LEACHING OF NITROGEN, PHOSPHOROUS, AND POTASSIUM FROM SAWDUST AMENDED WITH CHICKEN LITTER

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ABSTRACT: A six month study evaluated composting effects on nitrogen (N), phosphorus (P), and potassium (K) leaching from hardwood and furniture sawdust amended with 20% and 30% chicken litter. Toxicity Characteristic Leaching Procedure (TCLP) was used to obtain leachates from substrates. Moisture was provided through precipitation, and the substrate was aerated once or twice per week, depending on the amount of rainfall. Samples were collected at 45 day intervals for analysis. A significant reduction in N and K concentrations occurred for all amended compost by day 180. Hardwood substrate matured quicker than furniture compost based on a radish seed germination test. Toxicity reduction occurred in every treatment by day 180. Chicken litter control showed the best overall weight loss; however, its toxicity levels were still much higher on day 180.

INTRODUCTION

The disposal of furniture wood waste, hardwood waste, and poultry manure has become a major problem throughout the southeastern United States. In Mississippi, it is estimated that 600,000 tons of poultry litter are produced each year (Borazjani, 2004). The forest products industry also produces approximately 12 million tons of wood waste and bark residues throughout their production process (Borazjani et al., 2000). However, since landfills are becoming increasingly expensive and on site incineration, which is governed by strict Environmental Protection Agency (EPA), emissions regulations is not economical; thus, alternate disposal methods are needed (Borazjani et al., 1997).

Several options have been investigated within the poultry industry to deal with their waste disposal. A computer simulation determined that broiler litter had a value of $684 per metric ton as cattle feed. This method of litter disposal would be very economical, but cattle industry numbers are limited (Zimet et al., 1988). The litter was also tested as a fuel source for a gasification furnace. However, this technology resulted in high levels of slag, which reduces the heat output efficiency of the furnaces (Muir, 1987). The most common practice of litter disposal is to use the raw manure as a fertilizer for land applications. However, since the poultry industry in the south generates large quantities of waste, over fertilization of pasture lands often occurs. This results in ground and surface water contamination due to the excess nutrients and pathogens that runoff the land and into streams and rivers (Borazjani et al., 2000).

States are required to establish and regulate water quality standards through total maximum daily loads (TMDLs). The TMDL program requires states to determine the "impairment" level of a given river, stream, lake or watershed through sampling and identifying the types of pollutants (fecal coliform, nutrients, sediments) in that body of water. The states also determine what pollutant levels are "acceptable", the background level of pollution, and the pollution from point source. The remaining pollution is attributed to non-point sources. The TMDL program could require a reduction of source pollutants if the watershed exceeds acceptable state levels.

Composting is a simple solution for reducing the above waste problems because of its environmental friendliness and cost. Composting wood and poultry litter residue biologically decomposes the waste material into a stable state. Once stable it can then be handled or applied to land without adversely affecting the environment.

The objective of this study was to compost poultry litter, furniture wood waste, and hardwood waste, and measure: 1) the leachability of nitrogen (N), potassium (K), and phosphorous (P) using the toxic characteristic leaching procedure (TCLP) test during different stages of composting; and (2) the correlation between leaching and compost maturity.

MATERIALS AND METHODS

Hardwood sawdust used in this experiment was obtained from a sawmill located in Waynesboro, Mississippi. Furniture sawdust was obtained from a local manufacturing facility in Starkville, Mississippi. Poultry manure was acquired from a farm located in Forest, Mississippi. Both manure and sawdust were dried under a hood and used on a dry weight basis. The poultry manure and sawdust were cleared of larger debris using a series of screens. Eighteen twenty-gallon plastic containers with pre-drilled holes in the bottom were used to hold the sawdust and poultry manure amendments. Due to the small volume of available manure, three five-gallon plastic containers held the poultry manure control samples. Small screens were placed in the bottom of the containers to ensure that no compost would be lost over the 180 day time period. The drilled holes regulated the composts moisture content (MC) and prevented water retention that would have resulted in anaerobic conditions. The following treatments were evaluated:

1. Hardwood sawdust control with no chicken manure
2. Hardwood sawdust amended with 20% chicken manure (dry-weight basis)
3. Hardwood sawdust amended with 30% chicken manure
4. Furniture sawdust control with no chicken manure
5. Furniture sawdust amended with 20% chicken manure
6. Furniture sawdust amended with 30% chicken manure
7. Chicken manure control with no sawdust

The treatments were replicated three times, and thoroughly hand mixed before placing them into the containers. The compost cans were placed outdoors in a random arrangement for a maximum of 180 days.

