acids and volatile organic acids. The pH of composting materials usually increases significantly early during the process either because of the release of ammonia from degrading organic matter or from other chemical reactions. Ammonia is not stable under pH conditions above neutral (higher than 7) and becomes volatile, as does many forms of sulfide gas. Organic and fatty acids are formed from oxidation of other chemicals that are produced by microorganisms when conditions were not aerated as in composting (packed sublayers or cake in poultry houses or cattle barns, or undisturbed piles of manures or biosolids).

Based on the Biosolids Rule, many state regulatory agencies governing use and disposal of agricultural wastes require thermal treatment of animal manures that are to be land applied. Composting has been used successfully for many years to transform raw manures and other forms of organic matter, including poultry litter, to materials suitable for use as soil amendments. Composting is an increasingly important tool in poultry litter management, reducing some nutrient and pathogen contamination of water resources; a key issue affecting Louisiana and other poultry producing states. With the exception of phosphorus, nutrient solubility is significantly decreased in properly composted organic matter. Phosphorus solubility, however, is known to increase with composting. This increase in solubility may be a benefit to soils and vegetation, allowing increased infiltration of phosphate to rooting zones of soils, thus reducing the total concentration in runoff water as insoluble or organic forms.

Poultry grower litter management has become the focus of much criticism from environmental researchers and activists. Therefore, reducing the potential for nutrient and pathogenic microorganism contamination of surface and groundwater sources through runoff waters from stored or applied litter would reduce many environmental pressures placed on poultry producers to reduce nonpoint source pollution.

Increasing the cost effectiveness of poultry production is also an important goal nationwide. Extending the longevity of poultry litter as bedding, reducing reliance on chemical litter treatments and decreasing poultry mortality would be of great economic significance to poultry growers. Thus, using composting technology to pasteurize poultry litter between flocks may produce results consistent with these goals. The self-heating of poultry litter can kill *Salmonella, Escherichia coli, Clostridium, Campylobacter, Staphylococcus aureus* and other microorganisms pathogenic to humans and poultry, while fewer volatile emissions and lower litter moisture levels can reduce conditions that lead to significant losses of young birds, thus reducing mortality.

With invaluable cooperation and assistance from poultry producers in northern Louisiana parishes, LSU AgCenter personnel have evaluated the effectiveness of in-house pasteurization of broiler litter by conducting demonstration trials in commercial poultry houses. The main objective of this project was to develop a suitable process to pasteurize poultry litter in-house, between flocks, with minimal additional cost or inputs to growers. That would be sufficient to generate PFRP temperatures for pathogenic microorganism reduction. Secondary objectives were to evaluate the pasteurization technology to reduce litter moisture and ammonia emissions from litter, thus, reducing chick mortality. In addition, the effect of pasteurization on nutrient dynamics over time was a concern.

Methods

Initial Litter Moisture Requirements

Moisture in poultry houses must be minimized to reduce potential for illness and disease. Therefore, the in-house pasteurization process developed needs to be capable of generating temperatures above 131 F in litter at the lowest possible moisture content. The process used to make compost (a stable and mature soil amendment) typically requires moisture contents of more than 50 percent for optimal microbiological density, diversity and degradation of organic matter. Under lower moisture conditions (40 percent to 50 percent), however, temperatures typically exceed 150 F, a condition that reduces microbiological diversity and composting efficiency. Lower moistures may allow influence of external temperatures, reducing the self-heating of composting materials through increased air exchange. But, smaller particle size materials, such as poultry litter, are less susceptible to external temperature changes than materials with larger particle sizes that allow more air exchange within the materials.

Preliminary testing on poultry litter was conducted at the W.A. Callegari Environmental Center located at the LSU AgCenter Central Research Stations, near Baton Rouge, to determine the minimal moisture required for in-house pasteurization. A method typically used to assess compost self-heating or to optimize organic matter recipes used in composting is the Dewar flask test that measures the maximum temperature achieved in materials over time. A Dewar flask is similar to a thermos with a wide open top and insulates the contents well against changes in the external temperature. This method served well to determine the minimal moisture required to meet PFRP temperatures in poultry litter.

The litter used in initial trials had four flocks grown on it and used whole rice hulls as the bedding material. The litter used in treatments at ambient moisture levels or above was not dried, but water additions to achieve specific moisture levels were estimated using the bulk density. The litter for an air-dried treatment was air dried to near 15 percent moisture (95 F for 48 hours), maintaining some viable microbiological cells. The litter was compacted evenly into three replicate 2-liter Dewar flasks with a temperature probe inserted near the center. The temperature probe was connected to a digital thermometer that was capable of recording the current and maximum temperatures inside the Dewar flasks, and the date and time that the maximum temperatures were observed. The litter was allowed to compost for five days in the Dewar flasks, until the maximum temperature had been achieved and decreasing temperatures were observed.

Initial Windrow Treatments

Each demonstration trial was conducted between flocks (after birds were removed from the houses and prior to the placement of a new flock). Typically, a flock was in a house for 6 to 8 weeks, with a 7- to 10-day lag period between flocks. After flocks of broilers were harvested, poultry growers removed the compacted, high moisture sublayer of litter (cake). The interior of the houses were pressure washed to remove excessive dust buildup. Then, windrows were constructed using tractors and operators (supplied by poultry growers) and an extended-width blade (10 feet long, 1.5 feet deep). Self-heating during composting requires adequate material volume (1 cubic yard at least) to provide adequate insulation value. The nature of poultry litter and limited space and equipment available would not allow such volumes in the poultry house windrows.

