2016

Composting Swine Manure from High Rise Finishing Facilities

Edwin L. Ritchey
University of Kentucky, edwin.ritchey@uky.edu

Kim Cook
USDA-ARS

Repository Citation

Ritchey, Edwin L. and Cook, Kim, "Composting Swine Manure from High Rise Finishing Facilities" (2016). *Plant and Soil Sciences Research Report*. 8.
https://uknowledge.uky.edu/pss_reports/8

Agricultural Experiment Station
University of Kentucky, College of Agriculture Food and Environment, Lexington KY, 40546

College of Agriculture, Food and Environment
Plant and Soil Sciences

PLANT AND SOIL SCIENCES

RESEARCH REPORT

Vol 5, No 1, 2016

http://dx.doi.org/10.13023/PSSRR.2016.1

Composting Swine Manure from High Rise Finishing Facilities

Edwin Ritchey, Extension Soil Specialist, University of Kentucky
Kim Cook, Research Microbiologist, USDA-ARS, Food Animal Environmental Systems Research Unit

Introduction

Swine production has restructured considerably in recent years with increased production on fewer farms (Key et al., 2011). Most swine production facilities manage manure in liquid form either in deep pits underneath production facilities or in lagoons adjacent to the production facilities (Key et al., 2011). This management uses water to rinse manure from the facilities, which dilutes the nutrient concentration and value of the manure. The liquid forms are applied to land through irrigation systems or by liquid manure spreaders. Liquid manure management can have some operational constraints that composting eliminates (Bernal et al., 2009). The most common issue with handling liquid manure is that the manure has diluted nutrients and it is often not economical to transport large volumes of lagoon effluent to off-site locations. Surface spreading through an irrigator is commonly used, but wet environments can delay application. Odor can be a concern if liquid manure is surface applied and not incorporated; and although soil incorporation does reduce manure odors, they can still be a concern.

Composting is a controlled biological process that is managed to enhance natural decomposition to result in a stable end product (i.e. compost). Composting reduces volume, weight, odors, and pathogen numbers compared to the initial product. The goal in compost management is to provide an ideal environment for growth of microorganisms (bacteria, fungi, and actinomycetes) responsible for decomposition. The microorganisms responsible for composting get their energy from decomposing organic carbon (C). Carbon and nitrogen (N) are both to build new cells. Oxygen (O) is used for respiration. Heat is produced as a by-product of these reactions. The heat generated from composting can reach temperatures exceeding 150 °F. It is this heat that is responsible for killing weed seeds, pathogens, and microorganisms contained in the compost mixture. This C, N, and oxygen requirement is balanced by choice of bulking materials, turning frequency, and environmental conditions during composting that optimize proper moisture, gas exchange, and nutrient ratios (Miller, 1992).

The restructuring of swine production has resulted in the accumulation of large amounts of swine manure being concentrated in localized areas. Application of manure in close proximity to production facilities and can lead to elevated concentrations of plant nutrients, particularly phosphorus (P), which can be associated with degraded water quality in nearby waterways (USEPA, 2013). Composting swine manure is an alternative manure management strategy with several advantages over conventional manure handling procedures. Composting swine manure reduces manure weight and volume, produces a stable product, reduces pathogens, and allows for transportation to greater distances from production facilities. This method of manure management utilizes high-rise finishing production facilities (HRFF) where the swine production area is approximately 12 feet above the ground level used for manure management (Stowell, 2002). The ground level is “bedded” with woodchips or other material that absorbs the manure (urine and feces) that falls through the slatted floor of the production area above. This material is turned multiple times a week to uniformly mix the material and to distribute moisture throughout the bedding. Turning the material under the barn extends the “life” of the bedding material and results in a partially composted material. The partially composted material is removed from the facilities when it ceases to absorb moisture and the compost process is completed outside in windrows.

Objectives

This research investigated how the physical and chemical properties of finished compost were influenced by turning frequency and environmental conditions of partially decomposed swine manure-woodchip mixtures from a swine HRFF. Further, recommendations are provided to maximize composting efficiency based on the results of this research.

