BENCH- AND PILOT-SCALE TESTS FOR INCLUDING COMBINATIONS OF SWINE SOLIDS ASH AND TURKEY LITTER ASH IN GRANULAR FERTILIZERS

B. R. Bock[1] and T. R. Miles[2]

[1]B. R. Bock Consulting, Inc., 218 N. Sequoia Blvd., Florence, AL 35630
[2]T. R. Miles Technical Consultants, Inc., 1470 SW Woodward Way, Portland, OR 97225

ABSTRACT

Land application of manure from concentrated animal feeding operations (CAFO) in the Southeastern United States is causing accumulations of excess phosphorus in soils. There is increasing concern about phosphorus runoff from land application of manure causing water quality problems. Combusting manure and recovering the energy for use as process heat and nutrients for use in fertilizers and feed supplements is a promising alternative use of manure. This project demonstrated on bench- and pilot-scales that ash from combinations of swine solids and turkey litter can be granulated in a typical NPK granulation plant with standard fertilizer inputs. The pilot plant operation was typical of a commercial NPK granulation plant with a recycle rate of 2:1. The ash can be mixed with 40% P_2O_5 phosphoric acid to produce a pumpable slurry. The resulting slurry can be ammoniated to produce a final granular product similar to monoammonium phosphate. Physical properties of fertilizers containing swine solids ash and turkey litter ash were as good as or better than for typical commercial fertilizers. Virtually all the K_2O in the fertilizer granules produced is soluble. However, apparently due to the unexpectedly high silica levels (45% SiO_2) in the turkey litter ash, only about 40% of the ash P_2O_5 in the fertilizer granules was sufficiently soluble to be claimed on a fertilizer label. Laboratory tests with broiler litter ash containing lower levels of silica indicated that most, and perhaps all, of the ash P_2O_5 can be converted to available forms if the silica content of the turkey litter ash can lowered to about 20% or less. Less than 20% SiO_2 in turkey litter ash should be achievable with practical changes in turkey litter practices.

Key words: fluidized bed combustion, energy recovery, nutrient recovery, swine solids, turkey litter, ash granulation

INTRODUCTION

Land application of manure from concentrated animal feeding operations (CAFO) in the southeastern United States is causing accumulations of excess phosphorus in soils. Southeastern North Carolina has some of the largest regional P surpluses in the United States. In 2001, Duplin County produced about 38 times as much recoverable manure P as removed by crops in that county and Sampson County produced about 25 times as much recoverable manure P as removed by crops in that county (North Carolina Nutrient Management Database Project, 2005). Therefore, there is increasing concern about phosphorus runoff from land application of manure causing water quality problems. Also, practical alternatives to swine lagoon and spray fields are being sought. Research reported in this paper is from part of a project conducted to develop a practical alternative to swine lagoon and spray systems and land application of turkey litter in southeastern North Carolina.

This project was administered by Cape Fear RC&D and funded by Smithfield Foods through the Smithfield Foods/Attorney General's Agreement and Farm Pilot Project Coordination (FPPC). Technical coordination was provided by B.R. Bock Consulting and T.R. Miles Technical Consultants. This project is an addendum to a demonstration project in southeastern North Carolina using the Biomass Energy Sustainable Technology (BEST) system. The BEST system involves dual solids separation at the swine farm to remove solids from the wastewater and then combusting a mixture of turkey litter and swine solids and exporting the nutrient-rich ash out of the concentrated poultry and swine region in southeastern North Carolina for incorporation into commercial fertilizers. This is projected to be one of the most promising options for economically exporting surplus manure phosphorus out of southeastern North Carolina. Obtaining maximum ash value is a critical requirement for demonstrating the economic viability of the overall BEST system. The objective of the work reported here was to demonstrate optimum use of the ash from turkey litter and swine solids in granular fertilizers. The granulation test and demonstration was conducted by Applied Chemical Technology (ACT, 2005) in Florence, Alabama. Also as part of

this project, ash for use in the ash granulation test and demonstration was produced at the Energy Products of Idaho (EPI, 2005) pilot plant in Coeur d' Alene, Idaho and a detailed test of the EPI fluidized bed technology was conducted while the ash was being generated. Results from the combustion tests are reported in a companion paper (T.R. Miles and B.R. Bock, 2005).

The ash from swine solids and turkey litter is a finely divided material that needs to be granulated in order to be used in the existing US fertilizer infrastructure. Also, the ash has a high pH (~12) and not all the phosphorus in the ash is sufficiently soluble to be claimed on a fertilizer label. The goals of this ash granulation test and demonstration were:

- Neutralize the alkalinity and lower the pH ~12 to between 5.5 and 6.5
- Convert all the ash P and K to soluble forms that can be claimed on a fertilizer label
- Control the dustiness of the ash, especially the baghouse ash as described below
- Co-granulate the ash with standard fertilizer inputs
- Use standard fertilizer inputs as the "binder"
- Produce granules with hardness, bulk density, and size comparable to commercial fertilizers
- Do all of the above in existing NPK granulation plants without adding to the cost of granulation

