EFFECT OF PELLETIZED POULTRY MANURE ON CROP PRODUCTION AND VADOSE ZONE WATER QUALITY

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ABSTRACT

Poultry manure has long been recognized as the most desirable organic fertilizer, as it improves soil fertility by adding both major and essential plant nutrients as well as soil organic matter which improves moisture and nutrient retention. However, continuous application of poultry manure in the area where there is concentrated poultry farms raises great concern of water quality. Basically applying only what plants can utilize may reduce nutrient leaching to receiving waters, but manure born pathogens remain the main concern. Subsequently, Perdue AgriRecycle Inc. has initiated producing processed and pelletized poultry manure for easy handling and movement. In spite of the fact that its nutrient composition is known, its effectiveness on crop production and water quality is not well documented. The objective of this study was to investigate the effect of pelletized poultry manure on crop production and vadose zone water quality. The concentration of orthophosphate, nitrate, fecal coliform and total coliform in soil as well as soil water at the vadose zone was analyzed for two consecutive years. Using sweet corn as the main crop and wheat as the cover crop of the following season, results show that application of pelletized poultry manure positively affected the crop growth and biomass production of the cover crop. Soil water quality was also impacted where higher rates of manure application together with mineral fertilizer resulted in higher nitrate and orthophosphate leaching.

Key Words: Coliform; lysimeter; organic fertilizer; soil pH; phosphate

INTRODUCTION

Poultry manure is an excellent organic fertilizer, as it contains high nitrogen, phosphorus, potassium and other essential nutrients. In contrast to mineral fertilizer, it adds organic matter to soil which improves soil structures, nutrient retention, aeration, soil moisture holding capacity, and water infiltration (Deksissa *et al*., 2008). It was also indicated that poultry manure more readily supplies P to plants than other organic manure sources (Garg and Bahla, 2008). As the use of poultry manure becomes an integral part of sustainable agriculture, demand for poultry products increases and pasturelands as well as croplands become nutrient saturated, which has ultimately increased water quality and public health concerns. In addition to high N and P content, raw poultry manure has a potential source of pathogen or *E .coli* (Jamieson *et al*., 2002; Bustamante *et al*., 2007) and endocrine disruptors (Deksissa *et al*., 2007). Subsequently, despite the enormous progress that has been achieved in reducing water pollution, almost 40% of U.S. waters that have been assessed have not met water quality standards mainly due to non-point source pollution (Zygmunt, 2000). Several previous studies have shown that runoff from farmland was a major source of pollution contributing to water quality decline in the Chesapeake Bay (Chesapeake Bay Commission, 2007). This problem might be exacerbated by increase of demand for grain-based ethanol production, as this requires more application of organic as well as mineral fertilizer. Poultry litter is a suitable N source for corn, and continuous application of poultry litter in excesses of what the crop can utilize on an agricultural land may lead to accumulation of P which will ultimately leach and affect the receiving water quality (Norman *et al*., 2003; Collins *et al*., 2008).

In order to reduce the risk to water quality and public health, different options for processing and marketing poultry manure via for example pelletizing was considered. Perdue AgriRecycle Inc. is processing and pelletizing poultry manure for easy handling and marketing. Although it is expected to concentrate nutrient and protect water quality, some studies showed that N and P in pelletized poultry litter may not be as easily available as from inorganic fertilizer (Hammac *et al.*, 200) and its recommended rate of application for various crops is not yet established.

The objective of this study is to investigate the effect of pelletized poultry manure on the Corn biomass production and vadose zone water quality. Data collected during the growing season were vadose zone water samples at 45 cm and 90 cm depth, soil nutrient content at 0-15 cm depth, dry weight biomass, plant height, leaf chlorophyll index, and soil pH. Vadose water samples were analyzed for nutrients such as phosphorus, nitrogen, and coliforms. Data collected have been statistically analyzed, using the analysis of variance (ANOVA) to correlate the amount of poultry pelletized manure added to crop biomass and water quality.

MATERIALS AND METHODS

Experimental Field Layout

This study was conducted at the experimental plot of 18.3 m x 27.4 m established on a silt loam soil at the Muirkirk Agricultural Research Station in Beltsville, Maryland. The experimental design was a randomized complete block design with 6 treatments (Table 1) and 6 replications. Each main plot size is 4.6 m x 3.05 m. For each treatment 4 lysimeters were installed randomly, two at 45 cm and two at 90 cm depth. All lysimeters have a 2 bar porous ceramic cup at the bottom end and 6 cm tubes protruding from the top area (about 30 cm above the soil surface) which was otherwise sealed. A 2006 G2 pressure/vacuum hand pump was used to collect water samples.