Materials and Methods

Wood chips were used as the carbon source and bulking agent. Hardwood was chipped and sized to pass a 2 inch screen prior to bedding the barn. A mixture of partially decomposed swine manure and woodchips was removed from under the HRFF and delivered to the Western Kentucky Agricultural complex in Fall 2011 (FT) and Spring 2012 (ST). The FT contained 76 cubic yards of material that weighed 108,800 lbs and the ST contained 81.4 cubic yards of material that weighed 106,840 lb. The material was divided into three triangular shaped windrows each season (Figure 1). The FT piles were approximately 34 ft x 7 ft x 3 ft (L x W x H) and the ST piles were approximately 15 ft x 9 ft x 4 ft (L x W x H) plus one conical shaped 6 ft tall pile with a 10.5 ft base that was not turned (0X). All managed piles were turned using a windrow compost turner (Model CT-10, HCl Machine Works, Dos Palos, CA) either once per week (1X), three times per week (3X), or when internal temperatures at 24 inches reached 150° F with a compost temperature probe (150F). The ST 150F treatment did not reach the desired temperature and after 63 days the pile was turned on a weekly schedule for the remainder of the experiment.

Compost was collected at three locations within each compost windrow and the ST. Within each location, five samples were combined and analyzed as a composite sample. Samples were collected on day 0 (initial), day three, weekly for the first 12 weeks, and bi-weekly until composting was terminated. Compost temperatures were monitored at one hour intervals by HOBO Pro V2 temperature sensors (Onset Computer Corp., Bourne, MA) at three different locations in each pile. Turning frequency in 150F was determined by a different set of temperature measurements. Ambient temperature and precipitation were collected from the Kentucky Mesonet weather station located within 50 ft of the compost site (http://www.kymesonet.org). Compost moisture (%) was determined on a dry matter basis (wet weight-dry weight/dry weight)*100. Dry weight was determined after drying at 221°F for 24 hours. Compost samples were extracted with 2 M KCl and analyzed for ammonium and nitrate nitrogen by flow injection analysis (QuickChem FIA+, Lachat Instruments, Milwaukee, WI). Total carbon (TC) and total nitrogen (TN) were determined with a Vario Max CN analyzer (Elementar Americas, Mt. Laurel, NJ). The remaining elements were subjected to microwave digestion with HNO_3 and HCl and measured with inductively coupled plasma-optical emission spectroscopy (Agilent Technologies, Santa Clara, CA). Compost pH was determined in a 1:1 (w/v) compost to water solution by a combination electrode (Accuphast electrode, Fisher Scientific, Pittsburg, PA). Compost data was presented as treatment means. The mixed-model procedure was used to determine significant differences at $p < 0.10$ (SAS version 9.3, SAS Institute, 2013, Cary, NC). A more detailed description of the methods used can be found in Cook et al. (2015).

Results and Discussion

Compost characteristics varied between seasons (Table 1). Compost pH for FT decreased with the 1X and 3X treatment but not in the 150F treatment nor any of the ST treatments. Total N did not change from the initial to the final product in the FT, but decreased for all managed piles in the ST (Table 1). The reduction in TN for the ST and not the FT could be due to the longer duration of the ST composting (31 days longer) which allowed for greater loss of ammonia by volatilization (Fukumoto and Kazuyuki, 2009) and nitrate via denitrification and leaching of different forms of mineral N (Parkinson et al., 2004). A reduction in TC was observed with the 1X and 150F treatments, but not in the 3X treatment in the FT. This was not expected or the same trend that occurred in the ST where the 3X treatment resulted in the greatest reduction of TC (Table 1). It is reasonable that the more often a pile is turned the more CO_2 is released to the atmosphere and this treatment was turned three times more often than the 1X and the 150F treatment (Tiqui et al., 2002). The ST TC results were typical of the expected outcome, CO_2 evolution increased (TC decreased) as turning frequency increased.

No significant differences in percent P_2O_5, K_2O, or S were observed for the FT but did occur in ST (Table 1). The ST concentrated percent P_2O_5, K_2O, and S in the 1X and 0X treatments and K_2O in the 150F treatments, but no others. The concentrating of these elements is not unexpected because leaching and volatilization losses are not typical with P_2O_5 and K_2O, and S would only show volatile losses in highly anaerobic conditions. It is unclear why the 3X treatment failed to concentrate P_2O_5, K_2O, and S because this treatment in ST resulted in the greatest reduction of TC. One possible explanation is that limited leaching of these nutrients from the crust (outside of pile) occurred (Tiquia et al., 2002). Because this treatment was turned the most often, there was more opportunity for newly exposed crust to be subjected to precipitation and greater potential for leaching within the pile below the sample collection point. Parkinson and associates (2004) observed some increases in molybdate-reactive phosphorus concentrations during turning of compost piles. The same mechanism may help to explain why the 0X treatment resulted in the greatest P_2O_5, K_2O, and S concentrations in ST, less total exposure of compost led to less leaching. There is no way to confirm this based on the data collected.