METHODS

Production of Ash Used in Granulation Tests and Demonstration

The ash used in developing and demonstrating the ash granulation procedure was produced in the EPI pilot plant in Coeur D'Alene, Idaho as part of an evaluation of the EPI bubbling fluidized bed combustion technology for use with swine solids and turkey litter and combinations of the two feedstocks (Miles and Bock, 2005). Components of a commercial bubbling fluidized bed combustion system are illustrated in Figure 1. Part of the combustion air was injected through nozzles at the base of the sand bed, causing the sand bed to have the appearance of a boiling liquid. The sand particles were large enough so that they were not carried out of the combustor with the combustion gases. The swine solids and poultry litter fuel was injected on top of the sand bed where combustion was initiated. Nonvolatile portions of the fuel burned in the sand bed and volatile portions of the fuel were burned in the upper part of the combustor where additional combustion air was injected. There was virtually no unburned carbon and most of the ash particles were small enough that they were carried out of the combustor. In a commercial system the coarse ash collects in the boiler, air preheater, economizer and cyclone and the fine ash collects in the baghouse (Figure 1). In the pilot plant used in this study, the combustion gases leaving the combustor were directed directly to a cyclone so that the coarse ash was collected in a cyclone and a slip stream of the fine ash was collected in a baghouse. Ash produced was approximately 70 percent cyclone ash and 30 percent baghouse ash. Representative lots of cyclone ash from the 15-day combustion test were composited and representative lots of baghouse ash were composited. A 70/30 mixture of cyclone and baghouse ash composites was used in the ash granulation test and demonstration.

Granulation Tests and Demonstration

Applied Chemical Technology used turkey litter and swine solids ash produced by EPI to (1) refine laboratory-scale granulation tests conducted earlier by the International Fertilizer Development Center (IFDC) on broiler litter ash from the Delmarva Peninsula, (2) develop a continuous and scaleable process for the incorporation of turkey litter and swine solids ash in a typical NPK fertilizer granulation plant with minimum plant modification, and (3) demonstrate the continuous process on a pilot-plant scale.

After reviewing the earlier bench-scale tests by IFDC, it was determined that further laboratory granulation tests were needed to gain more insight into the ash granulation techniques. The purpose of these tests was to develop a general process along with operating conditions to determine the best equipment arrangement for the pilot plant. Two methods of granulation were selected for further testing in ACT's NPK pilot plant. Additional laboratory-scale tests were conducted in an attempt to remove silica from the cyclone ash (see later sections about silica levels in the ash). Attempts to physically or chemically separate the silica-containing material were unsuccessful.

Process Flow Diagram
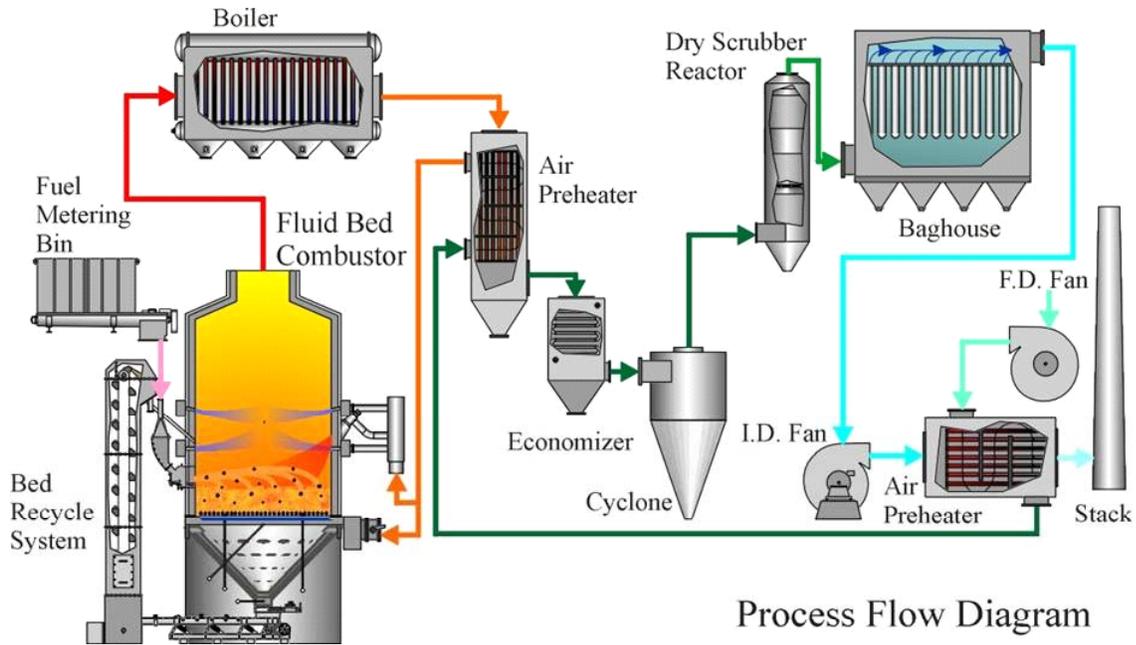
Courtesy Energy Products of Idaho

Figure 1. Components of a bubbling fluidized bed combustion system.

After completion of the laboratory-scale process tests, ACT's NPK granulation pilot plant (Figure 2) was modified for operation. A flow diagram is presented in Figure 3.

