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Fractionation of Solids, Plant Nutrients, and Carbon as a Result of Screening Broiler Litter

Alejandra Coloma

Graduate Student, Department of Agricultural and Biological Engineering, Clemson University, Clemson, S.C., acoloma@clemson.edu

John P. Chastain, Ph.D.

Associate Professor, Department of Agricultural and Biological Engineering, Clemson University, Clemson, S.C., jchstn@clemson.edu

Kathy P. Moore, Ph.D.

Director, Agricultural Service Laboratory, Clemson University, Clemson, S.C.

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Abstract. *Broiler farms have significant quantities of litter and more environmentally responsible alternatives for its utilization are needed. Treatment of broiler litter by screening will produce two fractions, a screened fraction and a retained fraction. The screened fraction has the potential to have an increased available nitrogen (AN) to P_2O_5 ratio to meet crop requirements when mixed with an inorganic source of nitrogen. An enhanced carbon-nitrogen ratio may be obtained from the retained fraction, which could possibly provide a more economical substrate for composting. Screening significantly concentrated many constituents in the screened fraction but it did not significantly increase AN:P_2O_5 ratios. A significantly higher C:N ratio was observed in the retained fraction. A screened litter-34% inorganic N blend could be created to meet the AN:P_2O_5 requirements of corn. This blend will reduce the amount needed to be hauled and land applied by 72% when compared to untreated broiler litter.*

Keywords. Broiler litter, separation, manure treatment, land application, nutrient management

Introduction

Screening broiler litter could have the potential to yield a valuable, low cost fertilizer and in doing so facilitate environmentally responsible utilization. Screening could enhance the available nitrogen (AN) to P_2O_5 ratio and provide a more balanced nutrient source for plants. Matching the AN:P_2O_5 ratio of the applied litter to meet the needs of a particular crop would prevent the increase of extractable P in soil. Reduction in soil-test P would reduce the potential for movement of phosphorus to nearby surface water by erosion of soil, or by movement of soluble P in runoff.

Limited literature concerning fractionation of litter is available. However, in a paper by Ndegwa, et al. (1991), a screening process was performed with broiler litter. Litter was screened in a two stage process, separating the material in particles larger than 3.3 mm, particles smaller than 0.83 mm, and particles in between these two sizes. The N-P-K distribution within the litter was analyzed. Ndegwa found that N concentration was significantly higher in the fine material (<0.83 mm) than in the rest of the fractions. No significant differences were found in P and K content of the three different fractions and the untreated litter.

Common commercial fertilizers, such as 17-17-17, do not always provide the correct balance of nitrogen and phosphorus for common crops either. Over application of P (typically expressed as P_2O_5) can lead to a build-up of plant extractable P in the top layer of soil. Excess phosphorus in top soil can leave the field with erosion or as soluble P in runoff, and enter nearby streams and lakes. Algal blooms are a result of high phosphorus concentration in water. Increases in turbidity from sediment and algae results in less sunlight being able to penetrate deep into the water and negatively affects aquatic life. The flow of excess P and soil into surface water bodies will also enhance the rate of eutrophication. Therefore, practices to reduce excessive amounts of soluble P in fields near surface water and to reduce soil erosion are both needed to reduce the impacts of agriculture on water quality.

Different crops have different N:P_2O_5 requirements. The major plant nutrient requirements of some common row and forage crops with their corresponding N:P_2O_5 and N:K_2O ratios are compared in Table 1.

Table 1. Nutrient requirements of some common crops (Camberato, 2001, MWPS, 1985).

Crop	Yield	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	N:P_2O_5	N:K_2O
Corn (total plant)	8.7 m^3/ha	149	65	150	2.29	0.99
	13.1 m^3/ha	207	90	241	2.30	0.86
Wheat	4.4 m^3/ha	96	38	113	2.53	0.85
Fescue hay	6700 kg/ha	130	63	178	2.06	0.73
Bermuda hay	13,500 kg/ha	336	94	282	3.57	1.19

1 bu/ac = 0.0871 m^3/ha

1 lb/ac = 1.12 kg/ha

1 ton/ac = 2244 kg/ha

The available nitrogen (AN) in poultry litter is approximately 23.7 kg/metric ton and the P_2O_5 content is roughly 34.5 kg/metric ton, resulting in an AN:P_2O_5 ratio of 0.69 (Chastain et al., 2001).

Plants commonly need a N:P_2O_5 ranging from 2.1 to 3.6 (Table 1). Corn requires an N:P_2O_5 ratio of 2.3. As a result, when corn is fertilized with broiler litter to meet its nitrogen demand P_2O_5 is over applied by a factor of 3.3.

Screening broiler litter has the potential to increase the AN:P_2O_5 ratio of the screened fraction. The fine screened litter can be blended with a granular nitrogen fertilizer to yield a more balanced inorganic/organic fertilizer.