Compost moisture varied across treatment for both trials although total precipitation and average temperatures were similar. There were 12.77 inches of precipitation and average ambient temperature of 65.9° F for FT and 13.5 inches of precipitation and an average ambient temperature of 65.8° F for ST. Although similar when averaged across the 112 and 143 days of the experiment, the distribution of temperature and precipitation varied (Figures 2 and 3). The initial compost moisture level in ST was 7.7% wetter than the initial compost moisture level in FT (Table 1). The ideal moisture range for composting is between 40 to 60% and both initial products were in the ideal range. Although the compost moisture content for ST was in the ideal range, the higher moisture content and precipitation at the beginning of composting coupled with cooler initial ambient temperatures (<60° F) contributed to slow initial heating in ST (Figure 3).

The FT temperature profiles were typical of expected outcomes: initially the piles would heat, then cool when turned, then reheat until turned again (Zucconi and de Bertoldi, 1987) (Figure 2). All piles maintained this pattern as temperatures started to decrease after 3-4 weeks, until day 60 when turning did not provide an increase in compost temperature. Although the temperature profiles varied across treatment, they all were very similar at the end of composting at 112 days and were very similar to the ambient temperature (Figure 2). All treatments were regarded as finished at this time. None of the treatments appeared to produce a superior product (based on nutrient profiles or physical appearance) at the end of composting or benefit by reducing composting completion time (Table 1 and Figure 2). The results of the FT indicate that reducing compost turn frequency is not detrimental to compost completion, end product, and would reduce management and energy inputs.

The ST temperature profiles differed from FT profiles (Figure 3). All treatments were slow to initially heat, but the 1X was the first pile to exceed 140° F for any of the treatments (day 32). The 3X treatment was the next pile to exceed 140° F (day 53). The 0X pile never exceeded 95° F during the time temperature was measured (84 d); the maximum temperature was achieved at day 38. The @150F ST treatment never heated to 150° F during the first 63 days and weekly turning was initiated at this time. It is interesting, but not unexpected, that the temperature profile mimicked the 0X pile when the pile was not being turned and performed like the 1X temperature profile within one week of being turned the first time (Figure 3). There appeared to be no detrimental effects of not turning for 63 days prior to initiating weekly turning on the temperature profile (Figure 3). For ST, conservation of moisture, TN, TC, P_2O_5, K_2O, and S were generally less than the 0X and similar to the 1X treatment (Table 1).

The 3X ST treatment was the only spring treatment that appeared to be finished (reached ambient temperature) when the project was terminated at day 143. However, compost moisture levels dropped to 25.7% in the 3X ST and were below the ideal range for composting. Treatments turned once per week still had moisture sufficient for composting and were still showing evidence of cyclic heating/cooling with turning at day 143 when the project was terminated. This suggests that either low moisture in the 3X ST treatment limited composting or that lower turning frequency delayed composting in 1X ST. Additional moisture in the 3X ST or greater duration for the 1X ST may have allowed composting to continue in this season, although all final products had acceptable appearance and nutrient profiles.

Initial ammonium-N concentration was about 7 lb/ton (~15% of TN) in FT and 11.5 lb/ton (~19% of TN) in ST and very little inorganic-N remained at the end of either trial (Figures 4 and 5). Ammonium-N in the 1X and 3X FT treatments and all ST treatments continuously decreased until the concentration was below 1 lb/ton (Figures 4 and 5). Nitrate-N was relatively low until day 50 in the 1X and 3X FT treatments and day 100 is all ST treatments, than began to increase with time, to a maximum of 2-3 lb/ton. Warmer and drier conditions were present early in FT where ST was cooler and wetter which supports these results (Figures 4 and 5). It also appeared that the nitrification process in the 1X and 3X FT treatments generated acidity sufficient to lower compost pH in these treatments, but this did not occur in the ST treatments (Table 1). The 150F FT treatment never completely consumed all the ammonium-N, nitrate-N concentrations remained lower, and compost pH did not decrease. Further, the 0X ST treatment was not turned, but nitrification proceeded after day 60 (Figure 5D). Although gas exchange promotes the composting process, sufficient temperature and moisture was present in this treatment and anaerobic conditions were not sufficient to hinder nitrification.