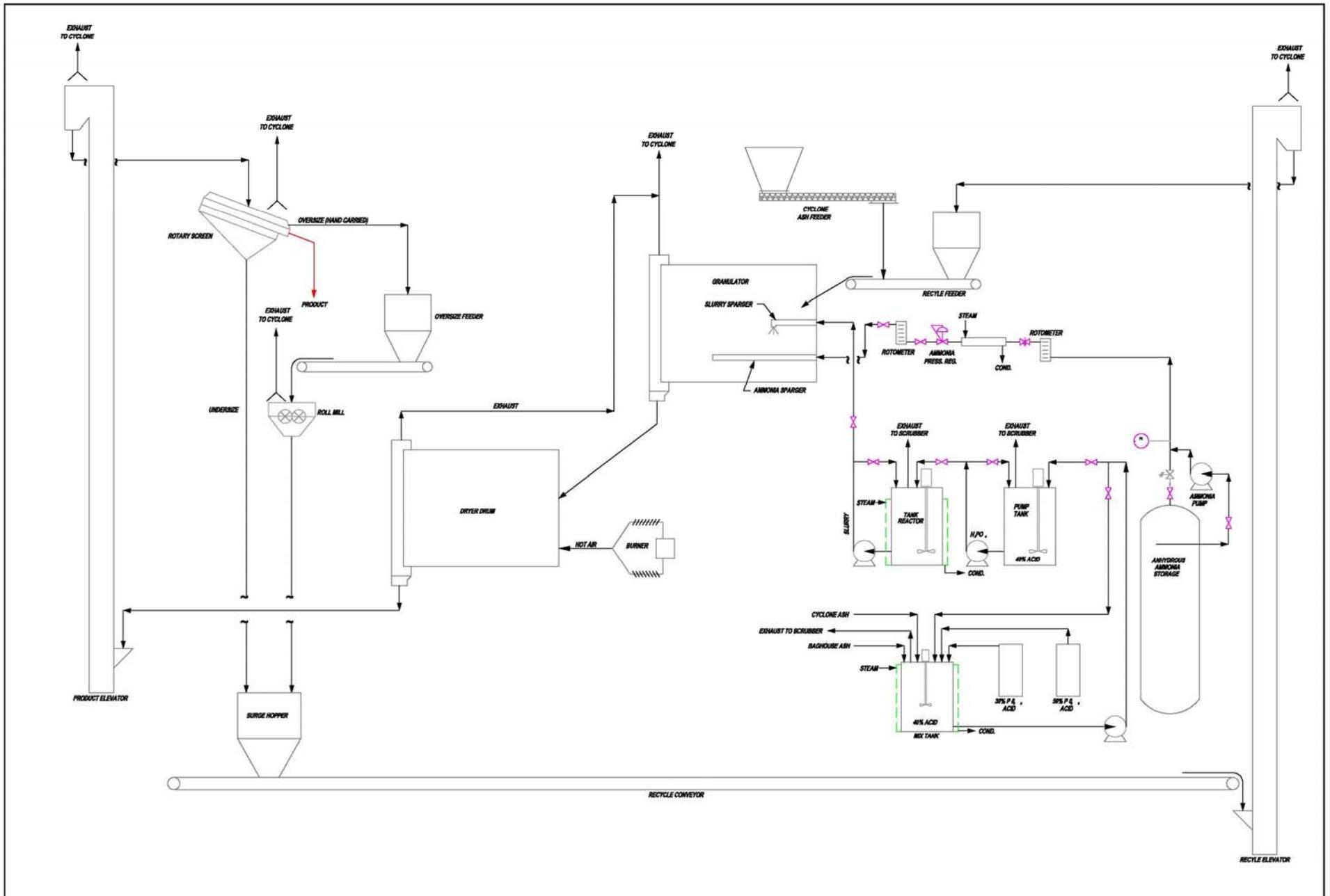Figure 2.   ACT 300 lb per hour NPK granulation pilot plant**.**

Figure 3. Flow diagram for ACT pilot plant granulation test and demonstration.

The turkey litter and swine solids ash was processed in the ACT pilot plant by two methods:

1. Baghouse ash was reacted with 40% P_2O_5 phosphoric acid. (Note that phosphorus in fertilizers is traditionally reported on an oxide basis, i.e., as $P_2O_{5;}$ this does not necessarily mean that the phosphorus is present in the oxide form) The resulting slurry was sprayed on the recycled undersize granules in the granulator bed. Cyclone ash was also metered onto the recycled undersize granules and the resulting mixture was ammoniated in the granulator bed.
2. Baghouse and cyclone ash were both reacted with the 40% P_2O_5 phosphoric acid. The resulting slurry was sprayed onto recycled undersized granules in the granulation bed and the resulting mixture was ammoniated in the granulator bed.

On a wet basis, the fertilizer granule inputs were 44.4% ash, 52.8% phosphoric acid (40% P2O5), and 3.3% anhydrous ammonia. On a dry basis, the ash comprised 55.1% of the final product.

RESULTS AND DISCUSSION

Physical Properties of Ash Produced
The cyclone ash was a very fine granular material with good flowability (Figure 4) and a bulk density of about 80 lb per ft^3. The baghouse ash was a fine powder with a bulk density of about 50 lb per ft^3.

Figure 4. Cyclone ash (left and upper right) and baghouse ash (lower right).