Table 1. Description of treatments and application rate of pelletized poultry manure and mineral fertilizer

Treatments	Experiment 1 (2007)	Experiment 2 (2008)
T1	2000 kg/ha Poultry Pellet + 500 kg/ha 10-10-10 Fertilizer	2500 kg/ha Poultry Pellet + 500 kg/ha 10-10-10 Fertilizer
T2	500 kg/ha 10-10-10 fertilizer	500 kg/ha 10-10-10 fertilizer
T3	1000 kg/ha Poultry Pellet + 500 kg/ha 10-10-10 Fertilizer	1250 kg/ha Poultry Pellet + 500 kg/ha 10-10-10 Fertilizer
T4	2000 kg/ha Poultry Pellet	2500 kg/ha Poultry Pellet
T5	1000 kg/ha Poultry Pellet	1250 kg/ha Poultry Pellet
T6	Control	Control

Soil and soil water quality analysis

Soil water quality analysis was conducted at the DC Water Resources Research Institute Water Quality Testing Laboratory at the University of the District of Columbia. The soil pH was determined in 1:1 soil to deionized water, 10 g soil in 10 ml of deionized water. After shaking it for 1 hour, the pH was analyzed using pH electrode. Nitrate was extracted from the soil sample (air dried and sieved) using 1 N KCl as an extracting solution. Five gram of soil was placed in 50 ml of extracting solution, which was then placed on an end-to-end shaker. After shaking the sample for 15 minutes, the sample was centrifuged at 14,000 g for 15 minutes, and the clear supernatant was analyzed for the nitrate concentration using DR2800 spectrophotometer.

Plant available phosphate, orthophosphate, was extracted using Mehlich I extracting solution (0.025 N H_2SO_4 + 0.05 N HCl). The extracted sample was centrifuged at 14,000 g for 15 minutes, and the clear supernatant was filtered and analyzed using molybdovanadate reagent and DR2800 spectrophotometer.

Organic matter content was determined using 3 g of air dried soil oven-dried at 105°C for 24 hr. Two gram of the oven-dried soil sample was placed in a crucible, which was subsequently placed in a muffle furnace set at temperature, first to 375°C for 1 h, and then ashed at 600°C for 6 hours. Then the percentage of Organic Matter (OM) was calculated on the basis of weight lost (100 - % Ash).

Total and fecal coliforms were determined using IDEXX products (colilert®). Using 1: 10 soil to deionized water, the extracted soil solution was allowed to settle for 15 minutes. Then, 20 ml of the supernatant was then poured into a sterile transparent non-fluorescent 100 ml vessel and diluted up to 100 ml using deionized water. After adding the colilert® reagents, the sample was poured into the Colilert® Quanti-Tray, sealed and incubated at 35ºC for 24 hours. The Most Probable Number of Total Coliform and Fecal Coliform were determined on the basis of yellow color formation and being fluorescent, respectively.

Plant height and Leaf chlorophyll index

Using regular measuring tap, five randomly selected plant heights were taken for each measurement and the average height was recorded as the representative height. Leaf Chlorophyll concentration was measured using digital Chlorophyll concentration meter, Apogee Model CCM200. In each chlorophyll measurement, five plant samples were randomly selected and the average height was considered as the plant height corresponding soil plot under consideration.

Crop biomass analysis

Crop biomass was sampled using a meter square ring which was thrown randomly in a plot and all surface biomass cut using a shear at about 5 cm above the ground. Two samples were collected per plot with 2m x 2m square per sample. Samples were placed in large brown paper bags which were oven-dried at 105 ºC for 24 hours; the dry weight biomass was determined using gravimetric analysis.

Statistical analysis

Data collected during this study were analyzed using analysis of variance, ANOVA or F-test at a 5% significance level (Steele and Torrie, 1980). The null hypothesis was that there would be no significant difference among the mean of the effect of the treatments. When the analysis of variance F-test was significant, the Least Significant Difference at 5% significance level, *LSD(0.05)* was calculated for each data set. The value of *LSD(0.05)* was then applied to examine the significant difference among the mean of the treatments.