Conclusions

Based on the results over the two seasons of this experiment, some general observations can be made to aid in compost management. Moisture management can be challenging when utilizing outside composting facilities. Turning frequency does not appear to greatly influence compost duration or final product if composting is initiated when weather is warm and moisture is adequate (e.g. FT). Lower turning frequency resulted in similar final products with less energy expenditures. Lower ambient temperatures coupled with early rainfall are much more challenging when trying to start the composting process. Turning frequently is more influential when initiating composting in cooler, wetter environments (e.g. ST). Turning will actually diminish evaporation and hinder compost heating within wet environmental conditions. When drier environmental conditions persist, turning will expose the pile to conditions that enhance drying, sometimes with detrimental effects. Environmental and compost conditions should be considered when determining turning frequency and timing rather than maintaining a set schedule. Covering an outdoor compost operation may not be feasible for controlling excess moisture; however adding supplemental moisture may be desirable to manage compost moisture content.

Acknowledgements

The authors thank O'Bryan Grain Farms, Inc. for providing access to materials, equipment, and facilities in support of this project. This project would not have been possible without technical support provided by Marty Haley, Jason Simmons, Stacy Antle, Derrek Brown, and Rohan Parekh, it was greatly appreciated.

References

Bernal, M.P., J.A. Alburquerque, and R. Moral. 2009. Composting of animal manures and chemical criteria for compost maturity assessment. A review. Bioresour. Technol. 100: 5444-5453.

Cook, K.L., E.L. Ritchey, J.H. Loughrin, M. Haley, K.R. Sistani, and C.H. Bolster. 2015. Effect of turning frequency and seaon on composting materials from swine high-rise facilities. Waste Manag. 39:86-95.

Key, N., W.D. McBride, M. Ribaudo and S. Sneeringer. 2011. Trends and Developments in Hog Manure Management: 1998-2009. US Dept. of Agriculture, Washington, D.C. p. 1-39.

Miller, F.C. 1992. Composting as a process based on the control of ecologically selective factors. p. 515-544. *In* F.B. Meeting Jr (ed.) Soil Microbial Ecology, Applications in Agricultural and Environmental Management. Marcel Dekker, Inc. New York, NY

Parkinson, R., P. Gibbs, S. Burchett, and T. Misselbrook. 2004. Effect of turning regime and seasonal weather conditions on nitrogen and phosphorus losses during aerobic composting of cattle manure. Bioresourc. Technol. 91: 171-178.

Stowell, R.R. 2002. Applicability of high-rise ™ hog housing for finishing operations. Nebraska Swine Rep., 54-59

Tiquia, S.M., T.L. Richard, and M.S. Honeyman. 2002. Carbon, nutrient, and mass loss during composting. Nutr. Cycl. Agroecosyst. 62: 15-24

USEPA. 2013. Literature Review of Contaminants in Livestock and Poultry Manure and Implications for Water Quality. U.S. Environmental Protection Agency, Washington, D.C. p. 137

Zucconi, F. and M. de Bertoldi. 1987. Compost specifications for the production and characterization of compost from municipal solid waste. p. 30-50 *In* M. de Bertoldi, M. P. Ferranti, P. L'Gernutem F. Zucconi (Eds) Compost: Production, Quality and Use. Elsevier, Essex, UK

Table 1. Chemical characteristics of initial and final compost as calculated on a % dry matter basis.