Currently, the cost of hauling and applying broiler litter in the Southeastern United States ranges from $US11 / metric ton to $US28 / metric ton. An increase in the N content of the blend fertilizer would be expected to decrease hauling costs since the amount needed per hectare will be reduced. Hopefully, this would make the wider distribution of litter nutrients a profitable enterprise.

Untreated broiler litter has a C:N ratio in the range of 12 to 15. The desired range of C:N ratio for composting is 20 to 40 (Rynk et al., 1992). The portion that does not pass through the screen, termed the retained fraction, is the least valuable fraction for fertilization. However, it is anticipated that the retained fraction will have a higher C:N ratio and porosity. Improvements in C:N and porosity could make the retained fraction more suitable for composting.

The objectives of this study are to: 1) quantify the fractionation of mass, nutrients, and carbon as a result of screening, 2) observe the differences in AN:P_2O_5 ratio and C:N ratio between treated litter (screened and retained) and untreated litter, and 3) study the advantages of creating a blend of broiler litter with inorganic nitrogen to meet the AN:P_2O_5 needs of a crop.

Experimental Methods

Large samples of broiler litter were obtained from a commercial farm in South Carolina. The broiler litter used for this study was mainly composed of manure, feathers, and wood shavings. The samples were transported to Clemson University for treatment and stored in three large covered plastic bins.

Procedure

Broiler litter samples ranging from 0.8 to 4.5 kg were screened manually using four standard sieves with mean size openings as follows: screen # 5 with 4 mm openings, screen # 10 with 2 mm openings, screen # 18 with 1 mm openings, and screen # 20 with 0.85 mm openings. The screening process was performed in the Agricultural, Chemical, and Biological Research Laboratory in the Department of Agricultural and Biological Engineering at Clemson University (Figure 1). Two fractions resulted from this process: a screened fraction, which contains the smaller particles, and a retained fraction, containing the larger particles that would not pass through the screen.

Figure 1. Screening of broiler litter using standard screens.

Two subsamples were taken for the untreated, screened, and retained fractions. One subsample was bagged and sent to the Clemson University Agricultural Services Laboratory immediately after screening for analysis of major and minor plant nutrients, and pH. The second subsample was used to measure bulk density, total solids, volatile solids, and ash for the untreated litter and the two fractions resulting from screening. Carbon was determined from the ash content. Untreated, screened, and retained litter samples were stored in a refrigerator if there was any delay between screening and analysis. This same procedure was performed for the four different standard screen sizes. Three replications were made for each screen size for statistical purposes.

Quantities Measured

The following quantities were measured for the untreated, screened, and retained litter: total ammoniacal nitrogen (TAN = NH_4^+-N + NH_3), total Kjeldahl nitrogen (TKN), nitrate nitrogen, total phosphorus (expressed as P_2O_5), total potassium (expressed as K_2O), calcium, magnesium, sulfur, zinc, copper, manganese, sodium, pH, total solids, volatile solids, fixed solids, and bulk density.

A bulk density was determined placing litter in a 323 +/- 1.7 mL container and weighed. The mass of litter was measured and then divided by the volume of the container.

Total solids, volatile solids, and fixed solids were measured in the Agricultural, Chemical, and Biological Research Laboratory in the Department of Agricultural and Biological Engineering at Clemson University according to standard techniques (APHA, 1995). Three subsamples were taken from the untreated and the two treated fractions of litter and were placed in porcelain dishes and dried in an oven at 105ºC for 24 hours. Total solids content was determined after the sample was allowed to cool in a desiccator. Fixed solids were determined by incinerating the dried solids in a furnace at 550ºC for 2 to 3 hours and allowing the sample to cool in a desiccator, and weighing its contents. Volatile solids were calculated as the difference between the total and fixed solids.

Percent carbon was calculated on a dry basis using the following equation (Rynk et al., 1992):

$$C_{DB} = \frac{100 - FS_{DB}}{1.8}\ . \qquad (1)$$

Where:

C_{DB} = carbon content on a dry matter basis, (%), and

FS_{DB} = fixed solids on a dry matter basis, (%).

Results

Characterization of Untreated Litter

Concentration of solids, plant nutrients, and other defined constituents of the untreated litter used in the screening experiment are given in Table 2. Mean constituent concentrations are shown for each treatment because the initial values were not assumed to be the same for all four treatments due to the nonhomogeneity of the litter stored in three bins.