Two poultry houses were used to examine the influences of moisture and method of application of water on the average temperatures generated in pasteurization of poultry litter. Two litter windrows were formed that ran the full length of both houses (500 feet) and were approximately 1.5 feet high and 4 feet wide. Each windrow was subdivided into three treatments, with a control treatment on both the brood end of one windrow (the end to which chicks are introduced to the house – usually wetter litter because of cooling systems located there) and the off end of the second windrow (the end of the house from which poultry is harvested – usually drier litter). For ease and convenience, one poultry house was used to construct incorporated moisture windrow treatments and one for surface-applied moisture windrow treatments.

Based on the ambient moisture, the approximate volume of litter in the area of each treatment, and bulk density (2 lb per 5-gallon bucket) of the litter, approximate gallons of water required for added moisture (to 30 percent and 35 percent moisture) were determined, and the water addition to windrows was controlled using a metering device attached between the hose and water supply. Three treatments were used to assess the required moisture for pasteurization in on-farm windrowed poultry litter; no moisture added, surface application of water to bring the litter moisture to near 30 percent and 35 percent followed by windrowing (the incorporated treatment), and surface application to windrowed litter to bring the average total moisture to 30 percent and 35 percent (the surface treatment). Both windrows contained one of each treatment.

To achieve the minimum moisture required to generate PFRP temperatures, some litter required the addition of water to windrow surfaces or to the litter prior to windrowing, while others relied on ambient moisture levels. These trials were designed to determine the effect of moisture on heating necessary for PFRP and to determine if added moisture could be reduced or not used at all. Too much moisture in the bedding could potentially be harmful to young birds placed in the house.

Subsequent Trial Windrow Maintenance

Subsequent in-house poultry litter pasteurization trials were held in various poultry houses ranging in size from 400 to 600 feet long and 40 feet wide. Windrows were constructed in the same manner as the previous trial, but varying ambient litter moistures were used to pasteurize the litter. Trials were repeated in the same broiler houses over several flocks to collect information about the effects of repeated in-house pasteurization over several broiler flocks on pasteurization process temperatures, pathogenic microbiological populations and accumulation and solubility of plant nutrients. During these trials, data were collected over the entire period between flocks, with windrowed litter redistributed immediately prior to introduction of a new flock.

Analyses and Monitoring

Temperatures were monitored at 6- and 12-inch depths at nine evenly spaced locations in each windrow (three replicate locations per treatment). The probes were manufactured by inserting the factory thermocouple end inside a 0.25-inch inner diameter tube 13 inches long, crimping the tubing snuggly to the thermocouple and sealing the ends of the probe with silicone sealant. The thermometers used were battery powered digital thermometers capable of recording the maximum, minimum and current temperatures inside the windrow and in the poultry house. The thermometers also provided the time and date of the maximum and minimum temperatures. The current, maximum and minimum litter temperatures were monitored in the windrows for duration of the pasteurization trials. Daily litter temperatures were recorded. The maximum and minimum temperatures and the date and the time of occurrence were recorded just prior to litter redistribution.

A hand trawl and 3-gallon bucket were sterilized by misting with 95 percent ethanol and allowing to air dry prior to collection of each sample. Samples were collected immediately after windrowing the litter and after pasteurizing trials were complete. Multiple 1 pound subsamples (five minimum) were excavated from multiple random locations in each treatment or windrow and deposited in the bucket. The bucket contents were mixed and a composite sample drawn and stored in a zip-lock bag to be used for laboratory analyses.

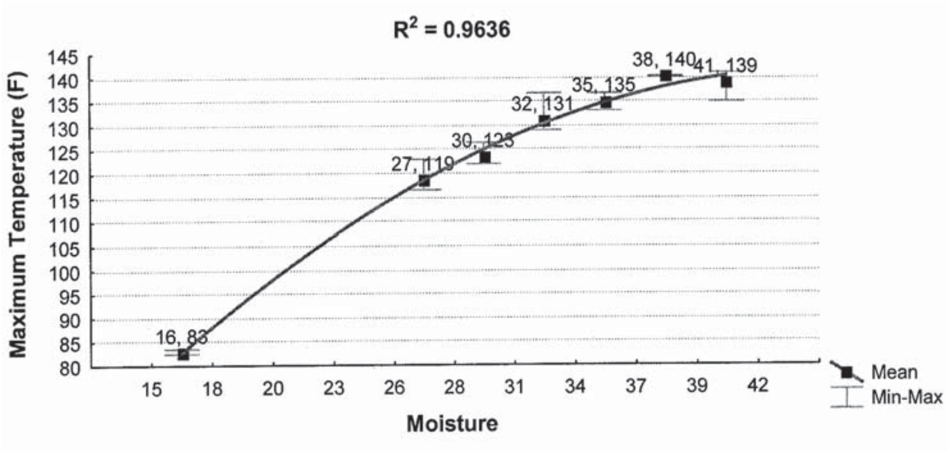
Total elemental analysis and extractable nutrients of litter samples were performed at the Department of Agronomy Central Analytical Laboratory at LSU. Total N, organic C, ammonia-N, pH, electrical conductivity and physical litter analyses were performed at the W. A. Callegari Environmental Center Organic Degradation Research and Analytical Laboratory. Nutrient analyses included total and plant available nitrogen (N), potassium (K), phosphorus (P), sodium (Na), calcium (Ca), magnesium (Mg) and sulfur (S). Sample pH, electrical conductivity (soluble salts), moisture, and the ash content (soil and inherent minerals) of litter were analyzed and used to determine the effects of pasteurization on poultry litter and plant nutrient dynamics. Microbiological analyses were performed in private environmental laboratories.