Treatment	pH	Moisture %	Total N %	Total C %	C/N ratio	P_2O_5 %	K_2O %	S %
Fall Trial								
Initial	7.7 c	49.4 c	2.3 a	27.9 b	12.1 c	3.9 a	2.6 a	0.8 a
1X (12)[1]	6.9 b	42.0 b	2.2 a	24.9 a	11.1 ab	4.6 a	2.4 a	0.8 a
3X (36)	6.6 a	44.1 b	2.3 a	26.3 ab	11.4 b	4.4 a	2.4 a	0.5 a
150F (11)	7.6 c	32.2 a	2.3 a	24.3 a	10.5 a	4.4 a	2.4 a	0.5 a
Spring Trial								
Initial	8.0 a	57.1 d	3.1 c	33.2 c	10.7 a	4.9 a	3.2 a	1.0 a
1X (18)	7.8 a	30.6 b	2.5 b	27.3 b	10.8 a	5.6 b	3.9 cd	1.3 b
3X (54)	7.8 a	25.7 a	1.9 a	22.0 a	11.4 a	4.6 a	3.3 ab	0.9 a
150F (10)	7.8 a	37.2 c	2.4 b	26.1 b	10.9 a	5.1 ab	3.6 bc	1.0 a
0X (0)	7.7 a	58.1 d	3.2 c	33.0 c	10.4 a	6.6 c	4.0 d	1.3 b

[1] numbers in (parenthesis) indicate the number of times each pile was turned for individual treatments. Means within a column with no common letter differ at P<0.10 for individual trials.

Figure 1. Compost piles for the fall trial (FT).The final product should result in a friable, easily spreadable, non noxious material.

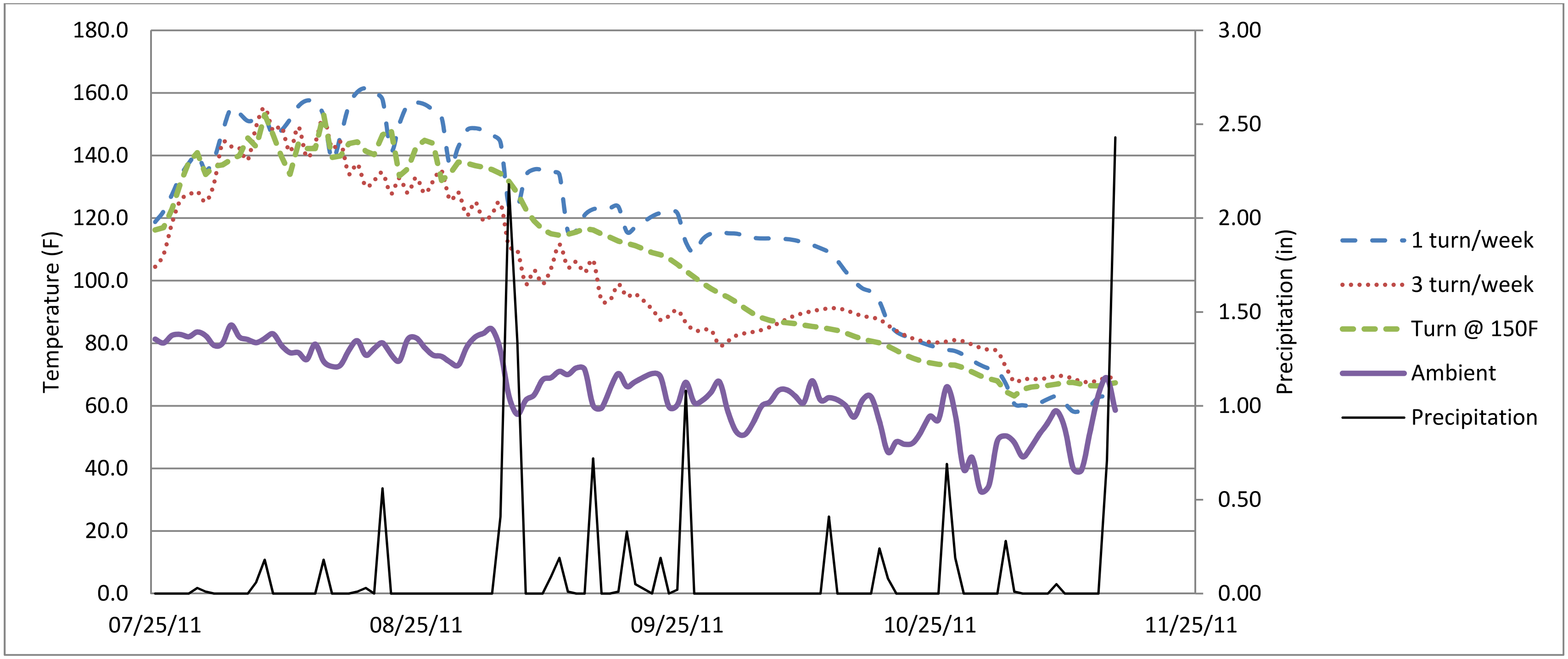

Figure 2. Compost temperature, ambient temperature, and precipitation profiles for the Fall Trial (114 days).