Table 2. Characteristics of untreated litter on a wet basis

Constituent	**Screen # 5 4 mm (g/g_{sample})**	**Screen # 10 2 mm (g/g_{sample})**	**Screen # 18 1 mm (g/g_{sample})**	**Screen # 20 0.85 mm (g/g_{sample})**
TAN	0.0051	0.0046	0.0047	0.0057
Org-N	0.0240	0.0216	0.0199	0.0220
NO_3-N	0.0016	0.0020	0.0021	0.0017
TN	0.0306	0.0282	0.0267	0.0294
P_2O_5	0.0348	0.0313	0.0315	0.0335
K_2O	0.0296	0.0276	0.0275	0.0299
Ca	0.0227	0.0211	0.0221	0.0215
Mg	0.0048	0.0043	0.0043	0.0047
S	0.0056	0.0050	0.0051	0.0053
Zn	0.0003	0.0003	0.0003	0.0003
Cu	0.0003	0.0003	0.0003	0.0003
Mn	0.0004	0.0003	0.0003	0.0004
Na	0.0070	0.0064	0.0065	0.0069
TS	0.7565	0.7560	0.7607	0.7493
VS	0.5523	0.5388	0.5374	0.5260
FS (Ash)	0.2042	0.2172	0.2233	0.2233
C	0.3245	0.3193	0.3183	0.3127
C:N	12.9	13.7	14.5	13.1
pH	8.5	8.7	8.7	8.7
Density (kg/m^3)	431.9	434.9	411.4	410.0

On the average, the untreated broiler litter was composed of 75.6% dry matter, of which 71% was VS. Carbon was 42% of the dry matter and 59% of the VS. Ash, or fixed solids (FS) was 29% of the dry matter.

Total N contained 76.3% Org-N. The average density was found to be 422.1 kg/m^3, and the average C:N ratio was 13.6. Average pH was equal to 8.7. Small to moderate concentrations of micronutrients were present in the untreated broiler litter as shown in the table.

Fractionation of Litter Mass

The mass of the broiler litter that passed through screens with openings ranging from 0.85 mm to 4 mm is shown in Figure 2. Linear regression analysis indicated that the data were best represented by the following equation:

$$M_{L\,S} / M_{L\,in} = 0.2869 \text{ Ln } (S) + 0.438. \qquad (2)$$

Where:

$M_{L\,S} / M_{L\,in}$ = the fraction of the litter passing through the screen,

$M_{L\,S}$ = mass of litter passing through the screen (kg),

$M_{L\,in}$ = mass of untreated litter placed on the screen (kg), and

S = screen size (mm).

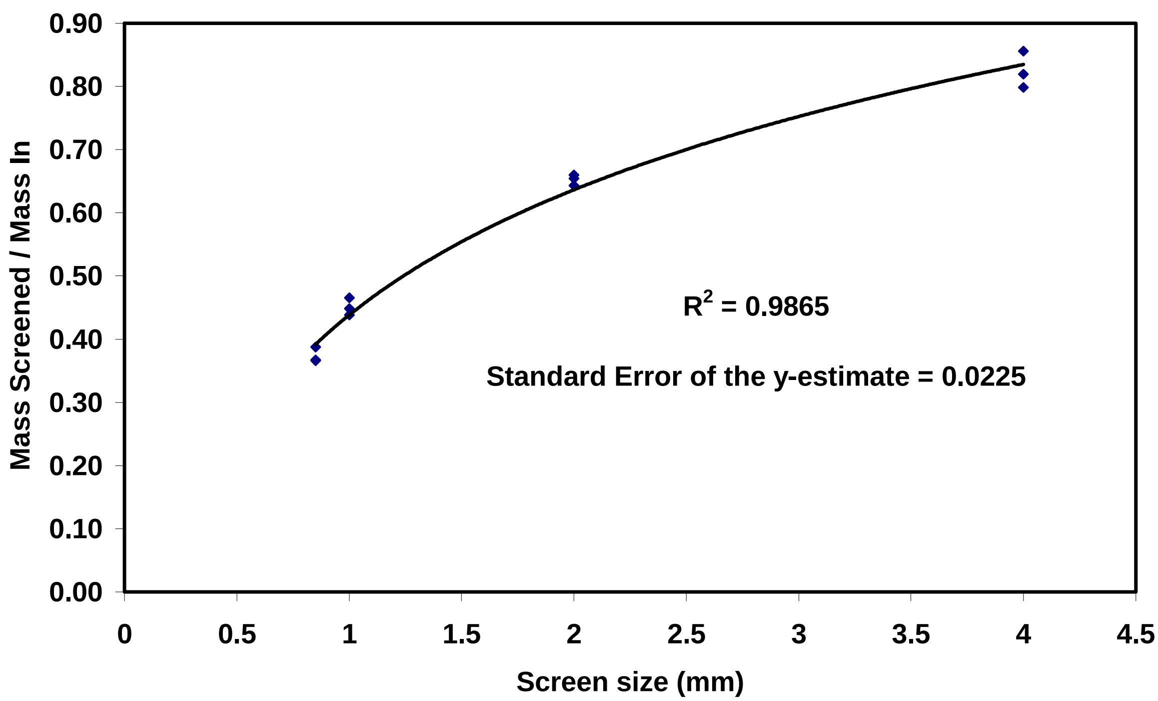

Figure 2 – Mass fractionation of litter screened with respect to screen size.