Results and Discussion

Appropriate Moisture: Dewar Flask Trial

The data obtained from Dewar flask moisture level tests are in Figure 1. The average maximum temperatures were achieved in 2.3 days indicating that a minimum of 3 days may be necessary to complete the pasteurization cycle. There was a 0.96 correlation between moisture and the maximum temperature in the Dewar flask trials. This correlation indicates that higher moisture contents would be expected to influence generation of higher temperatures during the pasteurization process. It was determined that slightly more than 32 percent minimal moisture was necessary in poultry litter to generate PFRP temperatures in three replicate Dewar flasks. Higher moisture levels (up to approximately 40 percent moisture) in litter also produced temperatures above 131 F and were considered for use in the demonstration trials. Concerns by the growers, however, that excess moisture may exist in litter after completion of the trials, negatively influencing production, dictated that a maximum of 35 percent moisture was expected to be used in on-farm trials.

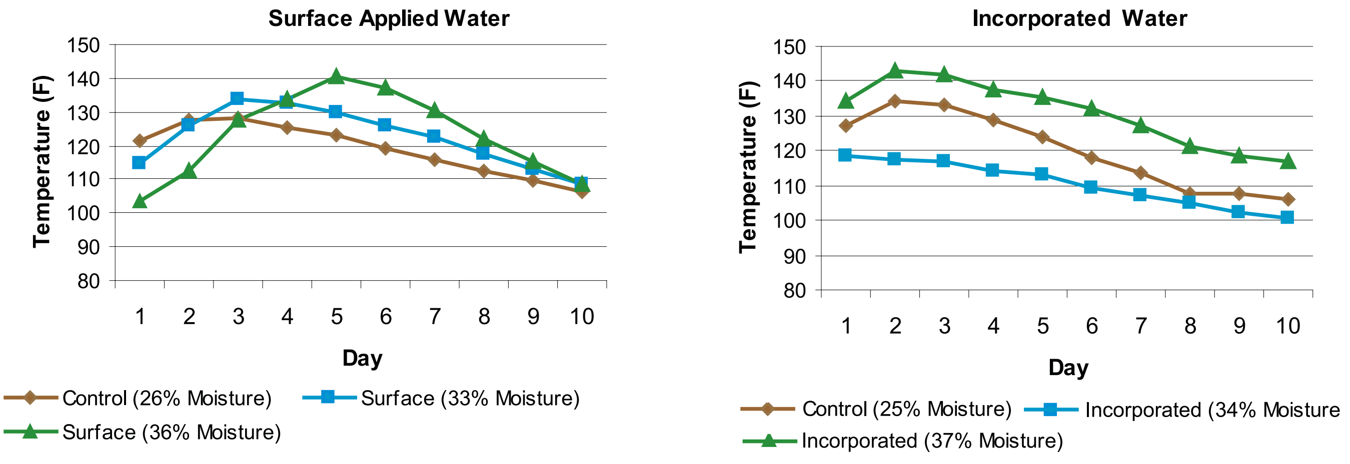
Figure 1. Plot of poultry litter moisture vs. temperature obtained for Dewar flask trials used to determine appropriate minimal moisture desired for demonstration trials.



Effects of Moisture: On-Farm Trial

The results of on-farm pasteurization trials using variable moisture contents and methods of application provided mixed results. Two important considerations to these trials were to determine the minimum moisture and moisture application method to produce temperatures at or above 131 F. The average daily temperature increased with increasing concentrations of surface applied moisture, as expected, but maximum temperatures were achieved earlier during the pasteurization period at lower moisture contents (Figure 2). When moisture was incorporated into litter, the maximum temperatures occurred at approximate-

Figure 2. Effect of surface applied and incorporated moisture on the average daily temperature of in-house pasteurized poultry litter.

