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Composition of Poultry Litter in Southern Brazil

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ABSTRACT: Determining the chemical composition of poultry litter is important in order to apply this waste as soil fertilizer without causing negative environmental impacts. The aim of this study was to evaluate the average and variability of some chemical parameters of 165 samples of poultry litter produced from confined animal production facilities located in the states of Santa Catarina and Rio Grande do Sul, Southern of Brazil. Samples of approximately 5.0 L were collected on 20 points from the truck at the time the material was unloaded into the application sites. Subsequently, they were oven-dried at 65 °C and analyzed. Values of pH in water, dry matter, N, P and K were determined in all samples; N soluble in water (soluble-N), ammonium (NH_4^+-N) and nitrate (NO_3^--N) were quantified in 50 samples; organic carbon (organic-C) and C/N ratio were assessed in 20 samples. There was large variation in the contents of N, P_2O_5 and K_2O among samples, with the average accounting for 2.2, 3.0 and 2.9 %, respectively; these nutrients correlated with each other. More than 90 % of the N was in the organic form, into which the fraction soluble in water accounted for 21.8 % of the total. Inorganic N was predominantly in the form of ammonium (NH_4^+-N), and nitrate (NO_3^--N) was absent. Average dry matter was 64.3 %, with a median of 66.5 %; pH was always alkaline (average of 7.8), with a low variation coefficient (7.4 %), and was negatively correlated with NH_4^+-N. The average of organic C and C/N ratio in dry matter was 28.3 % and 11.2, respectively, which results in the immediate release of N to the soil, with no microorganism immobilization. The chemical composition of poultry litters produced in confined systems in Southern Brazil is widely variable. Thus, to be successfully used as soil fertilizer, it is essential to know their composition, mainly in terms of moisture N, P_2O_5 and K_2O contents.

Keywords: animal waste, fertilizer, organic nitrogen.

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INTRODUCTION

Animal wastes have been used as soil fertilizers since primitive agriculture. Nowadays, the total confining poultry production yields large amounts of litter in small areas. Thus, poultry litter use as plant nutrients becomes an interesting economic alternative for partial replenishment of mineral fertilizers in the nearby croplands (Bolan et al., 2010; Lourenço et al., 2013). On the other hand, the indiscriminate disposal of this residue with no technical support may cause environmental pollution, especially to groundwater and rivers (Cox et al., 2013).

Brazil is the third major exporter of poultry meat. In 2012, 5.5 billion birds were produced (IBGE, 2013). Considering that each bird produces an average of 1.8 kg of waste, approximately 10 Mg yr^{-1} of poultry litter is generated. The poultry-confined system in Brazil produces between five and six flocks of animals over the same bed (Ávila et al., 2008). Thus, considering the contents of N, P and K in this material and the fact that all of the waste produced would be applied to the soil, it would supply 9.6, 8.5 and 5.8 %, respectively, of the Brazilian annual demand for 2011 (ANDA, 2012).

In contrast to mineral fertilizers, which have a defined chemical composition, the amount of nutrients in poultry litter is widely variable. Thus, it is difficult to determine the adequate rate to be applied to soil to meet plant requirements. Its chemical composition is affected by many factors such as: animal category (meat or egg production), feed composition and degree of spills, kind and amount of material used for bedding, animal density in the poultry house, length of residency of animals in the house, season of the year, and method and length of stocking (Tasistro et al., 2004; Dao and Zhang, 2007; Ávila et al., 2008).

When poultry litter is used as soil fertilizer in Southern Brazil, rates suggested are based on the mean macronutrient concentration, which is estimated taking into consideration the animal category and the number of lots grown on the same bed (CQFSRS/SC, 2004). However, the chemical composition is widely variable, and rates recommended to supply crop needs are not always corroborated by field studies (Ávila et al., 2008; Scherer and Nesi, 2009). Thus, laboratory analysis of the material must be performed to ensure the use of an adequate amount to optimize nutrient use efficiency by the plants.

The knowledge of poultry litter chemical composition is fundamental for the adequate supply of their nutrients to plants, in order to minimize the costs and the negative environmental impacts (Gordon et al., 2014; Sena Jr. et al., 2014). The objective of this study was to evaluate the composition with emphasis on the chemical part, in many poultry litter sources that are sold in the states of Rio Grande do Sul and Santa Catarina, Southern Brazil.

MATERIALS AND METHODS

A total of 165 poultry litter samples each from a barn of more than thirty poultry confined producing properties were collected at the time that the waste was unloaded to be used as soil fertilizer in apple orchards located in the municipality of Vacaria, RS. Each sample had 20 subsamples collected from different parts of the pile from each unloaded truck containing approximately 20 m^3. The litter was mainly a mixture of bed, constituted by dust wood or rice husks, and rests of poultry feed and excreta.