Elemental Analyses of Ash Produced
Elemental analyses of the ash from turkey litter and swine solids used in the combustion test and demonstration are presented in Table 1 (note: elemental analyses of ash generally are expressed on an oxide basis; this does not necessarily mean these elements are present in the ash in an oxide form). For comparison, mean elemental analyses of the ash from two turkey litter surveys in southeastern North Carolina (Bock, 2004) and a broiler litter survey from the Delmarva Peninsula (Bock, 1999) are also included in Table 1. The turkey litter fuel contained 27.0% ash (as-received basis) and the swine solids contained 2.5% ash (as-received basis), resulting in ash from turkey litter/swine solids mixtures to be predominantly from the turkey litter. The silica concentration in the turkey litter ash used in this project was much higher than expected based on two turkey litter surveys taken in southeastern North Carolina which had mean SiO_2 concentrations in the ash of 26.50 and 23.91%, in the Goldsboro Milling and Carroll's Foods surveys, respectively. The SiO_2 concentration in the turkey litter ash used in this project was also much higher than expected based on a survey of Delmarva broiler litter ash which had a mean SiO_2 concentration in the ash of 8.1%. These survey levels of silica are markedly lower than the 47.3% SiO_2 in the ash from the turkey litter used in this project. The very high levels of silica in the ash used for the fertilizer granulation tests and demonstration diluted the nutrient content of the ash as can be seen by comparing ash K_2O and P_2O_5 levels from turkey litter used in this

project vs. from turkey litter ash and broiler litter ash from the surveys (Table 1). The high silica levels in the ash used in this project also apparently interfered with solubilizing ash P during the granulation process, as will be discussed in more detail later. The likely reason for the high ash silica concentration will be discussed later.

Table 1. Elemental analysis of ash from turkey litter and swine solids used in combustion tests compared with survey results.

	Turkey litter Before shipping	Swine solids Before shipping	75TL/25SS Fuel feeder	50TL/50SS Fuel feeder	Goldsboro Milling Turkey litter survey	Carroll's Foods Turkey litter survey	Delmarva Broiler litter survey
SiO_2	47.27	8.34	42.67	47.64	26.50	23.91	8.1
Al_2O_3	<0.01	1.91	2.33	1.70	1.62	2.35	1.9
TiO_2	0.31	0.11	0.27	0.27	0.16	<0.01	0.2
Fe_2O_3	1.01	2.73	0.94	1.05	1.03	1.09	1.2
CaO	13.90	29.80	14.20	13.70	19.90	19.54	17.3
MgO	3.57	6.61	3.97	3.60	4.23	4.54	5.0
Na_2O	1.77	1.71	1.86	1.78	3.48	3.18	9.2
K_2O	8.26	8.31	8.43	7.72	12.40	15.12	16.3
P_2O_5	17.64	27.37	14.67	12.06	23.48	13.88	24.4
SO_3	3.68	3.21	2.42	2.82	3.78	5.26	6.7
Cl	1.28	0.48	2.03	1.19	2.96	3.48	
CO_2[1/]	2.52	3.27	2.12	0.34	0.28	4.26	
Total	101.21	93.85	95.91	93.87	99.78	97.01	90.3

[1/] Inorganic carbon expressed on an oxide basis.

Elemental analyses of ash from ½ turkey litter-½ swine solids fuel and the resulting cyclone and baghouse ash are presented in Table 2. These analyses indicate that silica from the fuel was partitioned primarily in the cyclone ash with 66.5% SiO_2 in the cyclone ash and 25.6% SiO_2 in the baghouse ash. Therefore, silica diluted nutrients to a greater extent in the cyclone ash than the baghouse ash. Dry and wet procedures were tested for removal of silica from the cyclone ash, but these procedures removed very little silica from the ash. Therefore, representative composites of cyclone and baghouse ash were used as-is (.i.e., without silica removed) in the ash granulation test and demonstration.

Table 2. Elemental analyses of ash from fuel and process ash samples

	1/2 turkey litter-1/2 swine solids		
	Fuel	Cyclone	Baghouse
	%		
SiO_2	47.6	66.5	25.6
Al_2O_3	1.7	1.0	2.3
TiO_2	0.3	0.3	0.3
Fe_2O_3	1.1	0.9	1.7
CaO	13.7	10.5	16.7
MgO	3.6	2.0	6.8
Na_2O	1.8	1.0	2.7
K_2O	7.7	4.1	12.3
P_2O_5	12.1	7.7	18.0
SO_3	2.8	1.5	5.5
Cl	1.2	0.1	3.1
CO_2[1/]	0.3	0.7	0.5
Total	93.9	96.3	95.3

[1/] Inorganic carbon expressed on an oxide basis.

Fertilizer Granulation Test and Demonstration

The pilot-scale granulation test and demonstration produced granules (Figure 5) with excellent physical properties that are as good as or better than for typical commercial fertilizers. Granule hardness was 4.0 lb, the bulk density was 70 lb/ft^3, degradation percentage was 0.9% by the IFDC abrasion resistance rotary drum method, and the granules were dust free.

Figure 5. Fertilizer granules produced in ACT pilot plant.

The phosphoric acid used in the granulation process neutralized the alkalinity in the ash, neutralized the ammonia, and lowered the pH of the final product to between 5.5 and 6.5. Virtually all the ash K_2O in the fertilizer granules was soluble (i.e., could be claimed on a fertilizer label). However, as discussed in more detail below, using the turkey litter and swine solids ash from North Carolina, ACT was unable to achieve the same conversion of ash P_2O_5 to available P_2O_5 as had been achieved at IFDC in an earlier project using broiler litter ash from Delmarva.