Aeration of the furniture, hardwood, and poultry manure substrate was done by two methods; 1) an auger bit attached to a cordless power drill; then 2) the compost was then physically turned by hand. Aeration of the compost ensured that the MC remained around 50%-70% within each container to prevent anaerobic conditions. MC was also adjusted through rain fall or by adding distilled water. Compost cans were aerated once or twice per week depending on precipitation conditions or how much distilled water was added.

Samples were collected in 45 day intervals for 180 days to analyze for pH, leachate, MC, and toxicity. Each compost can was turned thoroughly before an initial collection sample was made. During the collection process approximately two handfuls (0.6lbs dry weight basis) from each compost can were placed in a plastic gallon bag, then placed into a freezer. A sample of around 11g was taken from each bag and placed in an aluminum dish. The aluminum dish was then placed into an oven at 200^{o}C and allowed to dry over night. The dry weight sample was used to accurately calculate MC. The MC for this experiment was maintained around 55 to 70%.

To determine whether or not the compost had matured, a compost maturity test was administered. The test was conducted on all compost samples from day 0 through day 180. Potting soil was used for six control samples, and two samples of compost were placed in an eight ounce paper cup. Each cup contained six fast germinating radish seeds that were placed approximately one-quarter inch under the top layer of each sample. The samples were irrigated regularly to ensure that the compost cups remained moist. After seven days the number of seeds germinated was recorded and a germination rate was calculated. According to Florida's on-line composting center, a germination rate of eighty percent or higher indicates that the compost is matured (www.compostinfo.com).

Leachate from each sample was produced by TCLP test (EPA, 1983) and was analyzed for N, P, K, and Mn. Ten grams from each compost sample were measured on a dry weight basis then placed into 1000 ml bottles. The bottles were then filled with 750 ml of rain water and placed in a rotary mixer at 30 revolutions per minute (rpm) for 16 hours. After mixing the compost with the rain water, the substance was allowed to settle for 12 hours before being filtered through 125 mm pore size filter paper with the aid of an aspirator. A 1000 ml volumetric flask was used to collect the leachate water after it passed through the filter paper. 250 ml of effluent water was placed in amber bottles and a pH reading was taken for each sample. The pH was taken using an Accument® model AB 15 pH meter probe. pH levels for all treatments were between 6and 7 after day 90. The bottles were then sent to Mississippi State University soil testing laboratory for P, K, and Mn by Inductivity Coupled Plasma Atomic Emission Spectrometry. A 50-ml sample was taken from each 250-ml sample and was sent to Environmental Laboratories Incorporated located in Starkville Mississippi, for Total Kjedahl Nitrogen (TKN) using EPA Method 351.4

The toxicity test determined whether or not the leachate water would pass a chronic Ceriodaphina test. The test was only conducted on samples from day 0, 90, and 180. An average of 15g from each compost sample were combined together in a gallon size plastic bag and mixed thoroughly to ensure even distribution throughout the samples. Approximately 2g of each compost treatment was placed in a 40-ml glass vial and 18-ml of distilled water added. The vials were then placed into a sonicator for 10 minutes, and allowed to settle for 12 hours inside a refrigerator. After settling the top 10-ml of water was removed, transferred into test tubes, and placed into a centrifuge for 5 minutes at 50,000 rpm. 2.5-ml of water from each tube was removed and placed in a cuvette that contained 0.05g of NaCl. From the 2.5-ml cuvette, 500 microliters (µl) were removed and placed in four other cuvettes. This gave a total of 500-µl distributed evenly throughout five cuvettes. For each individual test, five control cuvettes containing ultra-pure water were used for comparison with each sample set. Exactly 10-µl of microtox reagent was added to each cuvette 5 minutes prior to being analyzed for toxicity using Microbics® M 500 toxicity analyzer. The toxicity analyzer measures the luminescence reduction of marine bacteria challenged with the sample solution to determine relative toxicity levels.