RESULTS AND DISCUSSION

Experiment 1

Soil and crop biomass

On the basis of two sets of treatment given in the 1st column of Table 1, the effect of pelletized poultry manure on the nutrient as well as crop biomass was analyzed. The result shows that addition of poultry litter buffers the soil pH as compared to mineral fertilizer, which is consistent with the previous studies (Ortiz-Escobara and Hunde, 2008). As illustrated in Figure 1, addition of mineral 10-10-10-fertilizer at 500 kg/ha has significantly reduced the soil pH, where as the soil plots without mineral fertilizer relatively showed higher pH. The highest pH was observed in the soil amended with no mineral fertilizer but pelletized poultry manure. Change in soil pH will ultimately affect the availability of soil nutrient content. Lower soil pH will result in lower nitrate nitrogen as well as orthophosphate in soil perhaps due to nutrient leach off. As illustrated in Figure 2, the result depicts that there is a strong correlation of soil pH and nitrate (r^2= 1) and orthophosphate (r^2 = 0.68).

The effect of pelletized poultry manure on the corn biomass and accumulation of nutrients as well as microbial biomass in the soil was analyzed. The result indicates that the highest application rate of both mineral fertilizers in combination with pelletized poultry manure has

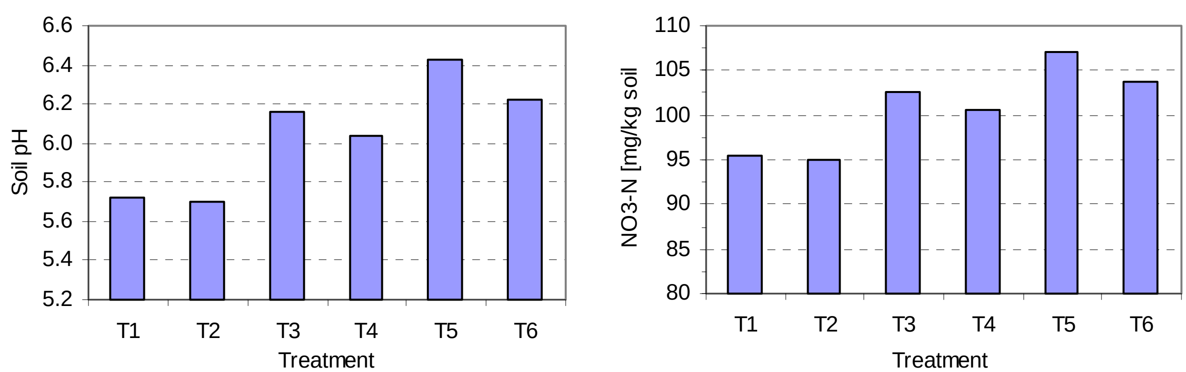


Figure 1. Effect of mineral fertilizer on the soil pH and nitrate nitrogen

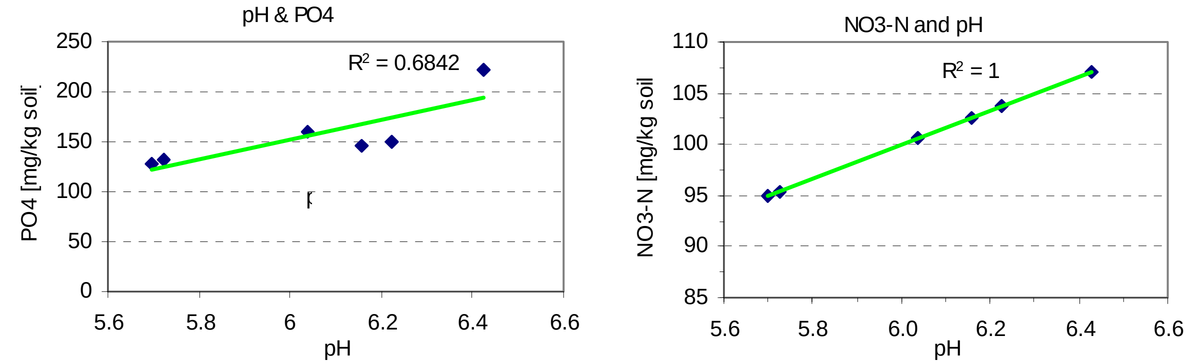


Figure 2. Correlation of pH versus nutrient content in the soil amended with poultry manure

resulted in the highest dry weight corn biomass (Figure 3). This shows that addition of low mineral fertilizer stimulated fast plant growth, as organic fertilizer slowly releases nutrients. Laboratory analysis for microbial growth indicates that there is no correlation between total coliform in soil sample and pelletized poultry manure. Fecal coliform was however not detected. The result also shows that accumulation of nitrate, orthophosphate and organic matter in soil is not significantly different at 5% level of significance.