The coefficient of determination R^2, indicates that 98.65% of the variability of y on x was accounted for by this model. The standard error of the y estimate was 0.0225 and the coefficient of variation about the regression line was 3.3%.

Using equation 1, it was determined that the fraction of litter that passed through the screen increased from 43.8% for the 0.85 mm screen to 83.6% for the 4 mm screen. The actual treatment means were: 0.374 for 0.85 mm screen openings, 0.451 for the 1 mm screen openings, 0.653 for the 2 mm screen openings, and 0.825 for the 4 mm screen openings.

Influence of Screening on Constituent Concentrations

A concentration factor was defined by dividing the constituent concentrations of the treated litter (screened or retained) by the constituent concentrations of the untreated litter for each replication of each treatment. The concentration factor was used to normalize the constituent concentrations of the treated litter to the control (untreated litter). This removed the variation associated with the different initial concentrations that was the result of the nonhomogeneity of the untreated litter. Concentration factors for the screened litter were defined as:

$$CF_{SJ} = \frac{C_{SJ}}{C_{inJ}} \quad . \tag{3}$$

Where:

$CF_{S\,J}$ = concentration factor of the j^{th} constituent screened,

$C_{S\,J}$ = concentration of the j^{th} constituent in the screened litter, and

$C_{in\,J}$ = concentration of the j^{th} constituent in the untreated litter.

Concentration factors for the retained litter were defined similarly as:

$$CF_{RJ} = \frac{C_{RJ}}{C_{inJ}} \quad . \tag{4}$$

Where:

$CF_{R\,J}$ = concentration factor of the j^{th} constituent for retained litter and

$C_{R\,J}$ = concentration of j^{th} constituent retained.

A one-way analysis of variance (ANOVA) with equal replication was used to analyze the concentration factors for the screened and retained fractions for each defined constituent. The ANOVA was composed of eight treatments (CF_S and CF_R for each screen size) with three replications per treatment. As a result, the variance for each ANOVA was based on 16 degrees of freedom.

Mean concentration factors for each constituent of the retained and screened litter fractions were compared to 1 using a t-test at the 90% and 95% confidence levels. A concentration factor equal to 1 means the concentration of the constituent in the treated litter is the same as untreated litter. The 90% probability level was selected as the lower limit for the statistical tests because the uncertainty in measurement of many of the defined constituents was on the order of ± 10% or more.

Mean constituent concentration factors for the screened and retained fractions for each treatment are shown in Table 3. The results of the t-test are also shown in the table.

Table 3. Comparison of screened and retained constituent concentration factors with untreated litter.

Constituents	Screen # 5 4 mm		Screen # 10 2 mm		Screen # 18 1 mm		Screen # 20 0.85 mm	
	$CF_{S\,J}$	$CF_{R\,J}$	$CF_{S\,J}$	$CF_{R\,J}$	$CF_{S\,J}$	$CF_{R\,J}$	$CF_{S\,J}$	$CF_{R\,J}$
TN	1.0017	0.9565	1.0683*	0.8760 **	1.2297**	0.9638	1.1129 **	0.9154 **
Org-N	0.9850	0.9675	1.0737	0.8657 **	1.2773 **	0.9841	1.1455 **	0.9299
TAN	0.9933	0.8911	1.0475	0.8421 **	1.1146	0.8157 **	1.0359	0.8210 **
NO_3-N	1.0461	1.0235	1.0634	1.0570	1.0417	1.1359 *	1.0647	1.1468 *
P_2O_5	0.9867	0.9512	1.1355 *	0.9237	1.2345 **	1.0399	1.0654	0.9394
K_2O	0.9946	0.9689	1.1212 **	0.9993	1.1578 **	1.0758 *	0.9933	0.9608
Ca	0.9627	0.9167	1.1561**	0.8238**	1.2994**	0.9063	1.2001**	0.9106
Mg	0.9798	1.0178	1.1416**	1.0522	1.2643**	1.1016	0.9966	0.9283
S	0.9793	0.9215	1.1728**	0.9425	1.2760**	1.0178	1.0341	0.9081*
Zn	0.9700	1.0106	1.1561**	1.0595	1.1932**	1.1297*	0.9780	0.9818
Cu	0.9355	1.1868**	1.0850	1.1821**	1.1342**	1.2171**	0.8931*	1.0252
Mn	0.9767	1.0309	1.1168*	1.0957	1.1765**	1.1477**	0.9548	1.0061
Na	0.9785	0.9684	1.1267**	0.9787	1.1528**	1.0426	1.0003	0.9746
TS	1.0026	0.9914	1.0067	0.9960	1.0068	0.9983	1.0075	0.9939
VS	0.9920	1.0120	1.0084	0.9460 **	0.9677	0.9962	0.9713	0.9810
FS (Ash)	1.0299	0.9320	1.0104	1.1190 **	1.1017 *	1.0060	1.0921 *	1.0239
C	0.9953	1.0082	1.0021	0.9603**	0.9765	1.0007	0.9761	0.9852