The compost cans were weighed on day 0 and day 180. MC was determined to adjust each compost can to a dry weight basis. The two samples of compost that were taken out on day 45 through day 180 were added to each can to ensure that the weight loss was based solely on composting.

The nutrient concentrations and weight loss within the compost study were determined using a completely randomized design. Three replications were used for each treatment. Mean comparisons were made using a least significant difference at the P=0.05 probability level by the Statistical Analysis System (SAS).

RESULTS AND DISCUSSION
Compost Maturity Test Results

Table 1 indicates that by day 90 all control and amended samples were matured. A higher level of germination for both hardwood and furniture controls could be attributed to excess N in amended treatments. Leachate results confirm that when N is lower, germination from the radish seeds occurred at higher rate. By day 180 all the seeds had a germination rate of 100%. Giusquiani et al. (1995) found that composting can adjust the nutrient levels to ratios which are desirable for the plant. According to Florida's online composting center a germination rate of 80% or higher determines whether or not the compost has matured (www.compostinfo.com).

Table 1- Seed Percent Germination rate.

Radish seed Test
Seed Percent Germination

Sample	Day 0	Day 45	Day 90	Day 135	Day 180
Top Soil Control	100%	100%	100%	100%	100%
Hardwood Control	83%	100%	100%	100%	100%
Hardwood Control	83%	100%	100%	92%	100%
Hardwood Control	75%	100%	92%	100%	100%
Hardwood 20%	0%	92%	100%	92%	100%
Hardwood 20%	58%	100%	100%	100%	100%
Hardwood 20%	0%	92%	92%	100%	100%
Hardwood 30%	25%	92%	92%	83%	100%
Hardwood 30%	16%	75%	100%	100%	100%
Hardwood 30%	25%	100%	100%	100%	100%
Furniture Control	42%	100%	92%	92%	100%
Furniture Control	42%	92%	100%	92%	100%
Furniture Control	25%	92%	83%	100%	100%
Furniture 20%	33%	83%	100%	83%	100%
Furniture 20%	25%	100%	100%	100%	100%
Furniture 20%	42%	92%	100%	100%	100%
Furniture 30%	33%	100%	92%	100%	100%
Furniture 30%	8%	100%	100%	100%	100%
Furniture 30%	58%	92%	92%	100%	100%
Chicken litter	0%	0%	0%	42%	100%
Chicken litter	0%	0%	0%	0%	100%
Chicken litter	0%	0%	0%	33%	100%

Nitrogen, Phosphorus, and Potassium Results
Hardwood Control

Most treatments showed a significant lower N, P, and K level on day 180 as compared with day 0. The average total concentration of nutrients for the hardwood control samples are illustrated in Figure 1. Since this is a control sample, the values for TKN, P, and K are very low. K showed a significant reduction from day 90 to 135. P levels were significantly lower on days

135 and 180. TKN levels were significantly higher on day 135 than any other day with regard to the hardwood control samples. This could be due to biodegradation of lignin, resulting in the fungi releasing bound N and P from the wood source.

Furniture Control

The furniture control samples, however, showed no significant difference for TKN (Figure 2). This could be attributed to the storage place of the sawdust. The furniture sawdust was stored inside, (before collecting it for the experiment) while the hardwood sawdust was stored outdoors. As a result, the furniture control samples may lack the microorganisms that the hardwood samples already contained. The furniture control samples also showed that K was significantly higher on day 0 with a mean value of approximately 17mg/L. P significantly decreased by day 45, compared to day 0, and also significantly decreased by day 135 compared to day 90. There was no change between days 135 and 180. Overall, with the exception of TKN the other two showed significantly lower P and K by day 180. One reason attributed to the unchanged TKN level could be related to less degradation of the furniture control (weight loss) vs. hardwood control.