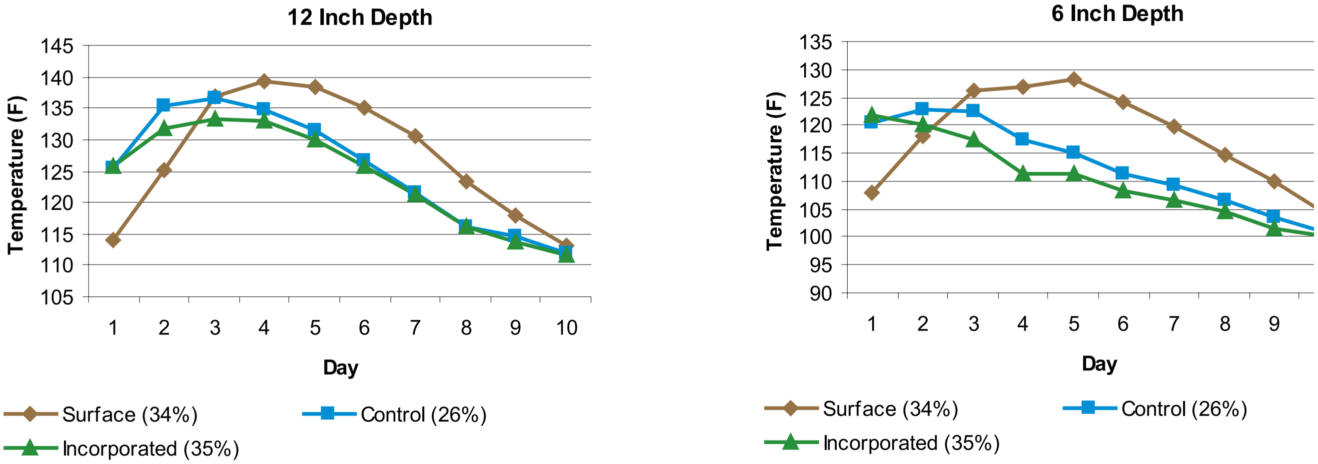


ly the same time during pasteurization under all moisture contents, and the highest average daily temperatures were maintained in litter that contained the highest moisture content. With surface- applied moisture, however, the lowest daily temperatures were observed with 33 percent moisture and with the lowest moisture content (26 percent). Surface-applied moisture appears to have formed an insulating envelope on the windrowed poultry litter surface that reduced gaseous exchange that could have significantly cooled the material. Thus, higher temperatures were observed in poultry litter with higher surface applied moisture. When incorporated into the litter, however, 34 percent moisture provided sufficient moisture to cause particle clustering from weak polar adherence of water molecules, increasing porosity and gaseous exchange inside windrows, resulting in lower temperatures during pasteurization. At higher moisture contents, porosity and gaseous exchange were reduced, and average daily temperatures were higher. Interestingly, at ambient moisture contents, near 25 percent, the control for incorporated moisture windrows showed maximum average daily temperatures above PFRP requirements for almost two days and a maximum temperature of 138 F. PFRP temperatures were not observed in the control for surface applied moisture (near 26 percent moisture), indicating a possible difference in the poultry litter porosities or nutritional properties between the two control windrows.

The method of applying moisture to the poultry litter appeared to have influenced the time required to achieve the maximum temperature during pasteurization. Even though there was no apparent correlation between the moisture content and the days required to achieve maximum temperature (r = 0.17), the ambient moisture and incorporated moisture treatments both achieved maximum temperatures in an average of 1.8 days vs. 3.8 days for surface applied moisture treatments. Therefore, adding moisture to litter before windrowing appears to be the best option to reduce the time required for pasteurizing poultry litter.

The effects of moisture on the average temperatures in pasteurized poultry litter windrows at 6- and 12-inch depths in surface applied and incorporated moisture windrows are in Figure 3 on the following page. No treatments produced temperatures above 127 F, 4 F below PFRP.

Figure 3. The influence of average surface applied, incorporated and no addition of moisture on average daily temperatures at 12 and 6 inch depths during in-house pasteurization of poultry litter (averages of six to eight replicate sample locations in windrows on two farms).



The poultry litter with surface applied moisture (average 34 percent moisture) generated the highest 6-inch temperature, with the control litter treatment, near 26 percent moisture, generating higher average temperatures than the incorporated moisture treatment (near 35 percent moisture). The maximum temperatures at the 6-inch depth for the control and incorporated treatments occurred on either day one or two of the pasteurization period, and on day four for the surface applied moisture treatment. All treatments, however, generated temperatures above 131 F at the 12-inch depth during pasteurization. The control treatment generated higher average temperatures during much of the pasteurization period than did the incorporated treatment and achieved a maximum temperature during the third day of pasteurization, with PFRP temperatures lasting for more than four days. The poultry litter with the surface-applied moisture generated the highest temperatures at the 12-inch depth, generated approximately the same temperature at day 3 as the control, but did not achieve the maximum temperature until day 4 and did not achieve PFRP temperatures until after one day of pasteurization.

Effects of Moisture in On-farm Trials

Evidence suggests that elevated moisture of 36 percent to 37 percent would ensure adequate temperatures at or above 131 F when incorporated or surface applied. But the high moisture content produced PFRP temperatures nearly one day after the lower moisture content litters. The 33 percent to 34 percent moisture litter, when the moisture was incorporated, did not achieve PFRP temperatures. No treatments produced PFRP temperatures at the 6-inch depth, but the control treatments produced the highest average temperatures at the 6-inch depth. Likewise, the control treatments produced the highest average temperatures at the 12-inch depth within 1 day of windrow construction and lasted for at least 4 days, assuring PFRP. Elevated moisture contents generated adverse residual effects in the reapplied litter. It was therefore determined that no moisture would be added to poultry litter during future pasteurization trials.

When the trial was over the litter that had received additional moisture caked onto the tires of the tractor, and it did not distribute evenly. The poultry producer was disappointed in the excessive moisture in the litter and was not receptive to further moisture trials.

