An ASABE Meeting Presentation

Paper Number: 064061

Aerobic Composting of Swine Manure Solids Mixed with Cotton Gin Waste

Matias B. Vanotti

USDA-ARS, Costal Plains Research Center, 2611 W. Lucas St, Florence, SC, 29501. vanotti@florence.ars.usda.gov

Patricia D. Millner

USDA-ARS, Sustainable Systems Laboratory, Beltsville, MD. millnerp@ba.ars.usda.gov

Ariel A. Szogi

USDA-ARS, Costal Plains Research Center, Florence, SC. szogi@florence.ars.usda.gov

C. Ray Campbell

Super Soil Systems USA, Clinton, NC. crcampb@bellsouth.net

Lewis M. Fetterman

Super Soil Systems USA, Clinton, NC. supersoil@intrstar.net

Written for presentation at the
2006 ASABE Annual International Meeting
Sponsored by ASABE
Oregon Convention Center
Portland, Oregon
9 - 12 July 2006

Abstract. *Liquid-solid separation treatment can solve many environmental problems associated with confined livestock production. However, treatment technologies are needed to transform the separated manure solids into value-added products. Our objective was to demonstrate, at full-scale, the composting of separated swine manure solids using a centralized solids processing facility. In this facility, the solids were combined with cotton gin waste and wood chips to optimize the* *composting process. The produced composts conserved 95-100% of the nitrogen and other nutrients and met EPA Class A biosolids quality standards due to low pathogen levels. The composts were used for manufacture of soil amendments, organic fertilizers, and potting soil. Results from this project have demonstrated that manure and other agricultural wastes can be transformed into value-added products using a simple and effective technology.*

Keywords. Animal waste treatment, swine manure solids, by-product utilization, aerobic composting, environmentally superior technology, EST, pathogens, cotton gin trash.

Introduction

The composting operation was part of a total system comprised of 1) on-farm wastewater treatment facilities that replaced anaerobic lagoon treatment with a system that uses liquid-solid separation, nitrification/denitrification, and soluble P removal technologies (Vanotti et al., 2006), and 2) a centralized solids processing facility where separated manure is aerobically composted and transformed into value-added products including soil amendments, organic fertilizers, container substrate, and soillesss media.

The total system went through full-scale demonstration and verification as part of the Smithfield Foods / Premium Standard Farms / Frontline Farmers - North Carolina Attorney General Agreement to identify technologies that can replace current lagoons with Environmentally Superior Technology (Williams, 2006). Objectives were to demonstrate at full-scale and evaluate the total manure treatment system to determine if it meets the criteria of an Environmentally Superior Technology.

The on-farm system was demonstrated on a 4,360-head finishing farm in Duplin County, North Carolina, and results are summarized in Vanotti et al., 2006. In this paper we report on demonstration and performance verification of the centralized solids processing facility that transformed separated manure solids into value-added compost products.

Compost Process Description

Composting is a natural decomposition process that stabilizes manure organic matter and reduces odors and pathogens. This is a rapid, self-heating aerobic process carried out by bacteria and fungi, which digest the wastes and reduce it to a stable humus. It has developed in recent years into a robust waste-management technology that generates valuable organic soil amendments. The compost design in this work is an agitated bed aerated system operated inside a pole-barn-type structure that protects the compost from rainfall. Solids are mixed with amendments and bulking agents and mechanically agitated and aerated, with subsequent curing in static windrows retained for at least 30 days.

The process was performed in three contiguous areas:

1. A concrete pad at the front of the process that received the manure solids arriving daily in trailers from Goshen Ridge farm. The same area was used to put the bulking materials (cotton gin trash and wood chips) used in the compost mixtures. A front-end loader was used to carry manure and bulking material loads to the composting bins immediately after trailer arrival.

2. Composting bins (or channels) where the compost mixtures were mechanically agitated to enhance the thermophilic phase (Figure 1). The bins were 58.5 m long, 2.0 m wide, and 0.9 m deep. There were five bins installed at the composting facility, all under one common roof; but only bins 1 and 2 were evaluated in this project (using swine solids produced at a 4360-head swine facility). A mechanical mixer (7.5 hp Compost-A-Matic 210, Farmer Automatic of America, Inc, Register, GA) that served all bins moved about daily through each of the bins, agitating the compost, and at the same time advancing the material from one end to the other.

3. Curing static windrows that were the final stage in the composting process. Two curing windrows were assessed; they received compost material from bins 1 and 2 (Figure 2).