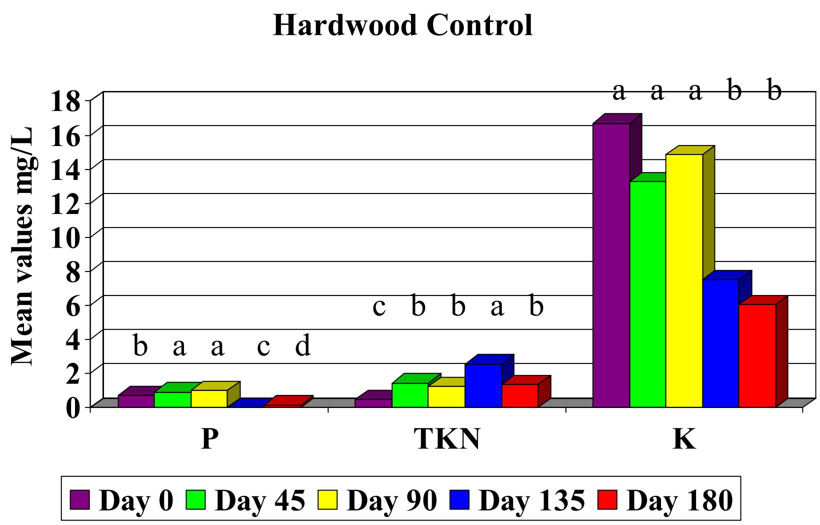

Figure 1. Hardwood control nutrient values from the leachate water samples. Columns with the same letter indicate no significant difference in nutrient values at the α = 0.05 probability level.

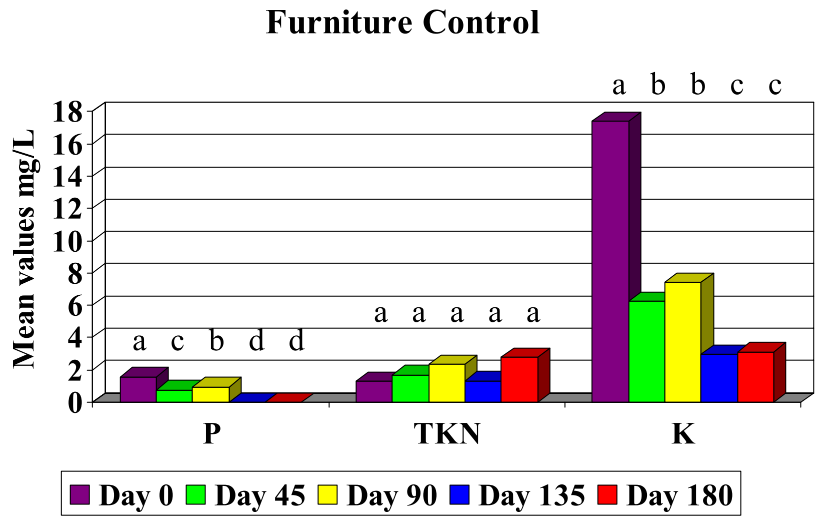

Figure 2. Furniture control nutrient values from the leachate water samples. Columns with the same letter indicate no significant difference in nutrient values at the α = 0.05 probability level.

Hardwood/Litter amended

The hardwood sawdust amended with 20% chicken litter showed a significant difference for K on day 0 composed to the level on the other days, but no significant differences were observed in K levels among the other dates (Figure 3). The TKN level for day 0 was also higher than any of the other days and significantly decreased between day 0 and day 45. There were fluctuations but no significant change during the remaining days. P levels, however, showed no significant change throughout any of the test days. Hardwood sawdust amended with 30% chicken litter did show a significant difference in P for day 0 when compared to the days 135 and 180 (figure 4). P appears to be the only element not declining, but increasing from day 0 to 135. This could be attributed to amount of chicken litter used in these treatments. Fontenot et al. (1983) points out that larger quantities of chicken manure contain high levels of P. Wood (1996) reported that poultry manure applications will increase concentrations of extractable P. Reuther (1973) suggests that P is chemically bound to aluminum and iron compounds within animal manure. When the samples were allowed to weather outdoors the P was released because it is soluble in water. This is why P levels are rising in the amendments. The TKN level for the 30% amendment was also higher on day 0 than any of the other days. There was a significant decrease from day 0 to day 45, 90, and 180. But day 135 showed a significant decrease from all of the days. K also showed a significant decrease from day 0 to all other days. Its lowest concentration was at day 180, although this value was not significantly different from days 45, 90, and 135.

