Using Geostatistics to Determine Spatial Variability of Nutrients Within a Poultry House

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Manure nutrient management calls for sampling poultry litter prior to field applications. The new Confined Animal Feeding Operations (CAFO) rules propose broiler (meat-type chicken) house sampling guidelines to derive nutrient load values, which may be used to determine fertilizer application rates or nutrient accountability upon litter transfer to a third party. Unanswered questions remain such as: how best to perform sampling of litter within the house, what is representative data, and how many samples are needed? Developing better sampling techniques may provide needed information for implementing sound manure management practices.

Numerous studies, that primarily report averages and ranges of nutrient composition, have addressed nutrient availability in poultry litter (Smith et. al., 1994, Chamblee and Todd, 2002, Bitzer and Sims, 1988, Gordillo and Cabrera, 1997 and Westerman et al., 1988). One study was conducted to determine the difference between cake litter and non-caked litter. This study found that caked litter was higher in moisture and metals; however the nutrient value was similar (Sistani et al., 2001). Also, Cabrerra et al. (1994) determined the nutrient content based on particle size of the litter and found higher mineralizable N in smaller litter fractions. These studies are important for nutrient management plans, but there have been no studies determining the spatial variability of nutrient concentration within a poultry house.

Poultry litter composition can vary significantly within poultry houses.

The advantages of deriving estimates and developing contour plots of nutrient concentration within a poultry house are numerous. The contour plots can be developed based on geostatistical methods like kriging. It is an interpolation technique based on the generalized least square method, which uses the variogram as a weighting function. This technique has the potential to serve as a powerful tool to determine variability within the sampling area and visually and mathematically determine interactions of the variables. Geostatistical techniques like cross variogram/co-kriging analysis may also allow better understanding of the interaction between multi-factors like chemical and physical properties of the litter that lead to ammonia volatilization, pathogen survival and nutrient accumulation. If consistent patterns are observed within poultry houses, best management practices may be targeted to minimize the potential for negative impacts.

Collection and Analysis of Litter

This research was conducted during summer on a tunnel ventilated working poultry house that was 146 m by 12.8 m. Prior to sampling, the litter had twenty-eight flocks of chickens raised with decaking between each flock. The poultry house litter was grid sampled on the day the house was restocked (day 1), and later on day 21; however, only day 1 data will be presented. The sampling was conducted on a grid at 5 m across the house and 12 m down the house for a total of 36 sampling points. The litter was collected and transported to the laboratory where it was analyzed for pH, moisture, total nitrogen, water extractable nitrate, ammonium and phosphorus. Water extractable P and N species were analyzed with a Lachat Flow Injection Analysis instrument. The total N was determined using the Kjeldahl Method. The moisture was determined by oven drying for 48 hours at 65 ^{o}C. The pH was measured in a litter:deionized water (1:5) solution using a pH electrode. Within the house the following parameters were measured: litter temperature at sampling times, ammonia (NH_3), methane, NO_3, CO_2 fluxes. Gas fluxes were determined using an INNOVA photoacoustic analyzer. All of the data were plotted using Surfer 8.0 by Golden Software.

Pooled Results of the Analysis

Pooled statistics of measured variables of chicken litter are listed in Table 1. The average values of the given variables are within ranges listed by other researchers. However, the maximum nitrate-N concentration appeared to be higher than reported.

Table 1. Pooled sample poultry litter measurements and analysis.

Variables	Average	Standard Deviation	Minimum	Maximum
pH	8.1	0.3	7.6	8.6
Moisture (%)	23.1	5.1	16.8	39.6
	------------------------ g kg^{-1}	----------------------------		
Nitrate-N*	0.12	0.15	0.02	0.46
Ammonium-N*	6.24	1.24	4.20	8.47
Phosphorus*	1.36	0.19	1.03	1.71
Total N**	45.3	5.0	35.5	52.2

* - Water extractable
** - Total N determined by Kjeldahl method

The graphical display of the chicken litter variables showed a non-symmetric distribution. Therefore, all variables were transformed to normal distribution before applying geostatistical techniques, a pre-requisite for geostatistic analysis.

Geostatisical Estimates and Contour Plots

The contour plots of different chicken litter variables illustrate the spatial differences within the poultry house. The spatial variability of some variables may be controlled by some fundamental parameters. As seen in Figure 1, the pH is approximately 1 pH unit lower in the brood end of the house than the non-brood end of the house. After interviewing the producer, it was determined that an intermittent litter treatment was used to decrease ammonia volatilization within the poultry house; however, no litter treatment was used immediately prior to or during this sampling. The poultry litter treatment lowered the pH, which in turn, generally caused higher values for ammonium (NH_4^+) and TKN in the brood end on the house (Figure 1).