Figure 1. Front of compost bin showing mixture of swine manure solids and cotton gin waste after initial mixing and the railing system used to move the mechanical mixer along the bins.

Figure 2. Curing static windrows used to complete the composting process. Darker compost (left pile) used a mixture of 1SS:2CGT, and lighter compost used 1 SS:2CGT:4WC.

Materials and Methods

The full-scale composting demonstration facility was installed at Hickory Grove farm in Sampson County, NC, and received the separated solids from the production swine facility 30 miles away. The solids were transported daily from the farm using trailers. The technology was evaluated under steady-state conditions during 6.5 months (June 1, 2004, to January 15, 2005). Two bins were needed to handle separated solids from a 4,360-head finishing farm.

Bin 1 was loaded with two types of mixtures during the length of the evaluation. A mixture 1SS:2CGT:4WC (1 volume of separated manure solids mixed with 2 volumes of cotton gin trash and 4 volumes of wood chips) was used from July 16, 2004, to October 27, 2004, and a mixture 1SS:2CGT was used from October 28, 2004, to the end of the evaluation period (January 15, 2005).

Bin 2 used a mixture 1SS:2CGT (1 volume of separated manure solids mixed with 2 volumes of cotton gin trash). Loading of bin 2 with this mixture started April 1, 2004. The compost product reached the end of the bin in about 1 month. Therefore, when verification started (June 1, 2004), the process in this bin was at steady-state.

Sample Collection, Analytical Methods, and Monitoring

For the separated solids, we collected one sample from each trailer that left Goshen Ridge farm. After moisture determination, solid samples from individual trailers were combined into two weekly samples for chemical analyses. For compost materials, once a month we collected duplicate samples of materials at the end of each compost bin and after curing.

Determination of volumes of the various compost mix components were based on daily records of trailers (before 9/20/04) or number of tractor scoops loaded into each bin (after 9/21/04). For compost products, volumes were calculated using daily records of tractor scoops used to unload the compost at the end of each bin. The volume carried by a tractor scoop was determined for each material by loading two scoops, emptying them on the concrete pad, and shoveling each load into calibrated buckets. We also determined compost production using a second method for comparison with the scoop accounting method. This second method used changes in curing pile volume and weight during the evaluation accomplished by surveying these piles at various times. Results showed a 94% agreement in the dry weight produced determined using the scoop accounting method vs. the dry weight produced that was estimated using the pile surveying method.

Volume determinations were combined with corresponding bulk densities, moisture, and chemical analyses to determine loading rates and nutrient mass balances. Bulk densities of manure solids, cotton gin trash, wood chips, and compost products were determined at the site using calibrated, 5-gal. buckets and an electronic scale.

Process moisture was determined weekly by the compost-master on samples collected at 15 points throughout the length of each bin. Moisture was determined gravimetrically by drying samples to constant weight using an oven and scale station that was set up at the composting facility. We also determined moisture in all samples taken to Florence and Beltsville laboratories and used for confirmation of the more intensive field determinations or specific reporting of pathogen results and cured compost.

Chemical analyses consisted of pH, electrical conductivity (EC), total nitrogen (TN), carbon (C), total P (TP), copper (Cu), zinc (Zn), ammonia-N (NH_4-N), nitrate-N (NO_3-N), and soluble P (PO_4) using Standard Methods (APHA, 1988).   Carbon and TN contents were determined using dry combustion analysis. Microelements were measured in acid digestion extracts using inductively coupled plasma (ICP) analysis. Soluble P was determined by the automated ascorbic acid method, NH_4-N by the automated phenate method, and NO_3-N by the automated cadmium reduction method. Total P was determined using acid block digestion and the automated ascorbic acid method adapted to digested extracts.

Temperatures of the compost process were measured daily by the operator at 15 points throughout the length of each bin using calibrated compost thermometers. Values reported at each point were the average of three thermometer readings. Temperature readings were checked against independent monthly readings done by the evaluation team at same points.

Microbiological analyses were done in the laboratory of Dr. Patricia Millner in Beltsville, MD, using the standard protocols for pathogens and indicator microbes for the examination of manure and composts.