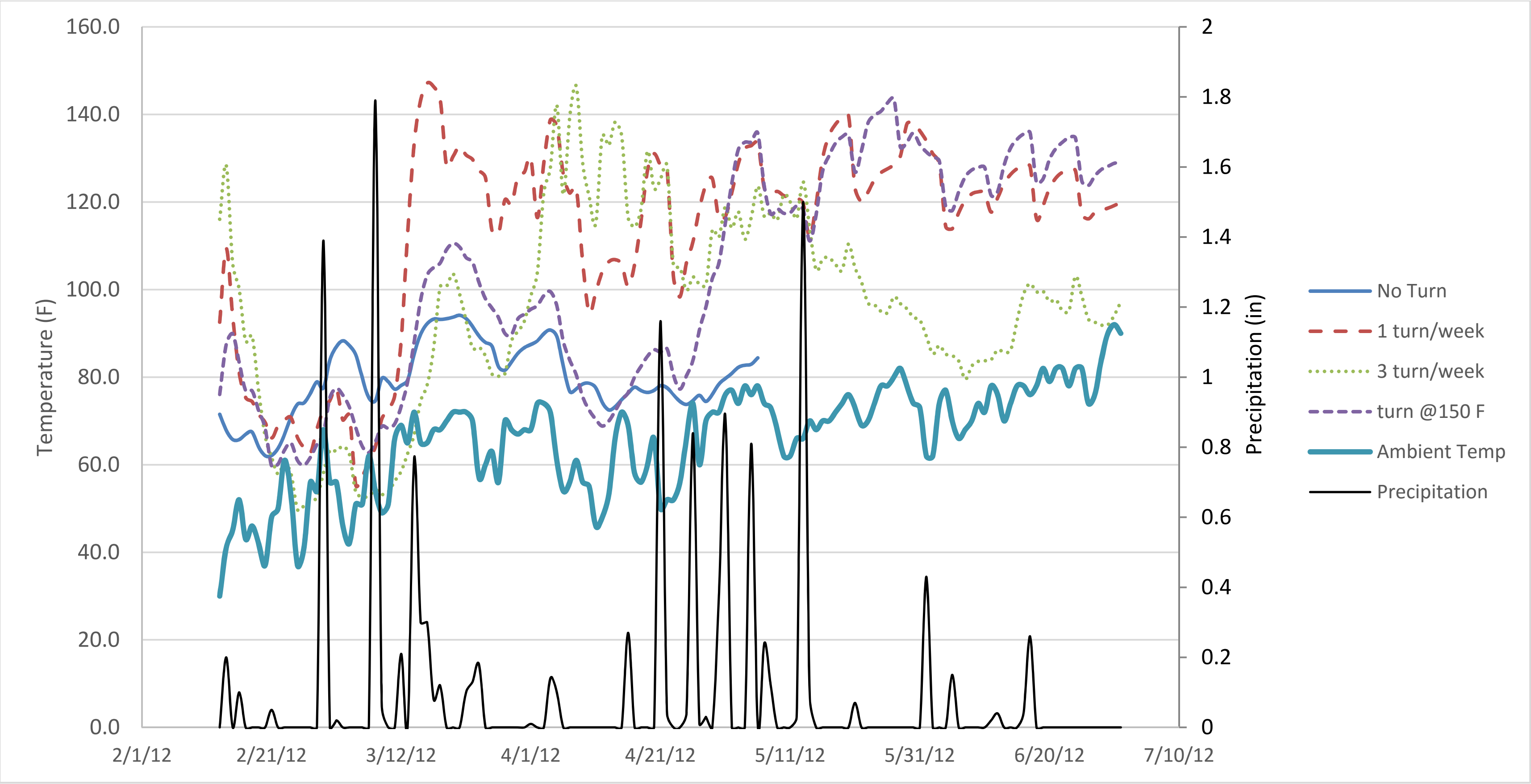

Figure 3. Compost temperature, ambient temperature, and precipitation profiles for the Spring Trial (140 days).