The spatial distribution of NH_4, total-N, NO_3-N and NH_3-flux concentration showed a consistent pattern across the poultry house and a negative pattern as compared to spatial distribution of pH values (Figure 1 & 2). However, the range of pH values are not broad enough to draw a cause-effect conclusion. The spatial distribution maps of NH_4, total-N, NO_3-N and NH_3-flux showed a relatively consistent positive pattern with the soil moisture map (Figure 2). This also indicates that areas of high moisture may be more prone to ammonia volatilization, suggesting a better and uniform ventilation of chicken litter house or application of clay-based products in the area(s) of high moisture that absorb odors and reduce ammonia release by absorbing moisture.

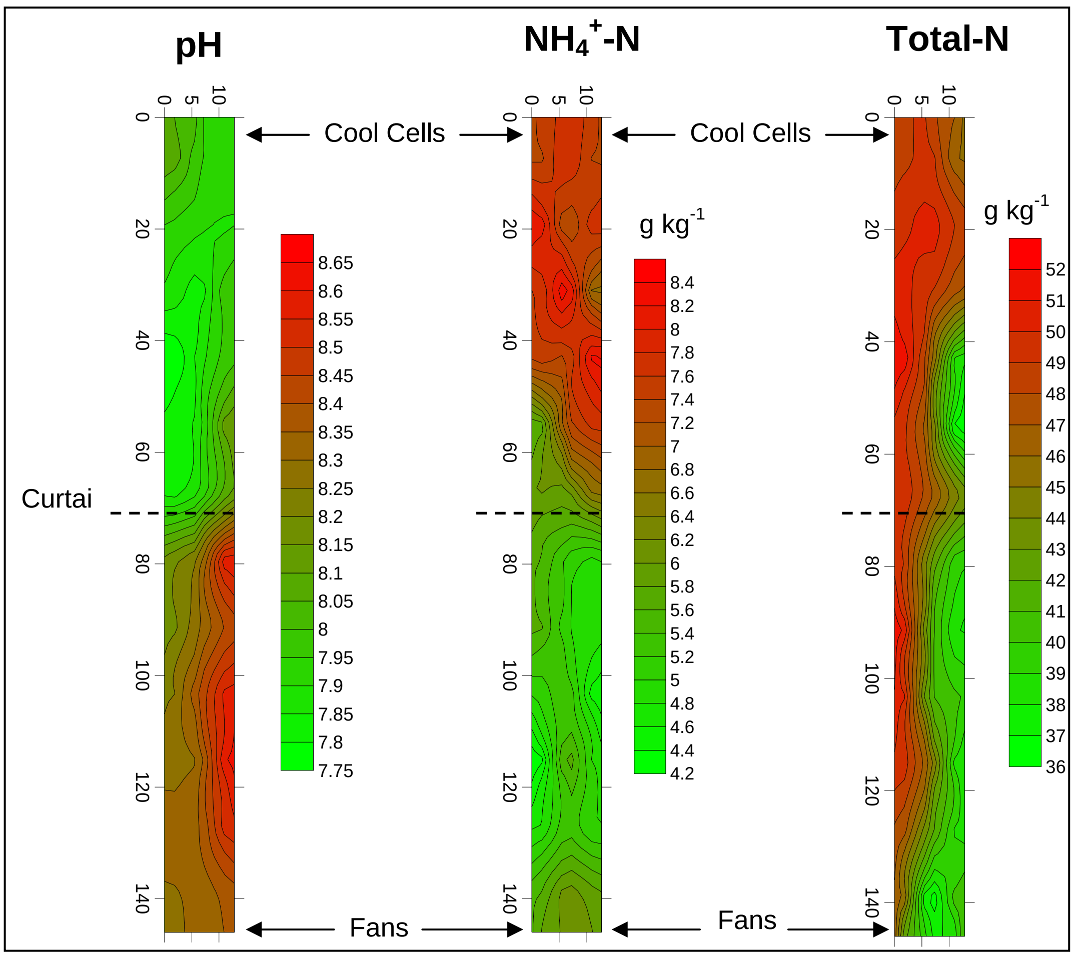

Figure 1. Plan view of the poultry house illustrating spatial distribution of nutrient concentration related to pH.