Operational Conditions of Compost Process

Data in table 1 show operational conditions of the compost process. Every time the machinery agitated the mixture, it also advanced the material. It took about 30 passes to move the compost from one end of the channel to the other end. The machinery was typically operated 5 to 6 times per week, which resulted in a typical retention time in the channels of about 40 days. The exception was during September 2004 and January 2005. In September 2004, lower amounts of manure available for composting, associated with low pig weight at Goshen Ridge farm, resulted in decreased loading rate and mixing intensity in the composting operation. The opposite occurred in January 2005; mixing frequency was increased to about seven days a week to process higher daily loads associated with market-size pigs at the production farm.

Once the compost mixture reached the end of the channel or bin, it was carried into subsequent curing in static windrows (no turning) for further stabilization. There, it was retained for at least 30 more days. The compost was considered mature after this curing stage.

Table 1: Operational conditions of compost process: Average daily loading, average mixing times per week, retention times, and moving speed. Volume load is a mixture of swine manure and bulking agents. The machinery has two functions: one is to turn the compost, the second is to move the compost thru the bin. It takes about 30 passes of the mixing machinery to advance the compost mixture from one end of the bin to the other (192 ft or 58.5 m). July data for bin 1 are for 16 days. January data for both bins are for the first 15 days.

Manure Loading	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Average
Bin #1									
Volume load (m^3/d)	--	2.98	3.84	1.74	4.14	3.38	2.23	4.81	3.30
Number of turns per week	--	5.7	4.7	2.6	5.9	5.6	5.6	7.0	5.3
Retention time (days)	--	36.9	44.3	81.8	35.8	37.5	37.2	30.0	43.4
Moving velocity (m/day)	--	1.58	1.32	0.72	1.64	1.56	1.57	1.95	1.48
Bin #2									
Volume load (m^3/d)	3.57	3.70	2.47	1.24	3.62	2.97	1.68	4.81	3.01
Number of turns per week	4.4	4.5	5.9	3.3	6.3	4.4	5.0	6.5	5.0
Retention time (days)	47.4	46.5	35.8	64.3	33.2	47.4	42.3	32.1	43.6
Moving velocity (m/day)	1.24	1.26	1.64	0.91	1.76	1.24	1.38	1.82	1.41

Loading Rates of Manure Solids and Nutrients

Monthly loading rates of swine manure solids, nutrients (N and P) and metals (Zn and Cu) into the composting unit are shown in table 2. A total of 297 m^3 of manure weighing 248 metric tons and containing 16.7% solids was processed in the composting facility from June 1, 2004, to January 15, 2005, to produce stabilized, value-added compost materials. The separated manure contained 5.3% total nitrogen, 4.0% phosphorus, 0.32% copper, 0.30% zinc (values on dry weight basis, table 3) that are equivalent to 2.2 metric tons of nitrogen, 1.7 metric tons of phosphorus, 125 kg of copper, and 125 kg of zinc.

Table 2: Monthly manure loadings into the compost operation during the evaluation period June 2004-Jan 2005. Separated solids from Goshen Ridge farm were transported daily to the centralized composting facility. Moisture content (%) = 100 – solids (%). January data are for the first 15 days. Table shows only manure components (SS).

Manure Loading	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Total (average)
Manure Volume (m^3)	35.7	45.0	42.5	17.5	41.8	47.6	30.3	36.1	296.5
Manure Weight (x 1000 kg)	29.3	37.5	34.9	14.8	35.9	39.6	25.1	30.3	247.5
Solids (%)	17.3	16.8	17.2	16.3	15.8	16.8	17.0	16.5	(16.7)
Manure Total N (kg)	251	324	334	139	322	371	223	234	2198
Manure Total P (kg)	234	293	281	104	219	250	144	149	1674
Manure Zinc (kg)	14.2	20.8	19.8	7.7	15.9	18.6	13.0	15.0	125.1
Manure Copper (kg)	15.7	20.2	19.2	7.9	18.7	22.0	14.5	16.5	134.1
% load into Bin 1	0	15.1	40.0	37.0	33.0	53.2	57.0	50.0	(35.7)
% load into Bin 2	100	84.9	60.0	63.0	67.0	46.8	43.0	50.0	(64.3)

Table 3: Composition of manure solids from liquid-solid separation treatment (Goshen Ridge farm) used in the composting process at the Hickory Grove facility. Concentration values are on a dry weight basis. Total nitrogen measurement includes ammonia-N. Data are means for the period June 1, 2004-January 15, 2005.