In the laboratory, samples were oven dried at temperature of 65 °C and sieved to pass in a 0.5 mm sieve. Dry mass, pH, and total amounts of N, P and K were determined in all samples. Ammonium (NH_4^+-N), nitrate (NO_3^--N), and water soluble N were determined in 50 samples; and organic C was determined in 20 samples.

Dry mass was quantified by weight difference between wet and oven dried samples. The concentration of N, P and K was measured after sample wet digestion, performed by using sulfuric acid and hydrogen peroxide according to Tedesco et al. (1995). Nitrogen was determined by acid titration after steam distillation in semi-micro-Kjeldahl equipment; emission spectroscopy was used for K, and P was determined by colorimetry according to the method described by Murphy and Riley (1962). For the quantification of ammonium (NH_4^+-N), nitrate (NO_3^--N) and water soluble N (N-sol. H_2O), 2.0 g of poultry litter sample was suspended in 100 mL of distilled water, which was sequentially shaken for 5 min in a horizontal shaker followed by 12 h of rest. Then, an aliquot of 20 mL was distilled to get the amounts of ammonium and nitrate, using 0.2 g of MgO and 0.2 g of Devarda's alloy, respectively. An aliquot of 10 mL was used to determine water soluble N, by the same procedure described previously to quantify total N. Organic soluble N was calculated by subtracting the amount of mineral N (NH_4^+-N + NO_3^--N) from the water soluble N. The pH was determined using water as a solvent, in a solution/sample ratio of 20/1. Organic C was determined with chromic acid solution according to Walkley and Black (1934).

The data were analyzed using the following statistical descriptive parameters: amplitude, central tendency and dispersion. In addition, linear Pearson correlation coefficients among parameters were tested.

RESULTS AND DISCUSSION

The dry matter content of the poultry litter averaged across all samples was 64.3 %, the median was 66.5 % and the coefficient of variation (CV) was 17.2 % (Table 1). The water content of the poultry waste depends on the hygroscopic capacity of the organic materials used in the beds, on the animal sanity, season of the year, and management of the birds in the barn, mainly related to the kind and position of drinkers and the ventilation system. The large amount of moisture in some samples suggests that they were exposed to rainwater before to be transported to the orchards. Since the price of this waste is quantified by volume rather than weight, it is improbable that they intentionally received water.

Poultry litter samples presented large variation in their chemical composition (Table 1). The averages for total N, P_2O_5 and K_2O were 2.2, 3.0 and 2.9 %, respectively, with CV of 29.0, 25.7 and 32.7 %, respectively. The composition of this waste depends on many factors including the lots of animals grown in the same bed since poultry reared for meat release approximately 55 % of the N, 70 % of the P and 80 % of the K ingested in their diet (Bolan et al., 2010). Thus, an increase in the number of lots grown over the same bed promotes a proportional increase of nutrients in the poultry litter (Ávila et al., 2008), mainly P and K, which are not lost to the environment in gaseous forms. However, the absolute amounts of nutrients existing in poultry litters varies between studies (Ávila et al., 2008; Scherer and Nesi, 2009), suggesting that the number of lots may not be a precise criterion with which to estimate the chemical composition of waste. We do not have information about the number of poultry lots grown on each material of our study, but we hypothesize that it is above three due to the cost of the material used for beds (Ávila et al., 2008). When we compared the average of nutrients in our samples, we found that they were lower than the values found in the official recommendations for Southern Brazil, especially for N. Averaged across all samples, the content of N was 2.2 % (Table 1), which is 30 % lower than the 3.2 % actually considered (CQFSRS/SC, 2004). In addition, half of our samples presented less than 2.0 % N.

The concentrations of N, P_2O_5 and K_2O in the poultry litter were always lower than 5.0 % (Table 1), which is small in comparison with those normally found in mineral fertilizers. Thus, in order to completely supply these nutrients to most plant species, it is necessary to add large amounts of this waste to the soil, which economically limits its use to those croplands which are close to the production sites, due to the cost of transportation.

Nitrogen in poultry litter is predominantly in the organic form (Table 1). Thus, microorganisms must decompose this fraction in order to release the N in a form that is available to plants. The water soluble N represented, on average, 32.3 % of the total N. This form corresponds to the fraction that is potentially available over a short period of time (Qafoku et al., 2001; Diaz et al., 2008) and is comprised of the mineral N (NH_4^+-N + NO_3^--N) plus the organic water soluble N. The amount of organic water soluble N represented 21.8 % of the total N, which is slightly lower than the values reported by Qafoku et al. (2001), which varied from 17 to 51 % for the same kind of waste.