Fertilizer analyses of cyclone and baghouse ash and fertilizer granules containing the ash are presented in Table 3. Granules produced from the North Carolina ash were produced in the ACT pilot plant. Granules produced from the Delmarva ash were produced on a bench scale by ACT. Of the 14.2% total P2O5 in the North Carolina ash composite, 5.9% P2O5 (42% of the total P2O5 in the ash) was available before the ash was incorporated into the fertilizer granules. Incorporating the ash into the fertilizer granules did not solubilize any additional P in the ash. After granulation, still only 5.9% P2O5 was available in the ash. Several process modifications were evaluated in an effort to solubilize more ash P during the granulation process. Heating the ash-phosphoric acid mixture at higher temperatures and for longer periods of time before granulation did not solubilize additional P in the ash. This lack of conversion was unexpected because in previous bench-scale tests by IFDC using broiler litter ash from the same combustion process, most of the ash P_2O_5 was converted to available forms during the granulation process, presumably because enough phosphoric acid was added during the granulation process to reduce the pH of the ash from about 12 to between 5.5 and 6.5. Defracting microscope analyses indicated that the North Carolina ash contained significant amounts of silica gel that coated ash particles whereas the Delmarva ash did not. Much less

silica gel formed in the Delmarva ash, apparently because the Delmarva ash contained only 19% SiO_2. ACT granulated some of the Delmarva ash on a bench scale using the same formulation and similar processing procedures as in the pilot-scale tests and the portion of P in the ash that was available was increased from 41% to 75% via the granulation process. These results suggested that the SiO_2 content of the ash needs to be kept below at least 20% in order to be able to satisfactorily convert ash P to available forms during the granulation process.

Table 3. Fertilizer analyses of ash and fertilizer granules containing the ash.

Material	Total N	Total P_2O_5	Water soluble P_2O_5	Citrate soluble P_2O_5	Available P_2O_5	Total K_2O	Water soluble K_2O	Citrate soluble K_2O	Soluble K_2O
North Carolina ash (ACT):					**%**				
Baghouse ash composite	0.24	18.6	0.7	9.0	9.7	12.2	6.8	3.8	10.6
Cyclone ash composite	0.01	12.3	0.4	3.8	4.2	3.5	2.1	1.4	3.5
70 cycl/30 bag		14.2			5.9 (42%)[3]	6.1			5.6
Fertilizer granules[1]	4.6	32.7	22.1	5.8	27.9	3.1	2.8	0.8	3.6
70 cycl/30 bag ash after pilot plant granulation (calculated)					5.9 (42%)[3]				
Delmarva ash (ACT):									
Cyclone ash w/o lime		23.0			9.5 (41%)[3]				
Fertilizer granules[2]		38.8			35.3				
Cyclone ash after lab-scale granulation (calculated)					17.2 (75%)[3]				

[1] Made from 70% cyclone ash/30% baghouse ash, phosphoric acid, and anhydrous ammonia.

[2] Made from cyclone ash, phosphoric acid, and anhydrous ammonia.

[3] Number in parenthesis is the percent of total P_2O_5 in ash that is available.

Apparent Source of High Silica in Turkey Litter Ash

As discussed in the previous section, there is strong evidence that high silica levels in the turkey litter ash prevented conversion of additional ash P_2O_5 to available forms during the granulation process. The high silica levels also dilute the nutrients contained in the ash. For these reasons, it is important to know why the silica levels were so high in the turkey litter ash used in this project and whether there are practical options for reducing the silica levels in the turkey litter and ultimately in the turkey litter ash.

There are three potential sources of silica in turkey litter: bedding, feed, and soil. Common bedding materials such as wood shavings contain some silica and are one source of silica. Some of the silica contained in feed likely is deposited in the litter as a component of the manure. The mineral (nonorganic) portion of soil is composed mainly of alumno-silicates and sandy soils contain quartz sand which contains silica. Therefore, soil contamination of turkey litter will increase the silica content of the litter. The question is: which of these three sources could account for the amount of silica found in the turkey litter combusted in the EPI combustion tests?

A rough estimate of the amount of silica contained in a whole-house clean-out of turkey litter like that used in the EPI fluidized bed combustion test is presented in Table 4. The estimate for percent ash in the litter (27% on an as-received basis) is from the combustion test and demonstration (Bock, 2004) and the concentration of SiO_2 in the litter ash (48%) is from Table 1. A typical whole house clean-out yields about 200 tons of turkey litter. These parameters give an estimate of about 26 tons SiO_2 in the litter from one whole-house clean-out (Table 4). Wood bedding is not likely to provide more that 0.5 ton of SiO_2 per whole-house clean-out, assuming the parameters in Table 4; this is close to a maximum amount of SiO_2 that would be expected from bedding. Therefore, bedding is not the main source of silica in the litter. Discussions with poultry nutritionists indicate that silica in feed could not account for 26 tons of SiO_2 per whole-house clean-out, even if all the silica passed through in the manure. This leaves soil contamination as the primary candidate as the source of most of the silica in the litter ash.