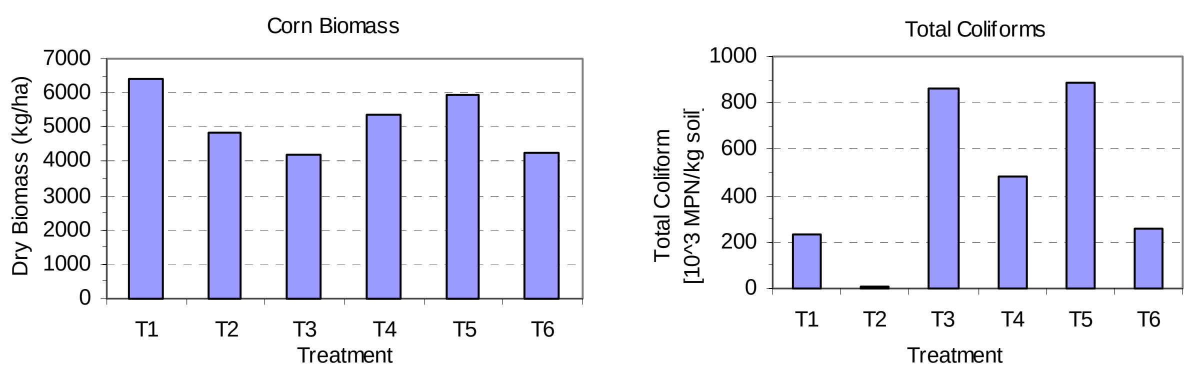


Figure 3. Pelletized poultry manure on Corn dry weight biomass and soil microbial growth

Vadose zone water quality

Using water sample collected at 45 cm and 90 cm lysimeter depth, the effect of pelletized poultry manure on the vadose water quality was analyzed. In the first experiment (Table 1, left column), the result shows that highest reactive phosphorus in the soil water was measured in Treatment 3 (Figure 4), which is consistent with the lower crop dry biomass (Figure 3). In both phosphate and nitrate content of soil water, the highest concentration of nutrients in the vadose zone was observed in the soil plots that were amended with 1000 kg/ha pelletized poultry manure and 500 kg/ha mineral fertilizer. This confirms that the addition of high organic manure in combination with mineral fertilizer could result in more nutrient leach off to the ground water. However, the highest rate of pelletized poultry manure did not result in the highest nutrient leached off as it releases the nutrients slowly. Furthermore, laboratory test results for fecal coliforms confirm that there was no positive test for the presence of *E. Coli* in the soil water.