Furniture/Litter amended

The furniture sawdust amended with 20% chicken litter also showed a significant reduction in K on day 0, but not any of the other days (Figure 5). TKN was also significantly higher on day 0 as compared to the rest of the days. Again the results indicate that the lowest concentration for TKN was found on day 135 but this time it is not significantly different from day 45, 90, or 180, however, it is still significantly different from day 0. P levels showed a significant difference between day 0 and 180. P levels for the furniture sawdust amended with

30% chicken litter showed no significant difference from day 0 through day 180 (Figure 6). The TKN level indicates that a significant reduction only appears after day 0, but the lowest concentration is still day 135. K levels indicate a significant reduction throughout the study. The lowest concentration was found on day 180, with this level being significantly different from any of the other days.

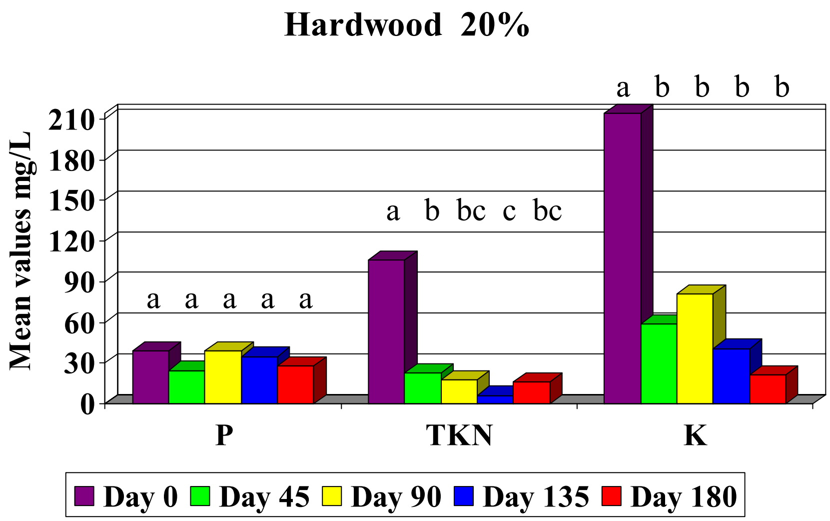

Figure 3. Hardwood amended with 20% chicken litter. Nutrient values from the leachate water samples. Columns with the same letter indicate no significant difference in nutrient values at the α = 0.05 probability level.

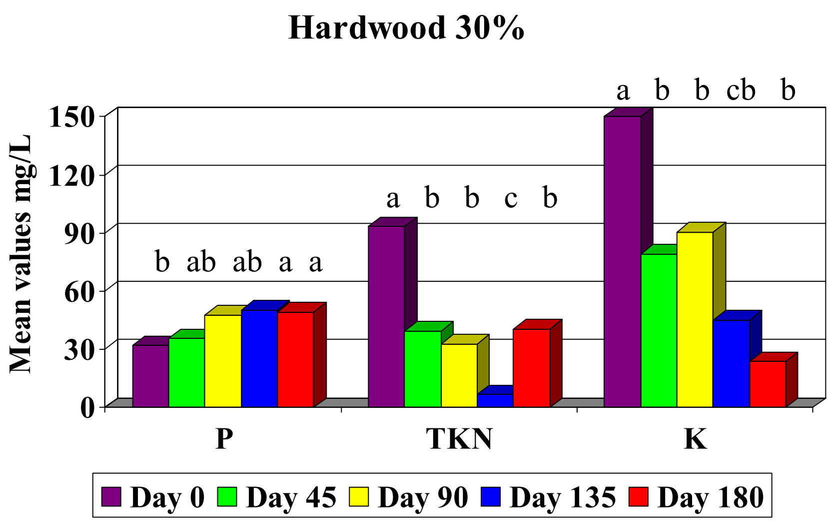

Figure 4. Hardwood amended with 30% chicken litter. Nutrient values from the leachate water samples. Columns with the same letter indicate no significant difference in nutrient values at the α = 0.05 probability level.