Table 4. Comparison of tons SiO_2 in litter, bedding, and soil[1/]

Tons litter/ house	% ash in litter	% SiO_2 in litter ash	Tons SiO_2 in litter
200	27	48	25.9
Tons bedding/ house	% ash in bedding	% SiO_2 in bedding ash	Tons SiO_2 from bedding
20	5	50	0.5
Assumed tons dry soil in litter/ house		% SiO_2 in dry soil	Tons SiO_2 from soil
30		85	25.5
Calculated depth (inches) of soil mixed with litter			
0.56			
House length, ft	House width, ft	Soil bulk density (dry basis), g/cm^3	Soil bulk density (dry basis), lb/ft^3
340	36	1.7	106.0

[1/] Silica is expressed here on an oxide basis (i.e., SiO_2) which is standard practice for ashes. This doesn't mean that silica is necessarily present as SiO_2 in either the process ash or the noncombusted feedstock.

The calculation in Table 4 indicates that about of 30 tons of soil would be required to provide 26 tons of SiO_2 in the litter. This calculation assumes 85% SiO_2 in dry soil which is typical for sandy loam soils that are common in southeastern North Carolina. Thirty tons of soil corresponds to approximately a half-inch depth of soil throughout the entire turkey house, assuming a bulk density of 1.7 g/cm (assumes significant compaction). Are there scenarios in which a half-inch of soil could be incorporated into turkey litter over the one-to-two year whole-house clean-out cycle?

The turkey litter combusted by EPI came from a farm that grows turkeys under contract with Carroll's Foods. The grow-out houses under contract to Carroll's Food do not start out with "new" bedding after each whole-house clean-out. Instead, they start out with "used bedding" from breeder houses in the area. Litter from an annual clean-out of a breeder house is stacked and allowed to heat and then transferred to a grow-out house for reuse. The "used litter" is typically left in a grow-out house for approximately two years before doing a whole-house clean-out. A Carroll's Food representative indicated that litter in breeder houses is roto-tilled weekly on a strict schedule. There is more variation in how often litter in grow-out houses is roto-tilled. The farmer who provided the litter generally roto-tills the litter in his grow-out houses twice per flock or about five to six times per year. This means that the litter combusted by EPI was roto-tilled about 52 times while in the breeder house and about 10 more times while in the grow-out house for a total of about 62 times. This means that if only 0.01 inch of soil was mixed with the litter during each roto-tilling, that a total of about 0.6 inch of soil overall would be mixed with the litter. This would correspond to over 30 tons of soil, the amount required to provide the amount of SiO_2 in the litter combusted by EPI. An average of 0.01 inch of soil per roto-tilling seems quite possible. A turkey litter survey conducted in southeastern North Carolina (Bock, 2004) indicated a wide range of SiO_2 levels in turkey litter ash. This variation probably reflects mainly the extent that roto-tilling mixed soil with the litter. It is not common practice to roto-till broiler litter. This probably explains why ash silica levels in the survey of broiler litter from the Delmarva Peninsula were much lower than ash silica levels in the turkey litter survey from southeastern North Carolina (Table 1).

A Carroll's Food representative indicated that he doubts that much soil generally is mixed with litter during roto-tilling because most turkey house floors are clay lined and farmers would not want to destroy the clay liner. He acknowledged that the clay liner may be gone in some of the older houses, in which case it might be more likely that roto-tilling would incorporate significant amounts of soil with the litter. Houses with and without clay liners may account for some of the variation in SiO_2 levels in turkey litter ash from southeastern North Carolina.

Alumno-silicate minerals contained in soils are likely sufficiently reactive in combustion systems to form silica gels such as were observed in the ash-containing fertilizer granules produced by ACT. This further supports the argument that soil was the primary source of SiO_2 in the turkey litter. On the other hand, sand particles from soils or other sources are inert and would not react in the combustion system to form silica gels. Sand from these sources would behave like the sand bed material which does not react with the fuel.

If turkey litter were to be used commercially in combustion systems, either roto-tilling practices would have to used that minimize the amount of soil mixed with the litter or some alternative to roto-tilling would have to be used. It would also be imperative that soil contamination of litter during whole-house clean-out be minimized.

Regulatory Considerations for Fertilizers Containing Turkey Litter and Swine Solids Ash
The trace metal levels in the ash-containing fertilizer granules produced by ACT are many times lower than required to comply with the EPA 503, Canadian, and AAPFCO standards (Bock, 2004). The trace metal safety factors for this particular fertilizer product are sufficiently large that other fertilizer formulations containing turkey litter and swine solids ash are also likely to easily comply with the above standards.

Fertilizer Value of Nutrients in Ash from Turkey Litter and Swine Solids
Estimated fertilizer values of nutrients in ash from turkey litter and swine solids are presented in Table 5. These estimates are based on available P_2O_5 and soluble K_2O concentrations in ash from the following:

1. Turkey litter combusted by EPI that was relatively high in ash silica (Table 1)
2. Surveys of turkey litter from Carroll's Foods and Goldsboro Milling contract turkey growers (Bock, 2004); the mean P_2O_5 and K_2O values are associated with intermediate levels of silica in the turkey litter ash
3. Nutrient values in number 2 above adjusted upward assuming the mean ash SiO_2 values could be reduced by 10 percentage points (e.g., the Goldsboro Milling mean of 26.5% SiO_2 was reduced to 16.5% and P_2O_5 and K_2O concentrations were adjusted upward by dividing by 0.9); these nutrient levels are projected to be achievable with modified practices that mix less soil with turkey litter via roto-tilling
4. Swine solids combusted by EPI (Table 1)