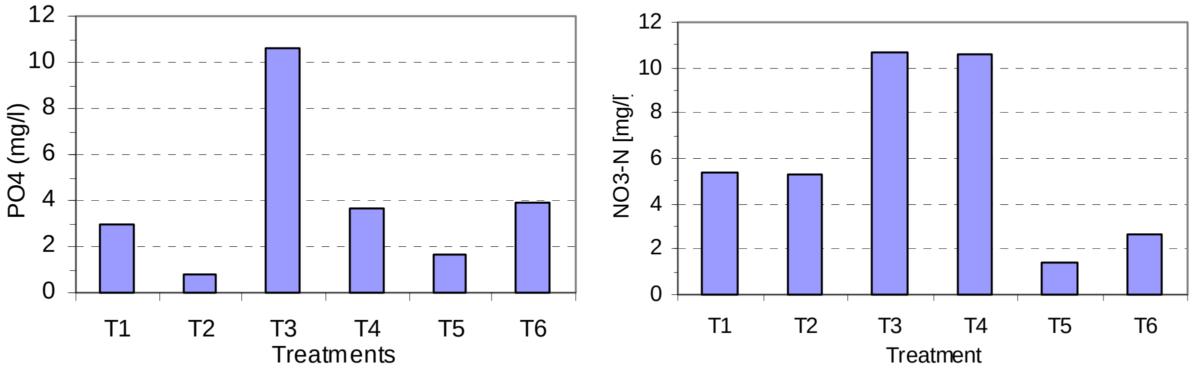


Figure 4. Effect of pelletized poultry manure on vadose zone water quality

Residual effect on the cover crop

Using wheat as a cover crop, the residual effect of previous application of pelletized poultry manure was analyzed. In the following spring, a comparative study was done on the basis of soil quality (nutrient content) and wheat biomass production. In most of the cases, the soil analysis for orthophosphate and dry weight biomass of wheat crop indicates that the higher rate of pelletized poultry manure application in combination with mineral fertilizer resulted in the higher accumulation of phosphate as well as higher cover crop dry weight yield (Figure 5). This confirms that pelletized poultry manure releases nutrient slowly through mineralization which will be available for the following cropping season. The available phosphate is positively correlated with the dry weight biomass (Figure 6). Over all results show that the highest crop biomass on dry weight basis was harvested from the soil amended with the highest rate of pelletized poultry manure. As indicated in Figure 5 right, the lowest dry biomass yield of the cover crop was observed in the soil plots that were amended with no pelletized poultry manure. This confirms that mineral fertilizer has limited residual effect, where as pelletized poultry manure can positively affect the crop dry biomass yield of the following crop.

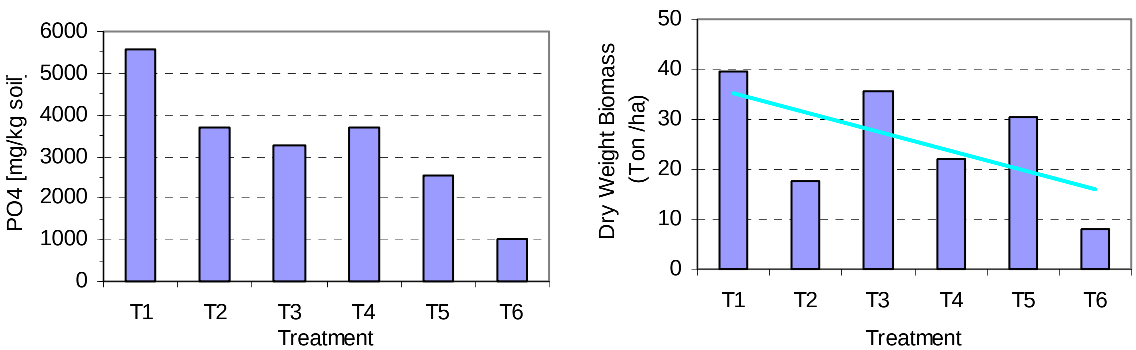


Figure 5. Residual effect of pelletized poultry manure application on the wheat as a cover crop

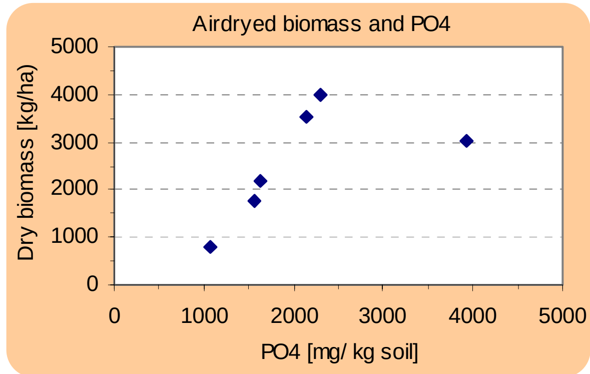
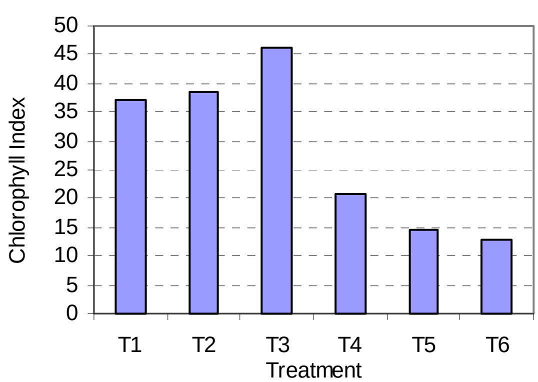


Figure 6. Correlation of cover crop dry biomass and accumulated phosphate in soil