Element	Average Concentration %	Monthly Min-Max Concentration %
Total Nitrogen	5.32	4.68-5.75
Ammonia Nitrogen	0.34	0.27-0.38
Total Phosphorus	4.03	2.98-4.68
Copper	0.32	0.31-0.33
Zinc	0.30	0.28-0.33
Total Carbon	38.16	33.52-43.04
Potassium	0.54	0.46-0.61
Calcium	2.31	1.89-2.68
Magnesium	2.09	1.96-2.24
Sulfur	1.25	1.19-1.32

Bulking Materials

Separated raw manure contained a high moisture content (83.3%), high bulk density (0.84 kg/L), and low C/N ratio (7.2); conditions that are not good for optimal aerobic composting conditions. To improve these conditions and optimize the composting process, bulking agents and amendments were used. Their addition reduced bulk density and moisture content and increased porosity and the C/N ratio, all of which are critical for production of quality composts. Amendments included cotton gin trash residue (Figure 9), an abundant waste in the region, and wood chips (table 4). Solids processed in bin 1 used a mixture of 1SS:2CGT:4WC (SS=separated manure solids, CGT=cotton gin trash, and WC=wood chips) from July 16, 2004, to October 27, 2004, and a mixture 1SS:2CGT from October 28, 2004, to the end of evaluation (January 15, 2005). Solids processed in bin 2 used a mixture 1SS:2CGT throughout the evaluation.

Table 4: Composition of bulking agents used in the compost mixtures with swine manure. Elemental concentration values are on a dry weight basis.

Characteristics of Bulking Agent	Cotton Gin Trash (CGT)	Wood Chips (WC)
Density (kg/L)	0.092	0.455
Moisture (%)	12.7	66.1
Total Nitrogen (%)	1.02	0.67
Total Phosphorus (%)	0.18	0.30
Copper (%)	0.0039	0.0087
Zinc (%)	0.0070	0.0147
Total Carbon (%)	42.88	42.13

Weather Conditions

Performance evaluation (June 2004-January 2005) included cold and warm weather conditions; average daily air temperatures ranged from 32.3 to 89.3^{o}F (0.2 to 31.8^{o}C) (Figure 3).

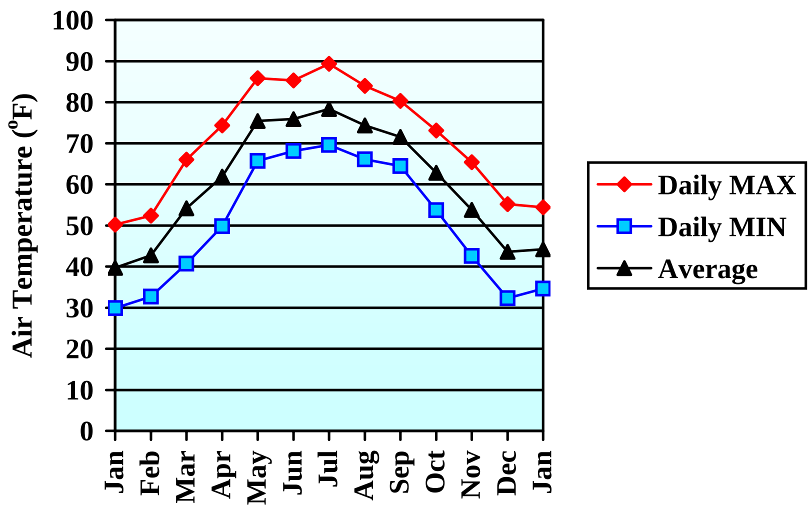

Figure 3: Air temperature during Jan 2004-Jan 2005. Data are monthly average of daily Max and Min air temperature and monthly average of 2-m average daily temperatures.

Mass Balance of Materials and Nutrients

Data in table 5 show mass balance calculations of the mixture materials before and after compost processing. Results obtained with both mixes were consistent. The process significantly reduced total volume, weight, and carbon. On average, final volume was reduced to about 29% of the initial volume, while total weight and carbon were reduced to about 56% of the initial amounts. This was expected because carbon sustains the biological activity in the compost and it is lost through microbial respiration.

Table 5: Mass balance of compost materials during composting process including total C, total N, total P, and heavy metals. Bin 1 was loaded with two types of mixtures: A mixture 1SS:2CGT:4WC (SS=separated manure solids, CGT=cotton gin trash, and WC=wood chips) was used from July 16, 2004, to October 27, 2004, and a mixture 1SS:2CGT was used from October 28, 2004, to the end of evaluation (January 15, 2005). Mass balance data for bin 1 include totals for the period August 1, 2004, to January 15, 2005. Bin 2 used a mixture 1SS:2CGT; mass balances are for the period June 1, 2004, to January 15, 2005.