* significantly different from untreated litter at the 90% confidence level

** significantly different from untreated litter at the 95% confidence level

The results for screen # 18, with 1 mm openings, showed significant differences in the screened fraction as compared to untreated litter for more constituents than any other screen size. Screening with a #18 screen resulted in a significant concentration of organic-N, P_2O_5, K_2O, and all defined micronutrients in the screened litter fraction. Concentrations of soluble nitrogen, TAN and NO_3-N, were not affected by screening as expected. The fixed solids or ash content in the screened fraction was 10% higher than for the untreated litter. However, the carbon content was not significantly influenced by separation with a #18 screen.

Screening with a # 5 screen (4 mm) had no effect on concentration factors of the screened fraction. Copper was the only constituent in the retained fraction that was significantly different from the untreated litter.

Screen # 10 (2 mm) significantly concentrated TN, P_2O_5, K_2O and all micronutrients in the screened fraction, with the exception of Cu. Total N, Org-N, TAN, Ca, VS, and C were significantly reduced in the retained fraction. Copper concentration was increased by 18.2% and ash content was concentrated by 11.9% in the retained fraction.

Screening with screen # 20 (0.85 mm) concentrated TN, Org-N, and Ca and ash in the screened fraction. Screen # 20 did not concentrate Org-N, P_2O_5, K_2O and most micronutrients as well as screen # 18.

Overall, there was an increase in the majority of the constituent concentration factors for the screened litter as the screen size decreased from 4 mm to 1 mm openings. A further decrease in screen size to 0.85 mm resulted in a decrease in most CF_S values. Screening with smaller than 1 mm openings does not appear to be advantageous for the purpose of increasing plant nutrient concentrations in the screened fraction.

Fractionation of Nutrients, Solids, and Carbon

The fractionation of plant nutrients and other defined constituents that passed through each of the screens was computed based on the following relationship:

$$F_{SJ} = \frac{M_{SJ}}{M_{inJ}} \times 100 . \tag{5}$$

Where:

F_{SJ} = mass fraction of j^{th} constituent passing through the screen (%),

M_{SJ} = mass of j^{th} constituent passing through the screen (g), and

$M_{in\,J}$ = mass of j^{th} constituent in the untreated litter (g).

Equation 5 can be rewritten in terms of the concentration factors defined in equations 3 and 4, and the fraction of the litter passing through each screen as:

$$F_{SJ} = CF_{SJ} \times \frac{M_{LS}}{M_{Lin}} \times 100 . \tag{6}$$

The fractionation of constituents for each screen was calculated using equation 6 with the CF_{SJ} values given in Table 3 and the average fraction of litter screened (M_{LS}/ M_{Lin}). The results are given in Table 4.

As the screen size increased from 0.85 mm to 4 mm the litter mass fraction that passed through the screen increased from 0.374 to 0.825. The proportion of nutrients, solids, and carbon that went through the screens followed the same trends as that of the mass fractionation of litter. If the CF_S for a particular constituent was greater than one, then the percent of that constituent that passed through a screen was greater than the corresponding litter mass fractionation in percent. Conversely, if the CF_S was less than one, the fraction of the constituent that passed through a screen was less than the litter mass fraction.

Bulk Density

The bulk densities for the untreated, screened and retained litter for the four different screens are compared in Table 5. A one-way ANOVA was performed on the untreated, screened, and retained densities for all screen sizes. The pooled variance for litter density was 321.9 based on 24 degrees of freedom. Least significant differences (LSD) at the 95% and 99% levels were used to test for significant differences between the bulk density of treated and the untreated litter.

Table 4. Fractionation of major and minor plant nutrients, solids, and carbon as a result of screening broiler litter.

	Screen # 5 4 mm	**Screen # 10 2 mm**	**Screen # 18 1 mm**	**Screen # 20 0.85 mm**
Fraction of litter screened	**0.825**	**0.653**	**0.451**	**0.374**
Constituent	**---------- Percent Passing Through Screen ----------**			
TAN	81.95	68.40	50.27	38.74
Org-N	81.26	70.11	57.61	42.84
NO_3-N	86.31	69.44	46.98	39.82
TN	82.64	69.76	55.46	41.62
P_2O_5	81.40	74.15	55.68	39.85
K_2O	82.05	73.21	52.22	37.15
Ca	79.42	75.49	58.60	44.88
Mg	80.84	74.55	57.02	37.27
S	80.79	76.58	57.55	38.68
Zn	80.02	75.49	53.81	36.58
Cu	77.18	70.85	51.15	33.40
Mn	80.58	72.93	53.06	35.71
Na	80.73	73.57	51.99	37.41
TS	82.71	65.74	45.41	37.68
VS	81.84	65.85	43.64	36.33
FS (Ash)	84.97	65.98	49.69	40.84
C	82.11	65.44	44.04	36.50

Table 5. Influence of screening on broiler litter bulk density.