Effects of Poultry Litter Age on the Pasteurization Processes

The first trials performed at ambient moisture levels could not be initiated on first flock poultry litter. Two poultry producers with third flock litter, however, were eager to participate in the in-house pasteurization trials. The temperatures observed during the pasteurization process appeared to be influenced significantly by the age of the litter, because of changes in the physical and chemical natures of the litter. The properties in poultry litter known to influence the pasteurization process did influence the observed maximum and daily temperatures observed during the pasteurization trials (Table 1).

The most prevalent influence on both average daily and maximum temperatures appears to come from the organic C content (r = 0.99 and 0.98 respectively), indicating that litter containing higher organic C concentrations will produce higher temperatures. Although not as strong, the positive influence of total N on the temperatures observed during pasteurization was observed (r = 0.60 when correlated with maximum temperature and r = 0.50 when correlated with average temperature) and probably resulted from the requirement of N in microbiological metabolism.

Elevated ash contents in the litter negatively influenced both maximum and average temperatures during litter pasteurization (r = -0.83 and -0.66 respectively). Ash contents were suspected to be an indication of soil contamination from the windrowing process because after using a blade that was wider than the tractor and deeper than previously used blades, a 14 percent ash reduction was observed between the fifth and sixth flock litter. The reduced ash content presumably occurred because fewer passes were required to move the litter into windrows, and the depth of the draw could be better controlled. The ash content also was highly variable in replicate litter samples for windrows with coefficients of variation ranging from 0.8 after the sixth flock to 11 after the third flock, indicating a significant difference in the precision of analyses.

Table 1. Average maximum and average daily temperatures, initial average chemical and physical properties and correlations of properties with average maximum and daily temperatures for pasteurized poultry litter over four flocks of broilers.

		Flock				Correlation With Maximum Temperature	Correlation With Average Temperature
Property	Unit	3	4	5	6	r	
Maximum Temperature	ºF	137	125	120	134	----	----
Average Temperature	ºF	123	113	100	117	0.95	----
Moisture	% Total Wt.	28.33	26.97	22.05	27.41	-0.40	-0.33
Ash	% Dry Wt.	25.50	28.11	27.79	23.95	-0.83	-0.66
Total N	% Dry Wt.	3.65	3.37	3.29	3.28	0.62	0.68
Organic C	% Dry Wt.	41.66	38.45	35.65	40.78	0.98	0.99
Ammonia	mg/kg	1,918	2,763	----	2,244	0.64	0.27
pH		8.52	8.68	----	8.90	-0.15	-0.47

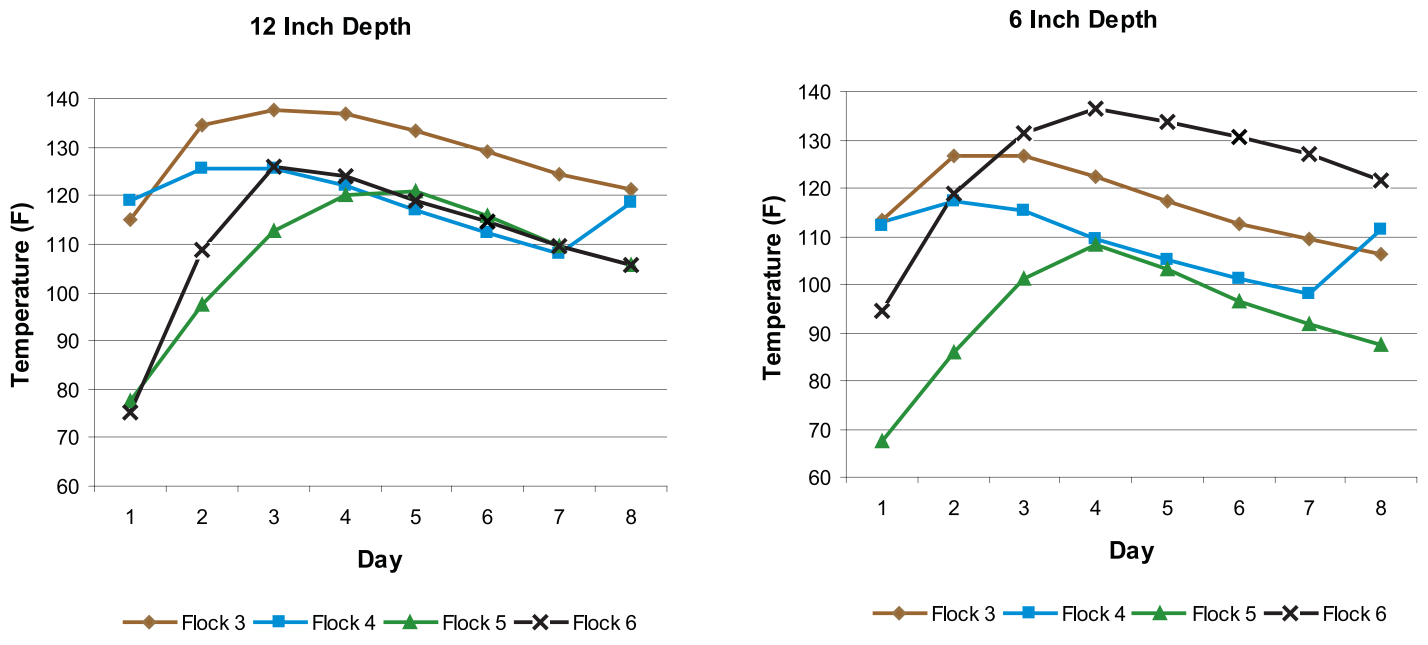
Though the correlation was low, the negative correlation between moisture and maximum and average daily temperatures during poultry litter pasteurization (Table 1) suggests that lower moisture levels in the litter may produce higher average temperatures. This finding is consistent with the in-house moisture trials previously conducted in which incorporated moisture near 35 percent (Figures 2 and 3) generated lower temperatures during pasteurization than did the control treatments near 25 percent moisture.