Mass Balance of Compost Materials and Elements	Mixture of Swine Manure and Bulking Agents	Compost product	Recovery (%)
1. Compost processed in Bin 1			
Material Weight (x 1000 kg)	184.8	102.2	55.3
Material Volume (m^3)	542.3	176.1	32.5
Total Carbon (kg)	25,908	13,601	52.5
Total Nitrogen (kg)	1134	1125	99.2
Total Phosphorus (kg)	631	630	99.8
Total Zinc (kg)	46.3	44.9	97.0
Total Copper (kg)	47.8	43.6	91.1
2. Compost processed in Bin 2			
Material Weight (x 1000 kg)	203.2	113.2	55.7
Material Volume (m^3)	661.2	166.0	25.1
Total Carbon (kg)	26,190	15,884	60.6
Total Nitrogen (kg)	1800	1707	94.8
Total Phosphorus (kg)	1185	1207	101.9
Total Zinc (kg)	83.6	84.5	101.0
Total Copper (kg)	87.8	86.0	97.9
3. All Composts (Bins 1 + 2)			
Material Weight (x 1000 kg)	388.0	215.4	55.5
Material Volume (m^3)	1204	342.1	28.4
Total Carbon (kg)	52,098	29,485	56.6
Total Nitrogen (kg)	2934	2832	96.5
Total Phosphorus (kg)	1816	1837	101.2
Total Zinc (kg)	129.9	129.4	99.6
Total Copper (kg)	135.6	129.6	95.6

For nutrients, we conducted mass balances for N, P, Zn, and Cu (table 5). Phosphorus, Zn, and Cu are considered conservative elements in the sense that they will not volatilize and can be used as a reference in mass balance studies to assess gaseous losses of non-conservative elements, such as N (ammonia) and carbon (CO_2). Results showed that nearly all (95 to 99%) of the N was accounted for in the compost product and that very little of the N (<3.5%) was lost probably through ammonia volatilization. Thus, most of the N was incorporated into stabilized forms. This conclusion is supported by quantitative recovery (~100%) obtained with the conservative elements.

Compost Product Characteristics

Characteristics of the cured composts are shown in table 6. Two composts were produced: A Supersoil compost that used mix formulation 1 (1SS:2CGT:4WC), which is used for soil amendment and as the main ingredient in the manufacturing of potting soil, soilless media, and container substrate; and a Supersoil compost produced with mix 2 (1SS:2CGT), which is used for fertilizer manufacturing and is being tested for use as a general soil amendment.

Nutrient grades of the cured products (as sampled on a wet basis) were 1.1N:1.6 P_2O_5:0.6K_2O and 1.5N:3.1P_2O_5:1.1K_2O for compost mix #1 and #2, respectively. Corresponding dry weight nutrient grades were 2.0:2.9:1.1 and 3.2:6.8:2.4, respectively. One of the benefits of the compost over raw manure is that it provides slow-releasing nutrients for plant uptake. For example, most of the nitrogen (96.5%) was stabilized and only 3.5% was present in soluble ammonia and nitrate forms. Our frequent examinations of these compost materials sampled either at the end of the bin or in the curing pile indicated that these materials had an agreeable, earthy scent and rich texture, and did not attract flies.

Table 6: Characteristics of compost products after 30-d curing. Mix 1 contained separated manure solids, cotton gin trash and wood chips processed in bin 1 during July-October 2004. Mix 2 contained separated manure solids and cotton gin trash processed in bin 2 during July 2004-January 2005. Percent elemental composition values are on a dry weight basis; to convert to wet weight basis, multiply by [(100 - % moisture)/100]

Compost Characteristics	Compost Produced Using Mix 1 (1SS:2CGT:4WC)	Compost Produced Using Mix 2 (1SS:2CGT)
Moisture (%)	44.6	54.7
Bulk Density (kg/L)	0.47-0.52	0.68-0.72
Total Carbon (%)	28.6	28.8
Total Nitrogen (%)	2.01	3.22
Ammonia-N (%)	0.05	0.11
Nitrate-N (%)	0.019	0.003
Total Phosphorus (%)	1.25	2.96
Soluble Phosphorus (%)	0.33	0.60
Potassium (%)	0.90	2.01
Calcium (%)	1.21	2.77
Magnesium (%)	0.54	1.41
Zinc (%)	0.0746	0.1708
Copper (%)	0.0677	0.1650
Sulfur (%)	0.48	0.96
pH	6.50	6.71
Electrical Conductivity (mS/cm)	7.60	10.10