Royster-Clark and Southern States Cooperative operate NPK granulation plants within practical transportation distances from southeastern North Carolina. Preliminary discussions with these companies indicate that, at least initially, they would offer about 30% less per pound of available P_2O_5 and soluble K_2O from ash than from traditional fertilizer inputs. The purpose of the discount would be to offset added costs of handling and storing an additional material that is somewhat lower in nutrient content and for dealing with the variability that is inherent in most by-product materials. The projected ash transportation cost from southeastern North Carolina to the NPK granulation plants in Norfolk, VA is $15/ton of ash. A 30% discount relative to standard fertilizer inputs and a $15/ton ash transportation cost are reflected in Table 5. Wholesale fertilizer prices of $4.00/20 lb P_2O_5 and $2.25/20 lb K_2O were assumed. These prices are based on wholesale prices for triple superphosphate and potash, respectively. The ash fertilizer values in Table 5 also are based on the assumption that no lime will be added with the fuel and that the ash won't be diluted by sand from the fluidized bed, unburned carbon, or lime amendment of the fuel to prevent bed agglomeration. The EPI tests demonstrated that lime amendment will not be required and that contamination of ash by bed sand is not expected once the system has reached steady state and any finer sand bed particles have been removed from the bed. The EPI fluidized bed combustion system provides virtually complete carbon burnout so that nutrients are not diluted by unburned carbon.

With the above assumptions, the net fertilizer value of turkey litter and swine solids ash at the fertilizer plant, after accounting for by-product discounts and ash transportation costs to the fertilizer plant, ranges from $47.35 to $79.81/ton of ash, assuming that all the ash P_2O_5 is available after granulation, and from $35.03 to $61.53/ton of ash, assuming that 75% of the ash P_2O_5 is available after granulation. Based on the ACT granulation work, it is

143

projected that a least 75% of the ash P_2O_5 will be available after granulation, if the SiO_2 content of the ash can be kept at about 20% or less. This appears to be achievable with less and more controlled roto-tilling of turkey litter. In all cases, all the ash K_2O was assumed to be soluble. Note that because of the relatively low ash content of the swine solids ash, the swine solids ash does not factor very heavily into the fertilizer value of ash from mixtures of turkey litter and swine solids. For example, in a 50/50 mix of turkey litter (15% ash) and swine solids (2.5% ash), 86% of the ash from the 50/50 fuel mix is from turkey litter and 14% of the ash is from swine solids.

Table 5. Net fertilizer value of ash at the fertilizer plant after accounting for by-product discounts and ash transportation costs to fertilizer plant.

	Ash[1]	Ash SiO_2	Ash P_2O_5	Ash K_2O	Fert. P_2O_5	Fert. K_2O	Ash P_2O_5	Ash K_2O	Ash $P_2O_5+K_2O$	Less discount[2]	Less Trans.[3]
		%			$/20 lb		Fert. replacement value, $/ton ash			$/ton ash	
Turkey litter--Assumes 100% of ash P_2O_5 is aviailable and 100% of ash K_2O is soluble after granulation:											
Turkey litter combusted by EPI (Table 1)	27	47.3	17.6	8.3	4.00	2.25	70.4	18.675	89.075	62.35	47.35
Carroll's Foods mean (Table 3)	17.1	23.9	13.9	15.1	4.00	2.25	55.6	33.98	89.575	62.70	47.70
Carroll's Foods mean less 10% SiO_2		13.9	15.4	16.8	4.00	2.25	61.78	37.75	99.53	69.67	54.67
Goldsboro Milling mean (Table 2)	15.0	26.5	23.5	12.4	4.00	2.25	94	27.90	121.90	85.33	70.33
Goldsboro Milling mean less 10% SiO_2		16.5	26.1	13.8	4.00	2.25	104.44	31.00	135.44	94.81	79.81
Swine Solids--Assumes 100% of ash P_2O_5 is available and 100% of ash K_2O is soluble after granulation:											
Swine solids combusted by EPI (Table 1)	2.5	8.3	27.4	8.3	4.00	2.25	109.60	18.68	128.28	89.79	74.79
Turkey litter--Assumes 75% of ash P_2O_5 is aviailable and 100% of ash K_2O is soluble after granulation:											
Turkey litter combusted by EPI (Table 1)	27	47.3	13.2	8.3	4.00	2.25	52.8	18.675	71.475	50.03	35.03
Carroll's Foods mean (Table 3)	17.1	23.9	10.4	15.1	4.00	2.25	41.7	33.98	75.675	52.97	37.97
Carroll's Foods mean less 10% SiO_2		13.9	11.6	16.8	4.00	2.25	46.33	37.75	84.08	58.86	43.86
Goldsboro Milling mean (Table 2)	15.0	26.5	17.6	12.4	4.00	2.25	70.5	27.90	98.40	68.88	53.88
Goldsboro Milling mean less 10% SiO_2		16.5	19.6	13.8	4.00	2.25	78.33	31.00	109.33	76.53	61.53
Swine Solids--Assumes 75% of ash P_2O_5 is available and 100% of ash K_2O is soluble after granulation:											
Swine solids combusted by EPI (Table 1)	2.5	8.3	20.6	8.3	4.00	2.25	82.20	18.68	100.88	70.61	55.61