Experiment 2

In the second experiment (Table 1, 2nd column), the rate of poultry manure was increased by 25% while the rate of mineral fertilizer was kept the same as the previous experiment, Experiment 1. The impact of such change of rate of pelletized poultry manure on the soil and water quality and crop biomass yield was analyzed (Figure 7). The results show that high rate of pelletized poultry manure together with mineral fertilizer has resulted in higher chlorophyll index as well as dry weight biomass of sweet corn as compared to pelletized poultry manure alone. However, there is no significant difference between higher rate and lower rate of poultry manure when it is supplemented by mineral fertilizer (see Figure 7, T1 –T3). This might be due to the fact that mineral fertilizer has dominated the effect, and therefore it must be applied in lower rate than what was applied in this study.

Without mineral fertilizer, however higher rate of pelletized poultry manure has resulted in higher crop dry weight biomass as well as chlorophyll index. Chlorophyll index is the surrogate measure of soil fertility, especially for N requirement of the crop. Therefore, higher pelletized poultry manure in the soil has resulted in darker green crop leaves or higher chlorophyll index which is strongly correlated (r^2 >0.91) to both fresh weight and dry weight biomass (Figure 8). The result shows that dry weight biomass is more strongly correlated to the chlorophyll index than wet weight.



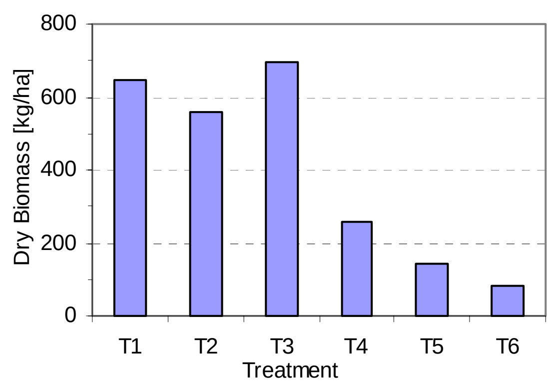


Figure 7. Impact of increased rate of poultry manure on the chlorophyll index and dry weight biomass of sweet corn

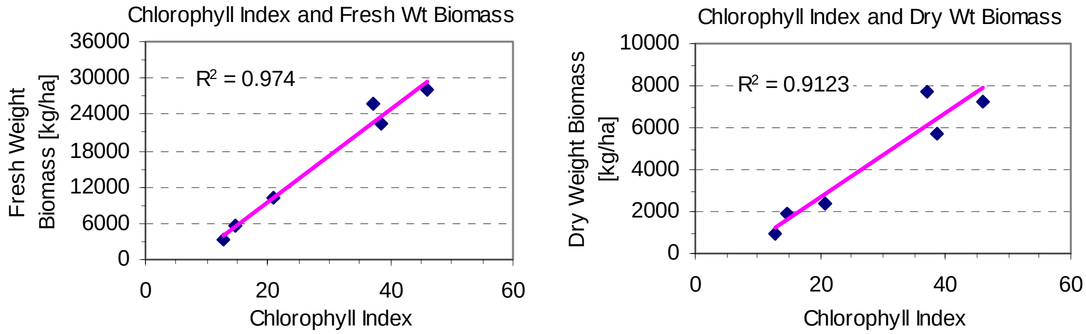


Figure 8. Correlation of chlorophyll index and sweet corn biomass

CONCLUSIONS

The effect of pelletized poultry manure on the crop biomass production and vadose water quality was analyzed on the basis of data gathered for two consecutive years. From the results presented we conclude the followings:

- Pelletized poultry manure has significant positive effect on the crop biomass yield when applied at 1000-2500 kg/ha;
- As it is processed at 70°C, pelletized poultry manure has no risk for the potential contamination of ground water with fecal coliforms;
- Higher rate of pelletized poultry manure in combination with mineral fertilizer may affect the receiving water quality via leaching for nitrate and runoff for phosphate, and therefore appropriate rate of application must be determined;
- Results of these field studies confirm that pelletized poultry manure can be an effective nutrient source for corn production;
- If managed with inorganic fertilizer a manner that will minimize nitrate leaching and prevent P accumulation in soils, pelletized poultry manure can be an effective and pathogen free organic fertilizer available in the market to be widely applied for crop biomass production, which then enhances biofuel production.

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