Compost Process Temperatures

Aerobic decomposition, the main process responsible for composting, is an exothermic process that releases a large amount of heat. Heat is generated by microbes that digest organic matter. An internal temperature in the range of 130 to 150°F is evidence that the compost is working well and that the environment is suitable. These high temperatures are produced by the biological activity of thermophilic microorganisms that decompose and stabilize organic matter. Then, as the microbes gradually deplete the food sources, their metabolic activity declines and so does the temperature of the mix. In addition to speeding up the decomposition process, the heat produced also helps in killing pathogenic microorganisms. Process temperatures obtained during the demonstration period were consistent in the two bins (Figure 4). Average temperatures quickly increased to > 130°F during the first 10 meters, peaked throughout the following 15 to 20 meters, and decreased at a steady rate while the mixture moved toward the end of the bin (Figure 4). Compost moved at an average velocity of 1.41 to 1.48 m/day; therefore, these high temperatures were sustained for an average of about 10 to 15 days. Compost process temperatures obtained during cold weather conditions were higher compared to values obtained during warm weather conditions. For example, average peak process temperatures obtained at 15 to 25-m distance were 131°F during the warmer months (June, July and August), and 145°F during the coldest months (Nov., Dec., and Jan). These conditions resulted in good pathogen killing and quality grade composts as shown in the following section.

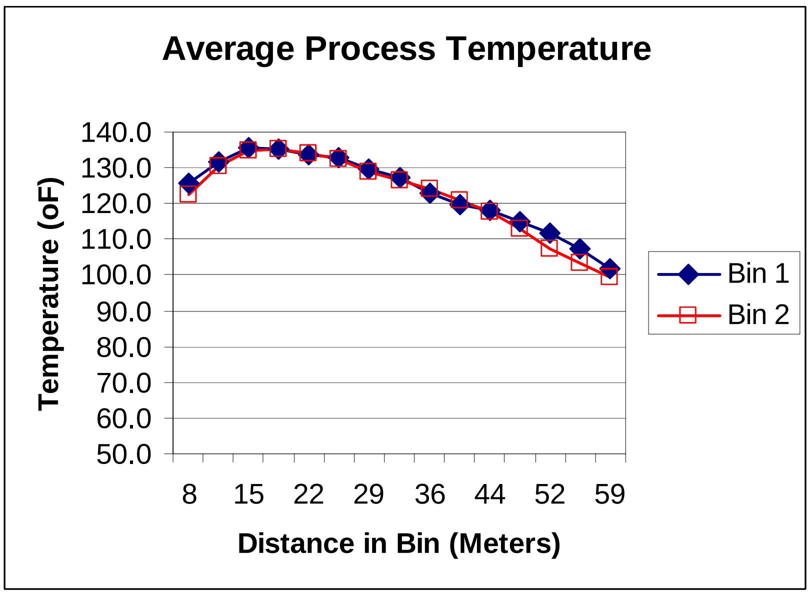

Figure 4. Compost process temperatures (°F) along the bins from start (0 m) to end (58 m). Data are averages of daily temperature records taken during evaluation period . Temperature measurements were taken between 7am and 9:30am.

Reduction of Microbial Indicators of Fecal Contamination by Composting Process

We measured total heterothrops and total fecal coliforms at various points in the process including untreated separated manure. Total heterotrophs are indicators of microbial activity in the composting process and include beneficial microorganisms. On the other hand, total fecal coliforms are pathogen indicators of fecal contamination that are also used to establish compost grade or class. The USEPA has developed a classification system for treated waste, including treated manure. Class A Biosolids compost must have a fecal coliform density of less than 1000 Most Probable Number (MPN)/gram of total solids on a dry weight basis (Code of Federal Regulations, 2004, 40 CFR Part 503.32). Composts meeting the Class A Biosolids standards may be used by the general public, nurseries, gardens, and golf courses. This standard is also required for biosolids to be sold in a container or to be applied to home gardens and lawns.