Ammonia and pH are often linked during composting of nitrogen-rich materials such as poultry litter. Ammonia is released by microbiological enzyme activity into thin water films surrounding the microorganisms and organic matter. Under oxidizing conditions, ammonia reacts with water to form the basic molecule ammonium hydroxide. This reaction causes an increase in the pH of the materials. Ammonia volatilizes under high heat or pH conditions creating more neutral pH conditions in the organic matter. It was therefore expected that elevated temperatures would negatively influence the pH during poultry litter pasteurization as was evidenced by the negative correlations between pH and maximum and average temperatures in Table 1 (r = -0.55 and -0.32 respectively).

The reaction of ammonia with water is exothermic, or releases heat. A moderately strong positive correlation between ammonia and the maximum temperatures observed during poultry litter pasteurization (r = 0.64) indicates that higher ammonia concentrations in the litter generated greater maximum temperatures (Table 1). The correlation, however, was low between the average daily temperature and ammonia concentrations (r = 0.27). Higher temperatures also will increase the rate of volatilization of ammonia, so the ammonia concentrations would not be expected to significantly influence the temperature throughout the pasteurization process, but only during the period where temperatures may have been influenced by elevated ammonia concentrations in addition to microbiological activity or other chemical reactions that may influence the temperature in pasteurizing litter.

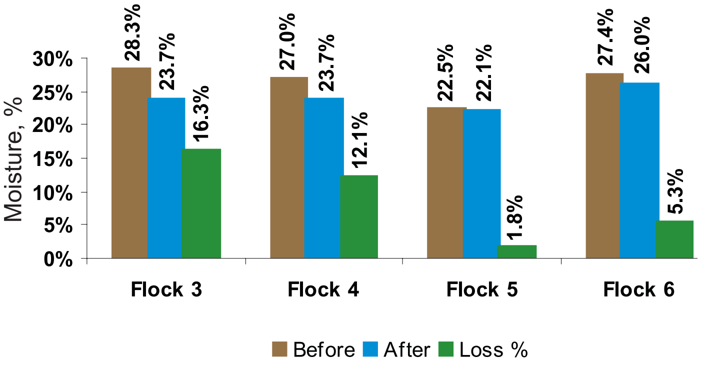
The average daily temperature at the 6- and 12-inch depths during poultry litter pasteurization is shown in Figure 4. With the exception of the third flock when higher organic C concentrations were observed in litter, other temperature profiles for the 12-inch depths were observed not to differ significantly after day four during the fourth, fifth and sixth flocks. At the 6-inch depth, maximum average readings were observed at progressively later times with increased age of the litter, possibly because of a decrease in the particle size, porosity and aeration properties of litter with age that reduced the oxygen availability for aerobic microbiological activity. While the third, fourth and fifth flock litter pasteurized at temperatures lower at the 6-inch depth than at the 12-inch depth, the sixth flock litter (6-inch depth) showed average temperatures compa-

Figure 4. Average temperatures at 12 and 6 inch depths during in-house litter pasteurization after four poultry production cycles at ambient moisture levels.


12 Inch Depth

6 Inch Depth

Figure 5. Moisture before and after pasteurization, and the percentage loss of moisture during the pasteurization process.



rable to the 12-inch depth temperature readings from the third flock litter. Lower moisture and elevated organic matter contents (Table 1), and reduced particle size and aeration in the sixth flock poultry litter may provide the reason for the increased temperature at the 6-inch depth.

Elevated temperature and convective aeration that occur during composting make moisture loss common. Therefore, it was assumed that moisture loss would be a benefit of in-house poultry litter pasteurization. Litter moisture did decrease by an average of 9 percent over the pasteurization period, ranging from 16.3 percent after the third flock to 1.8 percent after the fifth flock (Figure 5). Even with a higher loss observed after the sixth flock than the fifth flock, it appears that the average moisture loss during pasteurization decreases with the age of the litter. No relationship was evident, however, between moisture loss or the average or maximum temperature during pasteurization (r = 0.12 and r = -0.07, respectively). Therefore, the amount of moisture lost during poultry litter pasteurization is assumed to be a function of convective aeration more than heating.