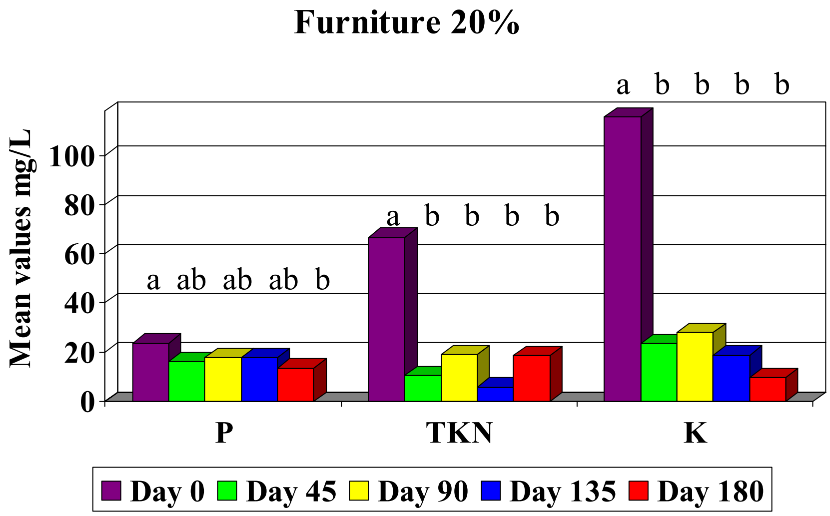

Figure 5. **Furniture amended with 20% chicken litter. Nutrient values from the leachate water samples. Columns with the same letter indicate no significant difference in nutrient values at the α = 0.05 probability level.**

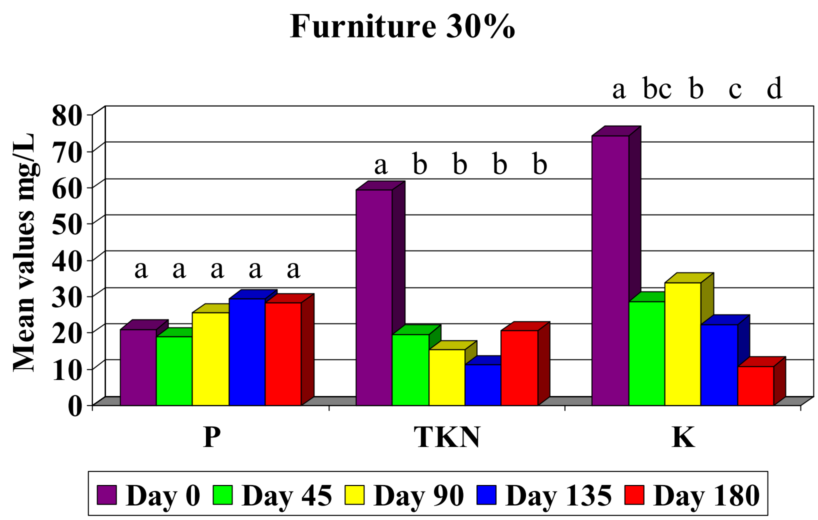

Figure 6. Furniture amended with 30% chicken litter. Nutrient values from the leachate water samples. Columns with the same letter indicate no significant difference in nutrient values at the α = 0.05 probability level.

Overall both the hardwood and furniture composts amended with chicken manure showed a significant reduction in TKN and K from day 0. Many researchers agree that composting will significantly reduce the amount of nutrients (Tyson and Cabrera, 1993; Wilde, 1958; Borazjani et al., 1998; Rynk et al., 1992). Nutrients such as N, P, and K promote the growth of decay organisms, which use the nutrients as an energy source to break down and decompose material within a compost. This is why composting dramatically lowers the potential for leaching nutrients.

Chicken Litter Control

Figure 7 illustrates the chicken litter control samples. The statistical analysis indicates a significant decrease in K after day 0 as compared to day 45, 90, 135, and 180. TKN levels were significantly higher on day 0 verses day 90 and 135 but not 180. P shows a significant decrease only on day 135. The nutrient values for the chicken litter control samples are much higher as compared to all other samples. This is in agreement with Tyson and Cabrera (1993) who state that poultry litter is excellent for the composting process due to the available amounts of nutrients that the litter contains. N levels for the chicken litter control samples have a range over 150 mg/L. This was the main reason for lack of germination in the radish seed test (Table 1). Overall, composted litter followed similar patterns as those of 20% and 30% amended treatments.