Treatment	**Screen #5 4 mm (kg/m^3)**	**Screen #10 2 mm (kg/m^3)**	**Screen #18 1 mm (kg/m^3)**	**Screen #20 0.85 mm (kg/m^3)**
Untreated	431.9	434.9	411.4	410.0
Screened	417.2	409.1	409.1	385.3
Retained	307.4**	340.3**	350.0**	361.7**

* significantly different from untreated litter at the 95% level

** significantly different from untreated litter at the 99% level

The results in Table 5 indicate that screening broiler litter with all four screens resulted in a significantly lower bulk density for the retained fraction. This suggests that the retained fraction has higher porosity than the untreated litter.

The bulk density of the screened litter was not significantly different from the untreated litter. Therefore transportation costs of the screened fraction should be no more than for untreated litter.

Influence of screening on C:N ratio

The influence of screening litter on the C:N ratio of the retained fraction is shown in Figure 3. Screening increased the C:N ratio in the retained fraction for all screens. The greatest improvement in C:N ratio was obtained for the 2 mm screen. The desired C:N ratio for composting ranges from 20 to 40 (Rynk et al., 1992). Even though screening did improve the C:N ratio, additional carbonaceous material would still need to be added to reach a C:N ratio in the recommended range for composting. The C:N ratios of the retained fractions for the 0.85 and 2 mm screens were significantly higher than the untreated litter at the 95% level.

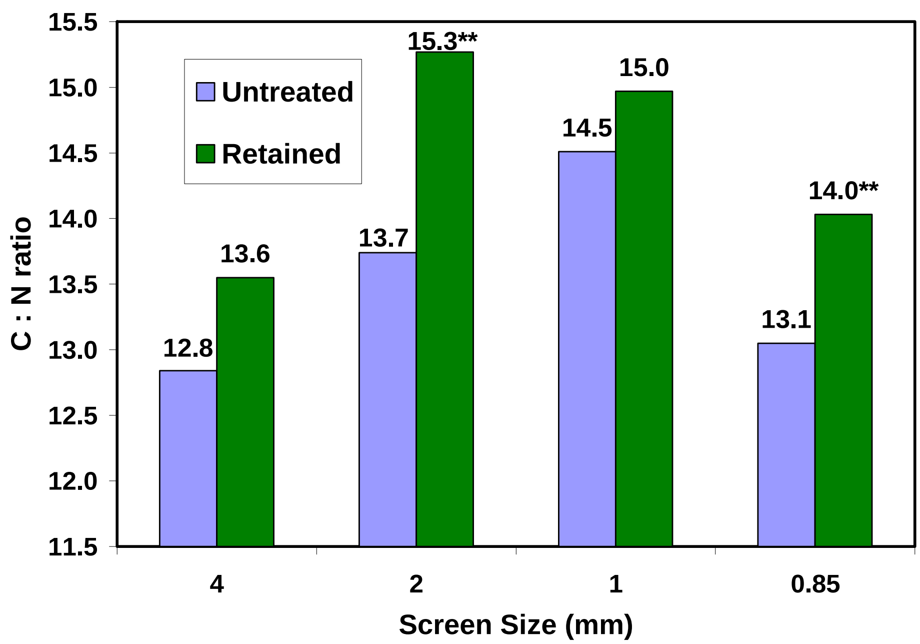

Figure 3 – Carbon to nitrogen ratio for untreated and retained litter with respect to screen size (**indicates significant difference from untreated litter at the 95% level).

Influence of screening on AN:P_2O_5 ratio

The nitrogen in manure that can be readily used by a plant is defined as the available nitrogen (AN). Only a portion of the organic-N in manure will be mineralized during a growing season. The amount of organic-N that is converted to NH_4^+-N depends on a variety of factors. The most important are soil temperature, moisture, and pH. The amount of organic-N that will be mineralized can vary from 30% to 90% depending on soil conditions and manure type (Chastain et al., 2001). Therefore, the mineralization factor, m_F, ranges from 0.3 to 0.9. An m_F of 0.6 was used for this study because that is the recommended value by Clemson University Extension for use in South Carolina. A portion of the TAN in manure can be lost following application. However, the amount lost is comparable to that lost when applying commercial fertilizers (Montes, 2002). The estimate of the AN used to compare broiler litter to fertilizer N sources was:

$$AN = (m_F \times Org - N) + TAN + NO_3 - N \quad (7)$$

The average $AN:P_2O_5$ ratio of untreated broiler litter was 0.61 (Table 2). The influence of screening on the $AN:P_2O_5$ ratio of the screened fraction is shown in Figure 4. None of the screens used induced a significant change in the $AN:P_2O_5$ ratio of the screened fraction based on an LSD test at the 95% level.