Effects of Pasteurization on Pathogenic Microorganisms and Plant Nutrient Dynamics

Pathogenic Microorganism Reduction

Fecal coliform bacteria are often used as an indicator species for determining fecal contamination of water. Many fecal coliform bacteria commonly found in poultry litter are pathogenic to humans and other animals (i.e., Salmonella, Clostridium, E. coli, etc.). Fecal coliform bacteria, however, are not the only anaerobic microorganisms in poultry litter that can be pathogenic. Prior to initiating the in-house pasteurization trials, three samples were collected from second flock litter during a 17-day period between the second and third flocks (Table 2). The data compared fecal coliform populations with total anaerobic microorganism populations. As expected, the data were highly variable for both fecal coliforms and total anaerobic bacteria, but even more so for fecal coliforms that showed strong day zero population counts (CFU/g), but then appeared to be completely gone by day 7, only to repopulate at low levels during the next 10 days. The data indicate that, even though the total anaerobic bacteria population data also was highly variable as indicated by the high coefficients of variation (CV) and wide ranging upper and lower confidence intervals (CI), the anaerobic bacteria counts would be best suited for determining the

Table 2. Fecal coliform and total anaerobic bacteria population counts in litter prior to in-house pasteurization trials.

		Fecal Coliforms (CFU/g dry litter)			
		Mean	Upper CI	Lower CI	CV
Day 0	Off End	16,000	----	----	----
	Brood End	2,300	----	----	----
Day 7	Average	0	0	0	N/A
	Off End	0	0	0	N/A
	Brood End	0	0	0	N/A
Day 17	Average	6	17	-5	1.72
	Off End	2	4	-1	1.35
	Brood End	12	28	-3	1.27
		Anaerobic Bacteria (CFU/g dry litter)			
		Mean	Upper CI	Lower CI	CV
Day 0	Off End	33,000	----	----	----
	Brood End	63,000	----	----	----
Day 7	Average	86,000	99,333	66,000	0.62
	Off End	139,479	161,762	114,083	0.63
	Brood End	32,521	36,905	17,917	0.73
Day 17	Average	201,143	354,563	47,724	0.76
	Off End	212,000	417,798	6,202	0.97
	Brood End	186,667	267,496	105,838	0.43

effectiveness of in-house litter pasteurization on pathogen reduction.

Some additional observations were made about pathogenic microorganisms in the litter (Table 2). A significant difference was observed between the anaerobic bacterial CFUs seen in samples taken on each of the three sampling dates (p = 0.0028). In fact, the anaerobic bacteria appeared to increase during the 17-day period, representing a potential increase in the probability that pathogenic infections may occur without additional litter treatment to reduce pathogen populations (day zero to day 7, a 62 percent increase; day 7 to day 17, a 57 percent increase). With the exception of the day zero sample, fecal coliform populations were typically higher in litter from the end of the poultry houses to which young birds are introduced during a growout cycle (the brood end). This litter is typically wetter than litter from the other end of the house (the off end). With the exception of the litter sampled on day zero, however, the total anaerobic microorganism populations appear to be higher in the drier litter of the off end of poultry houses.

The average temperature for pasteurizing poultry litter during all in-house trials was 114 F ± 13 F (6-inch depth, 110 F ± 13 F; 12-inch depth, 118 F ± 14 F), not sufficient to meet the requirements of the EPA 503 Rule PFRP. Although there was no noticeable difference in anaerobic bacteria population counts between flocks, we observed significant reduction in total anaerobic bacteria populations after pasteurization (p = 0.0033). The average anaerobic bacterial CFU/g dry litter and percentage differences between pre- and post-pasteurized samples for litter from three production cycles is in Table 3. Again, the variability was high for the CFU/g before pasteurization (CV), but it was significantly lower in the post-pasteurization sample analysis. The average reduction in anaerobic bacterial CFU/g was 78.57 percent. These data indicate that PFRP temperatures may not be necessary to adequately reduce the pathogenic microorganisms in the pasteurizing poultry litter. Aeration and conditions in the pasteurizing poultry litter may significantly contribute to anaerobic and pathogenic microorganism reduction.

Table 3. Anaerobic bacterial reduction after in-house poultry litter pasteurization after three flocks.

	Litter Sample	Anaerobic Bacteria (CFU/g dry litter) Mean	Upper CI	Lower CI	CV	Percent Change Before to After
Flock 3	Before	11,000	19,679	2,321	0.79	----
	After	4,433	5,870	2,997	0.32	59.70
Flock 4	Before	22,000	42,928	1,072	0.95	----
	After	1,200	1,900	500	0.58	94.55
Flock 5	Before	13,500	21,278	5,722	0.58	----
	After	2,500	3,207	1,793	0.28	81.48

Plant Nutrient Dynamics

Reuse of poultry litter as bedding material is limited, and the litter will eventually be removed from poultry houses. Poultry litter is an excellent source of nutrients for plants. Typically, litter is stacked in litter storage buildings to further reduce microbiological contamination potential, and then is applied to livestock pasture or hay fields. Land application of poultry litter, however, can introduce high concentrations of soluble phosphate and other nutrients to soils that can enter surface water through runoff during rainfall. Therefore, it was of interest to investigators to determine what changes occurred in total and soluble nutrients when poultry litter was reused over extended periods of time.

The changes in total and soluble nutrients among four poultry flocks are in Table 4. As anticipated, many of the total nutrient concentrations increased with the age of the litter. As organic matter degrades and organic C is lost as carbon dioxide, most elements will remain as a residual because there is no chemical means for loss. As organic matter degrades, a stable organic complex with high cation exchange and moisture holding capacities known as humus is formed. Many metals and nutrients are fixed or chelated into the organic structure of humus, often reducing the proportion of soluble nutrients and providing a slow release form of organic fertilizer.