[1] As-received basis

[2] Discount for ash nutrients vs. traditional fertilizer inputs purchased by fertilizer granulation plant

[3] Ash transportation cost from energy plant to fertilizer granulation plant

Discount= 30%

Transportation cost= 15.00

Example Granular Fertilizer Formulations

An example hypothetical granular fertilizer formulation based on the mean turkey litter ash composition from the survey of Goldsboro Milling growers (Bock, 2004), phosphoric acid, and anhydrous ammonia is presented in Table 6. The proportions of ash, phosphoric acid, and anhydrous ammonia were demonstrated by ACT to produce fertilizer granules with excellent physical properties. The final product analysis from this formulation is 3.4% N, 39.4% P_2O_5, 6.8% K_2O for a combined N-P_2O_5-K_2O analysis of 49.6%, assuming that all the P_2O_5 in the ash is available and all the K_2O is soluble as determined by fertilizer labeling procedures (Table 6). The final product analysis from this formulation is 3.4% N, 36.2% P_2O_5, 6.8% K_2O for a combined N-P_2O_5-K_2O analysis of 46.4%, assuming that 75% of the P_2O_5 in the ash is available and all the K_2O is soluble as determined by fertilizer labeling procedures (Table 7). These are very acceptable levels of overall nutrient content in commercial fertilizer products.

Table 6. Granular fertilizer formulation based on the mean ash composition (26.5% SiO_2) from the Goldsboro Milling growers survey (Bock, 2004) and assuming all the ash P_2O_5 and K_2O is converted to available forms that can be claimed on a fertilizer label.

	N	P_2O_5	K_2O		N	P_2O_5	K_2O
Granule compoments		%		Wt. fraction		Weighted %	
Ash (dry basis)	0.00	23.50	12.40	0.551	0.00	12.95	6.83
P acid (dry basis)[1]	0.00	64.90	0.00	0.408	0.00	26.48	0.00
Anhydrous ammonia	83.00	0.00	0.00	0.041	3.40	0.00	0.00
Fertilizer granules				1.000	3.40	39.43	6.83
% of granule nutrients from ash					0.00	32.8	100.00
% of granule nutrients from commercial fertilizer ingredients					100.0	67.2	0.00
Total, %					100.00	100.0	100.00

[1] Assumes 40% P_2O_5 phosphoric acid containing 41% water (64.9% P_2O_5, dry weight basis).

Table 7. Granular fertilizer formulation based on the mean ash composition (26.5% SiO_2) from the Goldsboro Milling growers survey (Bock, 2004) and assuming 75% of the ash P_2O_5 and all the ash K_2O is converted to available forms that can be claimed on a fertilizer label.

	N	P_2O_5	K_2O		N	P_2O_5	K_2O
Granule compoments		%		Wt. fraction		Weighted %	
Ash (dry basis)	0.00	17.63	12.40	0.551	0.00	9.71	6.83
P acid (dry basis)[1]	0.00	64.90	0.00	0.408	0.00	26.48	0.00
Anhydrous ammonia	83.00	0.00	0.00	0.041	3.40	0.00	0.00
Fertilizer granules				1.000	3.40	36.19	6.83
% of granule nutrients from ash					0.00	26.8	100.00
% of granule nutrients from commercial fertilizer ingredients					100.0	73.2	0.00
Total, %					100.00	100.0	100.00

[1] Assumes 40% P_2O_5 phosphoric acid containing 41% water (64.9% P_2O_5, dry weight basis).

CONCLUSIONS

The turkey litter and swine solids ash produced by fluidized bed combustion can be granulated in typical NPK granulation plants to produce granules with physical properties as good as or better than those of existing commercial fertilizers. The unexpectedly high silica levels in the turkey litter ash prevented complete conversion of the ash P_2O_5 to available forms that can be claimed on a fertilizer label. However, it is projected that turkey litter management practices can be adjusted to minimize the amount of silica in the turkey litter ash, in which case it is projected that 75 to 100% of the ash P_2O_5 can be converted to available forms during the granulation process. The net fertilizer value (after subtracting ash transportation costs) of the turkey litter and swine solids ash at an energy plant in southeastern North Carolina is projected to range from about \$35 to 60/ton of ash, assuming 75% of the ash P_2O_5 is available after granulation and to range from \$47 to 80/ton of ash, assuming all the ash P_2O_5 is available after granulation.

ACKNOWLEDGEMENTS

REFERENCES

Applied Chemical Technology (ACT). 2005. http://www.appliedchemical.com

Bock, B.R. 1999. Appendix A: Fertilizer nutrient value of broiler litter ash. http://www.nrbp.org/pdfs/pub20b.pdf

Bock, B.R. 2004. Demonstrating optimum fertilizer value of ash from the Biomass Energy Sustainable Technology (BEST) demonstration project for swine & poultry manure management. Final Report Summary to: Farm Pilot Project Coordination, North Carolina State University, and Smithfield Foods. http://www.fppcinc.org/pdf/capefear.pdf

Energy Products of Idaho (EPI). 2005. http://www.energyproducts.com

Miles, T. R. and B. R. Bock. 2005. Energy and nutrient recovery from combustion of swine solids and turkey litter (in press). 2005 Animal Waste Management Symposium. North Carolina State University. October 5-7.

North Carolina Nutrient Management Database Project. 2005. http://arcims.soil.ncsu.edu/nutman/