Table 7: Microbiological analyses of separated swine manure solids and compost samples. Percent moisture was determined for each sample and cfu/g was adjusted to reflect the dry weights of the samples. Values are means of duplicate samples. BDL (below detectable limit of the test) indicates there were no positive colonies to be counted on spiral-plated samples (<1.00E+00); MPN series were performed in order to quantify the counts (values in parenthesis). Mix 1 was 1SS:2CGT:4WC; mix 2 was 1SS:2CGT.

Sampling date and location	Total Heterotrophs cfu/g dry	Total Fecal Coliforms cfu/g dry (MPN/g)	Log 10 Reduction of Total Fecal Coliforms	EPA Class A Biosolids
Sampling date 7/29/04				
Separated manure solids	5.77×10^8	7.02×10^5	--	no
Cured compost mix 2 (30 days)	2.07×10^7	BDL	5.85	yes
Sampling date 9/1/04				
Separated manure solids	2.32×10^9	6.46×10^5	--	no
End of bin compost mix 1	1.47×10^7	9.62×10^1	3.83	yes
End of bin compost mix 2	1.59×10^7	1.33×10^3	2.69	no
Cured compost mix 2 (35 days)	1.86×10^7	BDL (3.50×10^1)	4.27	yes
Cured compost mix 2 (86 days)	1.76 x 107	BDL (1.33×10^1)	4.69	yes
Sampling date 11/1/04				
Separated manure solids	8.03×10^8	2.97×10^5	--	no
End of bin compost mix 1	1.11×10^9	4.68×10^3	1.80	no
Cured compost mix 1 (12 days)	7.77×10^6	1.35×10^3	2.34	no
Cured compost mix 1 (35 days)	4.21×10^8	BDL ($<3.0 \times 10^0$)	5.47	yes
End of bin compost mix 2	2.25×10^9	1.48×10^3	2.30	no
Cured compost mix 2 (17 days)	4.75×10^7	8.76×10^2	2.53	yes
Cured compost mix 2 (33 days)	3.44×10^8	5.37×10^2	2.74	yes

Composting of manure solids with cotton gin trash and wood chips in the channel mechanically agitated, aerated system showed substantial reduction in pathogen indicators during the thermophilic phases, with further stabilization dependent on subsequent curing in static windrows retained for at least 30 days (table 7). Reduction in fecal coliform at the end of thermophilic phase (after approximately 43 days RT in the agitated channel) was not sufficient to meet the strict Class A requirements, but subsequent curing stage (30 d) produced a quality compost that met the USEPA Class A pathogen requirement in fecal coliform standard (table 7).

Conclusions

Results from this project have demonstrated that manure and other agricultural wastes can be transformed into value-added products using a simple and effective technology.

A total of 273 tons of raw manure solids was converted into 237 tons of valuable organic materials with an earthy scent and rich texture that can be used for fertilizer manufacture, soil amendments, and potting soil. The composts conserved 95-100% of the nitrogen and other nutrients into a stabilized product. The process showed substantial elimination of pathogen indicators meeting EPA Class A biosolids standards.

It was verified that the technology is technically and operationally feasible. Based on performance results obtained, the treatment system was certified as an Environmentally Superior Technology (Williams, 2006).

Acknowledgements

This research was part of USDA-ARS National Program 206: Manure and By-product Utilization; ARS Project No. 6657-13630-003-00D “Innovative Animal Manure Treatment Technologies for Enhanced Environmental Quality.” Technology verification was partially funded by North Carolina State University and its sponsor Smithfield Foods, Inc. through USDA Agreement 58-6657-2-202, NCSU Subcontract #2001-0478-02. The authors are grateful to Nelson Renfrow of Super Soil Systems USA for field help and Aprel Ellison and David Ingram of USDA-ARS for help with sampling and laboratory analyses.

References

APHA, AWWA, WEF. 1998. Standard Methods for the Examination of Water and Wastewater. 20th Edition. Washington, D.C., USA.

Vanotti, M.B., Szogi, A.A., Hunt, P.G., Millner, P.D., Humenik, F.J. 2006. Development of environmentally superior treatment systems to replace anaerobic swine lagoons in the USA. *Bioresource Technol.* (in press).

Williams, C.M. 2006. Development of Environmentally Superior Technologies. Phase III Report for Technology Determination per Agreements Between the Attorney General of North Carolina and Smithfield Foods, Premium Standard Farms and Frontline Farmers. March 8, 2006. Available at: http://www.cals.ncsu.edu/waste_mgt/smithfield_projects/phase3report06/pdfs/report%20summary.pdf