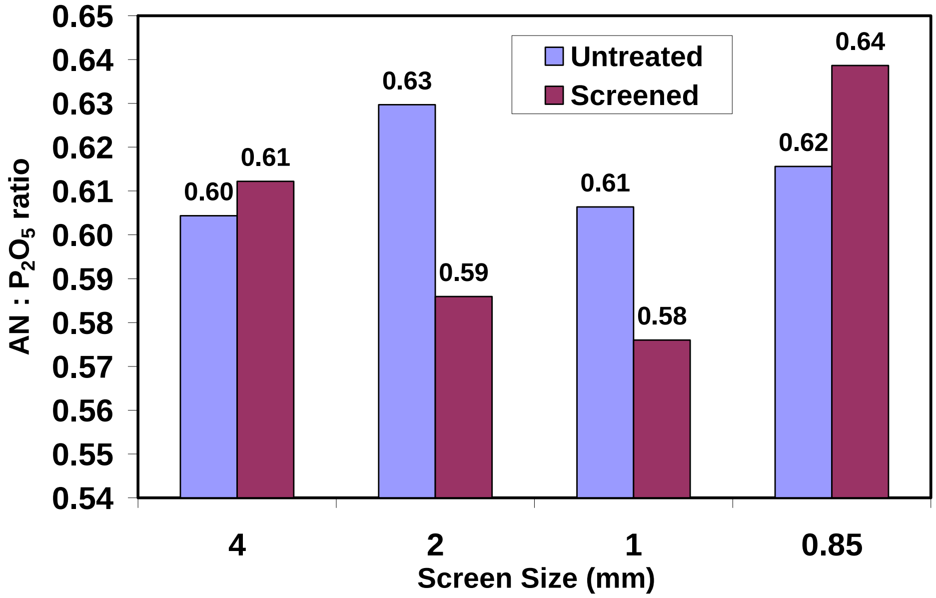

Figure 4 – Available N to P_2O_5 ratio for screened and untreated litter with respect to screen size.

Discussion

The $AN:P_2O_5$ ratio was not significantly increased by the screening process. However, it was observed that screened fractions were more homogeneous than untreated litter. It is believed that the screened fraction could be blended with an inorganic nitrogen source to create a blend with an $AN:P_2O_5$ ratio that meets crop needs.

A 2 mm screen was chosen for this example for three reasons: (1) the screened fraction resulted in an enhanced concentration of several plant nutrients, (2) 64% of the litter passed through the screen (based on equation 2), and (3) a 2 mm screen resulted in the largest improvement in C:N ratio for the retained fraction. The 1 mm screen resulted in a greater concentration of N, P, and K in the screened fraction than the 2 mm screen. However, it was not selected for this example because only 45% of the litter mass passed through the screen.

The different textures of the screened and retained fractions obtained after screening with a 2 mm screen are compared in Figure 5. It can be seen that the particle size of the screened fraction was more homogeneous and did not contain feathers and large wood shavings. The retained fraction contained the larger particles and had a more coarse texture.

Figure 5. Texture of screened and retained fractions for broiler litter screened with screen #10 (2 mm openings).

The plant nutrient concentrations for untreated broiler litter are given in Table 6. These values are the average of the means given previously in Table 2. Similar plant nutrient concentrations of the litter that passed through a 2 mm screen are also shown in Table 6. These concentrations are the product of the untreated litter concentrations and the corresponding CF_S values for a 2 mm screen (Table 3).

The value of blending inorganic N fertilizer with screened broiler litter will be demonstrated for an application rate of 100 kg AN/ha for a crop that requires an AN:P_2O_5 ratio of 2.3 (corn). A granular fertilizer that was 34% AN, 0% P_2O_5, and 0% K_2O (34-0-0) was selected for this example. It was determined that 0.182 metric tons of 34-0-0 must be added to each metric ton of screened broiler litter to achieve an AN:P_2O_5 of 2.3. The concentrations of the screened litter/34-0-0 blend are given in Table 6.

To provide 100 kg AN/ha, 5.01 metric tons of broiler litter are needed per hectare. In comparison, only 1.40 metric tons of the screened litter/34-0-0 blend is needed per hectare. Therefore 72% less material would be applied per hectare if the screened litter/34-0-0 blend is used to provide 100 kg AN/ha. This substantial reduction in material application rate could potentially reduce land application and transportation costs in comparison with untreated broiler litter.