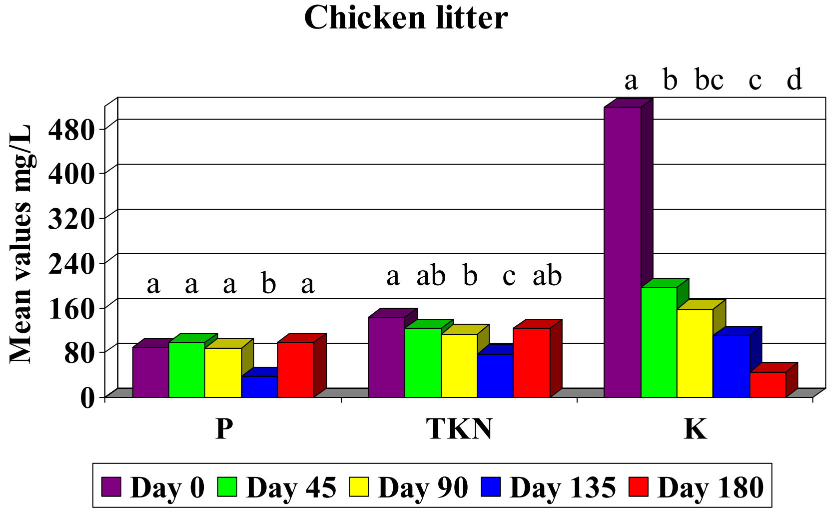

Figure 7. Chicken litter control nutrient values from the leachate water samples. Columns with the same letter indicate no significant difference in nutrient values at the $\alpha = 0.05$ probability level.

Toxicity

During the composting process both the hardwood and furniture sawdust amendments showed a reduction in toxicity by day 90 (figure 8). The lowest overall toxicity for hardwood control, hardwood 30%, furniture 30% and chicken litter was observed on day 180. Chicken litter control showed the best overall weight loss; however, its toxicity levels were still extremely high on day 90 and 180 compared with the other treatments. Chicken litter contains more microorganisms than the sawdust, and this could explain why the amended treatments (day 0) and chicken litter control samples are higher. After day 90 however, the amended treatments composted lowering the toxicity. This is in agreement with Borazjani et al. (1998) who also found that that chicken litter amended with furniture wood waste has a lower toxic effect than unamended controls after 180 days of composting.

Weight loss

A reduction in weight loss was also evident as indicated by Figure 9.
Hardwood amended with 20 % chicken litter was not significantly different from the 30% mixture. However, it was significantly different for both of the furniture amendments. Both hardwood and furniture sawdust amended with the poultry litter showed a high weight reduction. Although the chicken litter control showed the highest percent of weight loss, its toxicity levels are still high. This is why an amendment such as sawdust should be added. Poincelot (1974) found that amendments, such as sawdust from hardwood and furniture, increase the C content.

Cabrera et al. (1993) continues by stating that the growth of bacteria, fungi, and actinomycetes are stimulated by the C content; while the N content provides certain types of proteins and enzymes. Edward and Daniel (1992) point out that poultry manure contains a very high level of N. Thus, the content of C within the wood combined with the levels of N in the poultry manure significantly reduces the weight and bulk of a compost.