Nitrogen loss, however, was expected during successive production cycles because of the volatilization of ammonia from litter. The manure from poultry is comprised of uric acid that is readily degraded by microorganisms. As ammonium is released during degradation of the manure and at pH levels above 6.3, gaseous ammonia is formed. Ammonia interacts with water to form ammonium hydroxide that further increases the pH in litter. Higher ammonia losses would therefore be expected as pH increases, or as materials dry, thus contributing to high loss of Total N (Table 4).

Table 4. The total and soluble nutrients in litter at the beginning of each cycle, and the percent of the total nutrients represented by the soluble fraction.

		Flock			
Property	Unit	3	4	5	6
Moisture	% total wt.	28.33	26.97	22.05	27.41
pH	----	8.52	8.68	----	8.90
Total N	mg/kg	36,520	33,674	32,910	32,845
Total P	mg/kg	19,520	18,435	20,984	34,054
Total K	mg/kg	26,055	28,640	36,065	58,250
Total Mg	mg/kg	4,938	6,163	7,511	13,596
Total S	mg/kg	6,761	7,077	8,808	13,289
Total Ca	mg/kg	23,500	25,355	30,348	55,419
Ammonia-N	mg/kg	1,918	2,763	----	2,244
Plant available P	mg/kg	18,172	11,956	18,778	20,652
Plant available K	mg/kg	12,940	15,671	19,888	23,159
Plant available Mg	mg/kg	3,520	2,476	2,840	3,235
Plant available S	mg/kg	----	5,390	----	8,512
Plant available Ca	mg/kg	4,802	3,902	2,576	1,977
Ammonia-N	% of total N	5.25	8.21	----	6.83
Plant available P	% of total P	93.09	64.86	89.49	60.64
Plant available K	% of total K	49.66	54.72	55.14	39.76
Plant available Mg	% of total Mg	71.29	40.18	37.81	23.80
Plant available S	% of total S	----	76.17	----	64.06
Plant available Ca	% of total Ca	20.43	15.39	8.49	3.57

If the litter is to be land applied after pasteurization, reduction of nutrient solubility will help decrease the potential for contamination of water from soluble nutrients in runoff. Solubility of plant nutrients was expected to decrease as the poultry litter aged because of the humus immobilization in stable organic complexes. Though the data show fluctuations in plant available nutrient concentrations, plant available ammonia and N, P, K and S showed a trend toward higher concentrations over time. Calcium and Mg solubility, however, were observed to decrease over the flocks and may have been introduced in a liming source used in the original bedding material to control parasites.

The true effects of litter age on soluble nutrient forms can be seen as the percent of the total nutrients that are present in a plant available form (Table 4). Overall, the percent of the total nutrient concentrations that were plant available appear to decrease between the third and sixth flocks, even though there is some fluctuation in the data. The short periods of pasteurization between poultry flocks may have contributed a small amount to the decrease in solubility of nutrients over time, but the decrease probably resulted more from the natural degradation of the litter in the poultry houses than to in-house pasteurization. Phosphorus solubility in other experiments has been shown to increase after composting, but the slower degradation process that occurs in poultry houses over time may help reduce soluble forms of phosphorus. If these data are correct, in-house pasteurization and continued reuse of poultry litter for extended flocks may be a valuable activity for reducing surface water contamination by water runoff from soils amended with poultry litter.

Conclusions

In-house pasteurization of poultry litter cannot be performed at elevated moisture contents that would produce adequate temperatures to meet the U. S. EPA Part 503 Biosolids Rule for pathogenic microorganism production. By increasing the initial moisture in the poultry litter to 31 percent or more, the average temperature is at or above the target 131 F temperature, but the moisture decreased workability of litter into windrows for pasteurization, and the litter was wetter than desired for reintroduction of chicks for the next flock. Even though the in-house pasteurization trials performed on litter at ambient moisture contents did not produce the desired temperatures, data indicate that fecal coliform bacteria were at adequate levels for land application as a Class A biosolid (<1,000 CFU/g) prior to the pasteurization process. Additionally, even after pasteurizing at an average temperature below the target 131 F, total anaerobic microorganism populations were reduced by more than 78 percent during the pasteurization process. Another bonus to in-house pasteurization was a 9 percent average reduction in moisture contents of litter. These data indicate the value of in-house pasteurization to decrease the potential for sickness and disease to poultry and extend the usefulness of the litter.

The typical end use for poultry litter is in crop, hay or pasture production. Poultry litter typically has a high concentration of phosphorus and other plant nutrients that can benefit plant production, but that also can be carried into nearby surface waters during runoff events, causing environmentally damaging contamination near locations where litter is applied. Although the data are not conclusive, reuse of poultry litter over four successive production cycles shows that most total and plant available nutrient concentrations increase over time, but the percentage of the total nutrients that are plant available appear to decrease. This shows that as the litter ages, more nutrients become complex in degraded organic matter, decreasing the solubility of the nutrients and reducing the environmental risk of water contamination. The result may be a more environmentally safe product for use in land application.

In-house Pasteurization of Broiler Litter

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