The resulting application rates of P_2O_5 and K_2O and defined minor plant nutrients for the untreated broiler litter and screened litter/34-0-0 blend are also given in Table 6. Increase in the AN:P_2O_5 ratio from 0.61 to 2.3 resulted in an increase in the AN:TN ratio from 0.70 for the untreated litter to 0.91 in the screened litter/34-0-0 blend. Seventy six percent of the TN in the untreated litter was in the organic form, whereas only 25% of the TN was in the organic form for the screened litter/inorganic-N blend. As a result, the nitrogen in the screened litter/ inorganic-N blend would be more available to a plant while maintaining a significant amount of N in a slow-release form.

The AN:K_2O ratio of the screened litter/34-0-0 blend was increased by a factor of 3.6 as compared to untreated broiler litter. The recommended AN:K_2O ratio for corn is around 0.93 (Table 1). When untreated litter is applied as fertilizer, K_2O is overapplied by a factor of 1.3, whereas it would be under applied, by a factor of 0.36, using the screened litter/34-0-0 blend. The K_2O application rate would need to be compared with application recommendations based on soil test for a particular field and crop.

Table 6. Constituent concentrations and application rates for untreated broiler litter and a screened litter and 34% inorganic N blend.

	UNTREATED LITTER Apply 5.01 metric tons/ha		**SCREENED LITTER 2 mm SCREEN**		**SCREENED LITTER/34-0-0 BLEND Apply 1.40 metric tons/ha**	
Constituents	**Concentration (kg/metric ton)**	**Application rate (kg/ha)**	**CF_S**	**Concentration (kg/metric ton)**	**Concentration (kg/metric ton)**	**Application rate (kg/ha)**
TAN	5.025	25.2	1.0475	5.264	N/A	N/A
Org-N	21.875	109.6	1.0737	23.487	19.875	27.80
NO_3-N	1.815	9.1	1.0634	1.930	N/A	N/A
TN	28.713	143.8	1.0683	30.674	78.248	109.5
AN (0.6) *	19.965	100.0	1.1355	22.670	71.476	100.0
P_2O_5	32.755	164.1	1.1212	36.725	31.077	43.5
AN:P_2O_5	0.610	N/A	N/A	0.617	2.300	N/A
K_2O	28.640	143.5	1.1561	33.111	28.018	39.2
Ca	21.844	109.4	1.1416	24.938	21.102	29.5
Mg	4.539	22.7	1.1728	5.324	4.505	6.30
S	5.251	26.3	1.1561	6.071	5.137	7.19
Zn	0.297	1.49	1.0850	0.323	0.273	0.38
Cu	0.312	1.57	1.1168	0.349	0.295	0.41
Mn	0.349	1.75	1.1267	0.393	0.333	0.47
Na	6.695	33.5	1.0067	6.740	5.704	7.98
TS (%)	75.56%	N/A	1.0084	76.19%	N/A	N/A
AN:TN	0.70	N/A	N/A	0.74	0.91	N/A
AN:K_2O	0.70	N/A	N/A	0.68	2.55	N/A
Org-N:TN	0.76	N/A	N/A	0.77	0.25	N/A

N/A= not applicable

* m_F = 0.60

Applying the screened litter/34-0-0 blend to provide 100 kg AN/ha would result in reduced micronutrient application rates when compared to untreated litter. The S application rate was decreased from 26.3 kg/ha for the untreated litter to 7.2 kg/ha for the blend. Common S application rates range from 11.2 kg/ha to 16.8 kg/ha (Jones, 1998). Therefore, land application of broiler litter based on N often provides more S than needed. Using the screened litter/34-0-0 blend would provide sufficient amounts of S in many cases.

Zinc and copper application are reduced by about 25% when the screened litter/inorganic-N blend is used when compared to untreated litter. Excess plant available Zn in the soil can have a toxic effect on peanuts (Camberato, 2001). High plant extractable Cu levels in the soil can result in high Cu levels in forage, which in turn can cause health problems in cattle. Therefore, use of a screened litter/inorganic-N blend could potentially reduce Zn and Cu build-up in soil.

Conclusions

- The mass fraction of broiler litter passing through a screen increased with increasing opening size in a curvilinear manner.
- The fraction of nutrients that passed through a screen followed a similar pattern as the fractionation of litter mass.
- Screening broiler litter with the 1 mm screen resulted in the greatest increase in the concentrations of organic-N, P_2O_5, K_2O, Ca, Mg, S, Zn, Cu, Mn, and Na in the screened litter fraction.
- Screening did not significantly influence the AN:P_2O_5 ratio of the screened fraction.
- Screening increased the C:N ratio of the retained litter fraction for all screens. The greatest improvement in C:N was for the litter retained on a 2 mm screen.
- The AN:P_2O_5 ratio for a specific crop can be achieved by blending the screened fraction with a 34% inorganic N fertilizer. If the AN:P_2O_5 ratio is increased to 2.3, the material application rate would be reduced by 72% when compared to untreated broiler litter.

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