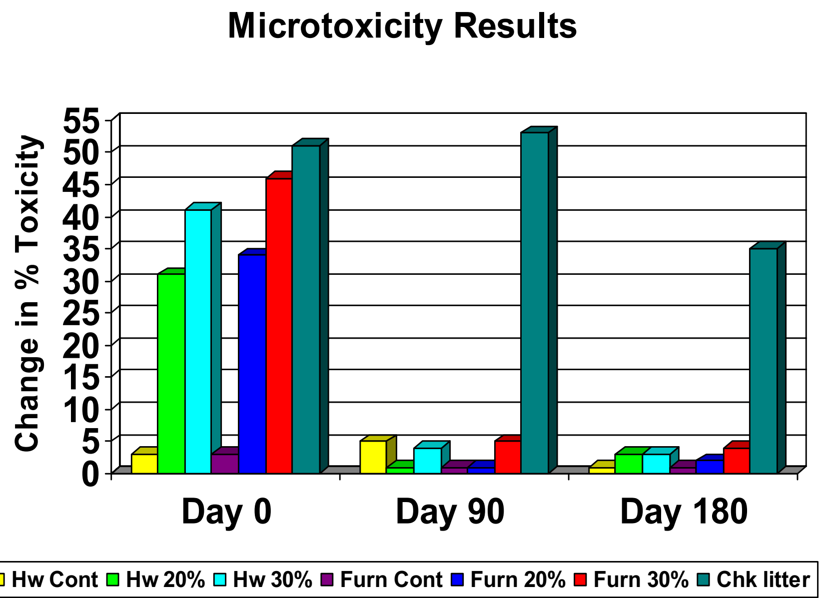

Figure 8. Percent effects of more or less than 5% indicates that effluent will likely not pass a chronic Ceriodaphnia test.

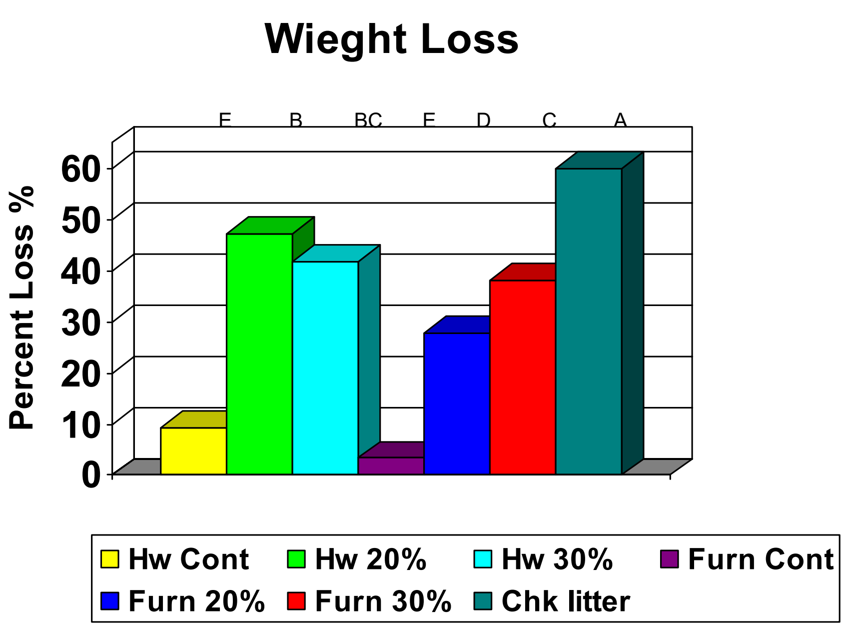

Figure 9. Percent weight loss on day 180. Columns with the same letter indicate no significant difference in nutrient values at the α = 0.05 probability level.

CONCLUSION

This study found that sawdust amended with chicken litter and then composted reduces the leaching potential of N and K, thus helping to prevent contamination which may adversely affect the environment. The leachability of P, however, generally stayed the same throughout the study or slightly increased. The composted product could be used in areas which contain P deficient soils or nurseries which require P for plant material.

Nitrogen amendments such as chicken litter can increase the rate at which a compost is degraded, and since the poultry industry is primarily located in the southeastern United States the nitrogen source is available. Many sawmills and furniture facilities are also located within the southeastern United States. The carbon from the sawdust amended with the chicken litter and composted would produce a value added product. The radish seed maturity test showed that even partial composting of sawdust and chicken litter had an advantage over uncomposted raw material.

Composting is an effective way of dealing with both sawdust and chicken litter. The composted amendments reduce the weight, leaching potential, bulk, and toxicity. This could solve problems not only in the southeast, but other regions as well. The finished compost could be used as a soil additive in areas with low organic matter. This would make it popular among nurseries and farmers throughout the southeastern United States. This could be of great importance to poultry producers, forest product companies and land farmers.

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