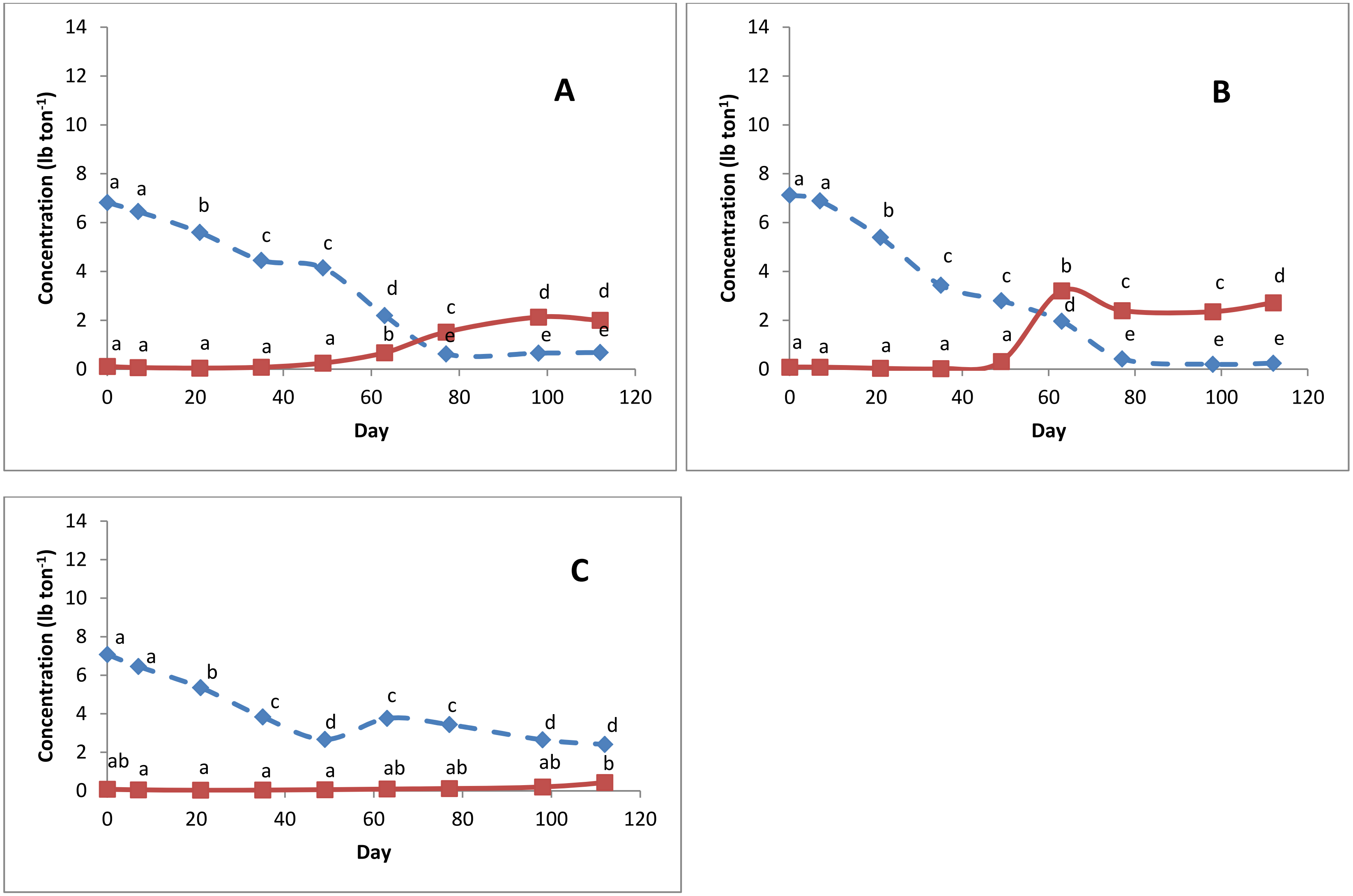

Figure 4. Nitrogen dynamics for ammonium- (blue dashed lines) and nitrate-nitrogen (red solid lines) for the fall trial. Piles were turned one time per week (A), three times per week (B), or when piles reached 150F (C). Different letters within nitrogen forms differ at P<0.1.