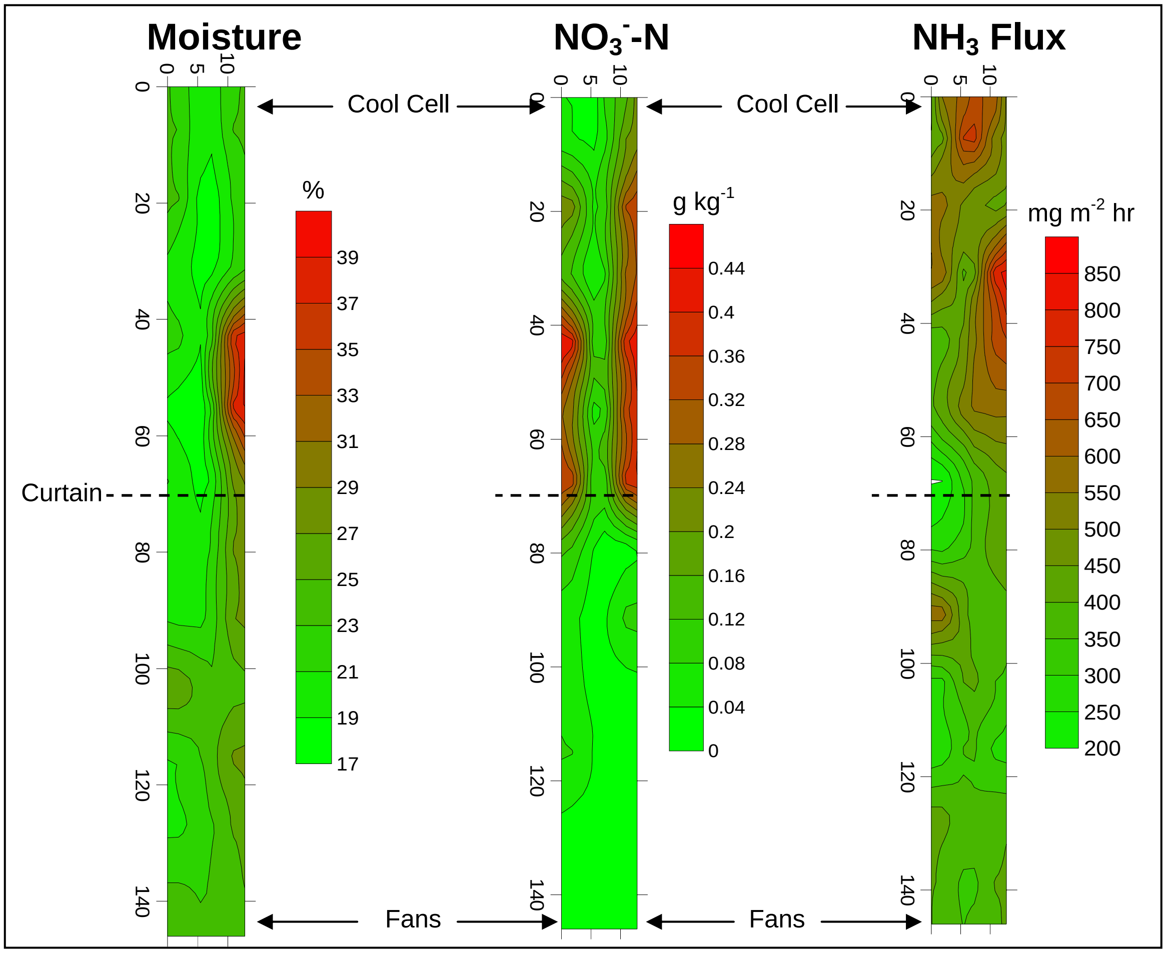

Figure 2. Plan view of the poultry house illustrating spatial distribution of nitrate concentration and ammonia flux related to moisture.

Conclusions

Data from pooled samples yielded values that were within ranges reported in other studies; however, the contour plots illustrated problems associated with characterizing nutrient concentration variability in broiler litter. The method of sampling this house could dramatically affect the outcome of the nutrient analysis and land application. The geostatistical estimates and contour plots may allow determination of multi-factor chemical and physical properties of the litter that lead to ammonia volatilization, pathogen survival and nutrient accumulation. If consistent patterns are observed within poultry houses, best management practices can be established to minimize the potential for negative impacts.

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