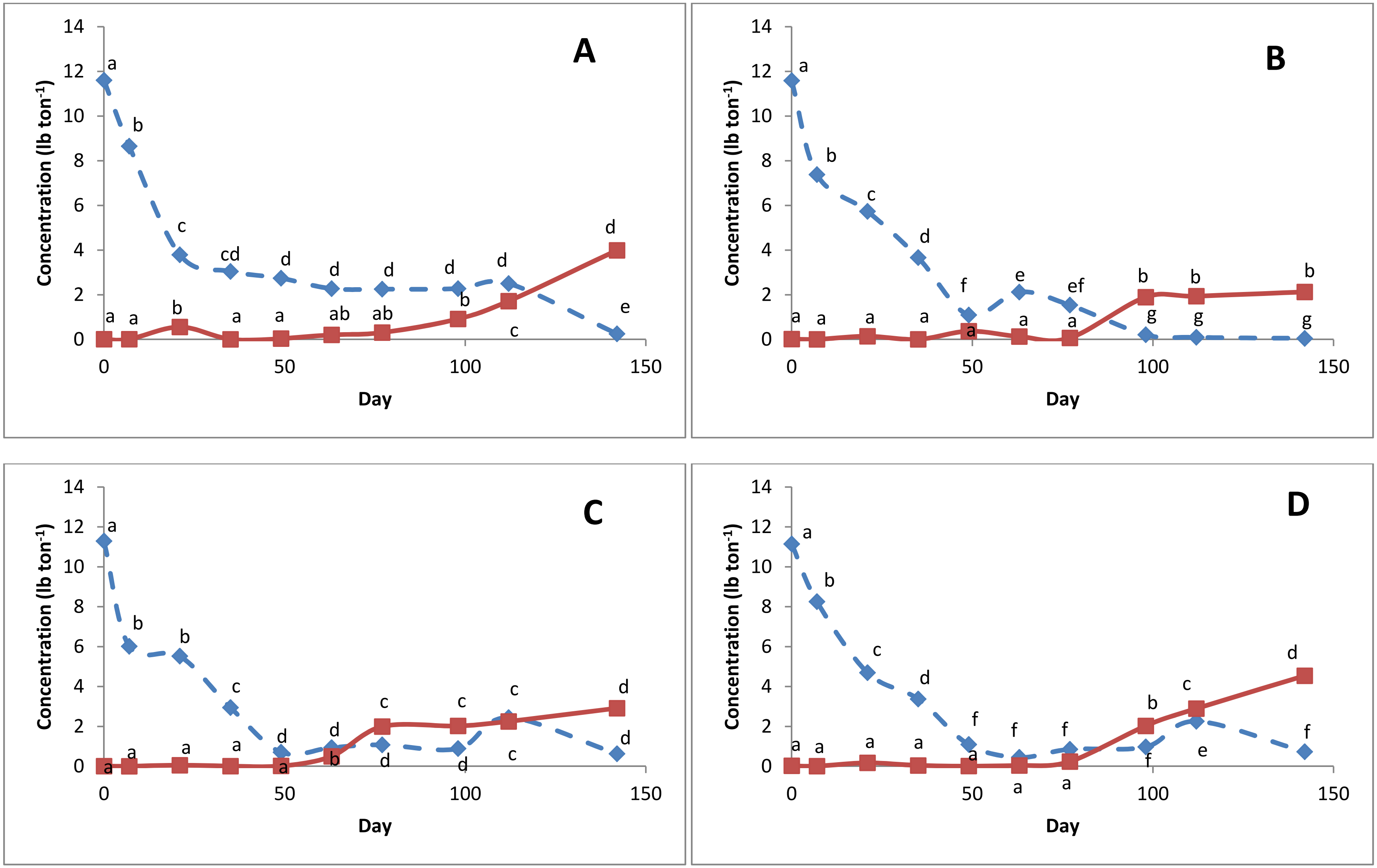

Figure 5. Nitrogen dynamics for ammonium- (blue dashed lines) and nitrate-nitrogen (red solid lines) for the spring trial. Piles were turned one time per week (A), three times per week (B), when piles reached 150F (C), or not turned (D). Different letters within nitrogen forms differ at P<0.1.