The amount of ammonium (NH_4^+-N) in the poultry litter represented, on average, 9.6 % of the total N, which is equivalent to ⅓ of the total water soluble N (Table 1). The other water soluble-f N is mainly uric acid, which corresponds to 60 to 70 % of the N excreted by poultries (Nahm, 2003). Mowrer et al. (2013) determined the forms of N in 118 samples of poultry litter and found that uric acid and ammonium represented 9.4 and 17.4 %, respectively, of the total N. Significant amounts of ammonium may be lost from this kind of organic waste, mainly under high temperatures (Oliveira et al., 2003; Carvalho et al., 2011). Thus, drying the material before analysis, even at temperatures in the range of 40 to 60 °C, may result in significant losses of N as ammonia (Wood and Hall, 1991). Mosquera et al. (2008) found that drying the poultry litter at 250 °C decreased the N content by 20 %. Ghaly and Alhattab (2013) also found losses of 35 % of the total N, with 42 % of this being from the ammonium form, after drying the poultry manure at 60 °C. For this reason, NH_4^+-N must always be determined in the poultry litter samples before drying.

We have not shown the nitrate values (NO_3^--N) because they were too low, always less than 1 % of the total N. The small concentration of nitrate is probably due to the low availability of oxygen in the waste, resulting from the high activity of microorganisms. The absence of molecular oxygen stops the activity of ammonium nitrifying bacteria, which are obligatory aerobic, and favors losses of N by denitrification. Mowrer et al. (2013) also found small values of NO_3^--N in poultry litter samples, corresponding to 1.2 % of the total N.

The pH of the poultry litter was alkaline and presented the smallest CV among the evaluated chemical attributes (Table 1). Averaged across all samples, poultry litter presented pH 7.8 and CV of 7.4 %. Most of the samples presented pH higher than 7.0. These high pH values are due to many factors, including the dissociation of alkaline products present in the composition of the animal diet, which is spread out by the birds, the transformation of uric acid into urea (Nahm, 2003), as well as the use of calcium oxide during poultry house disinfection (Wolf et al., 2014).

Averaged across all poultry litter samples, organic C in the dry matter was 28.3 % and the C/N ratio was 11.2 (Table 1). The amplitude of these attributes varied, respectively, from 21.3 to 43.3 % and from 9.2 to 18.1. As a result of the high C contents and small C/N ratio, poultry litter is normally used for soil conditioning, as a substrate for composting, and as a source of N to crops because a C/N ratio smaller than 25 releases all its N in readily available forms, with no immobilization by microorganisms. The amount of C in poultry litters varies according to the material used for bedding, the number of flocks produced in the same bed, and the environmental conditions (temperature, moisture, ventilation, etc.), which affect the decomposition rate of the wastes in the barns. As the poultry grow, the amount of excreta over the bed increase and this promotes a decrease in the C/N ratio.

There was a moderate ($0.40 < r > 0.70$) to strong ($0.70 < r > 0.90$) positive correlation among the contents of N, P_2O_5 and K_2O in the poultry litter, suggesting that these nutrients are accumulated to a similar degree in the residue (Table 2). On the other hand, the association between poultry litter dry matter and its chemical composition was weak ($r < 0.40$), mainly because the content of water in the waste depends on many factors, especially on the management of waste after its removal from the barns where it is normally stored in the open-air.

Table 1. Statistical analysis overview of chemical attributes from poultry litter samples(1)

	pH(H_2O)(2)	DM(3)	P_2O_5(4)	K_2O(4)	Total-N(4)	N-Sol. H_2O(5)	NH_4-N(6)	Org-C(7)	C:N(8)
					%				
Mean	7.8	64	3.0	2.9	2.2	32.3	9.6	28.3	11.2
Median	8.0	66	3.0	2.8	2.0	29.2	7.5	29.0	11.7
Maximum	8.9	85	4.9	4.6	4.4	60.9	20.3	43.3	18.1
Minimum	6.0	34	1.0	0.7	1.1	11.8	1.2	21.3	9.2
CV (%)	7.4	17	26	33	29	42	106	20	13

(1) n = 165 for DM, N, P_2O_5 and K_2O; n = 50 for pH, N-sol. H_2O and NH_4-N; n = 20 for org-C; (2) pH determined in a water/waste ratio of 20:1; (3) DM = dry matter, obtained by difference between moist weight and dry weight at 65 °C; (4) Determined after sulfuric digestion (Tedesco et al., 1995); (5) N water soluble relatively to the total N; (6) N in the ammonium form relatively to the total N; (7) organic C determined by moist oxidation (Tedesco et al., 1995); (8) ratio between organic C and total N; CV: coefficient of variation.

Table 2. Pearson correlation coefficients (r) between chemical attributes from poultry litter samples(1)

	N	P_2O_5	K_2O	NH_4-N	N-sol. H_2O	pH(H_2O)
DM	0.38^{*}	0.22^{*}	0.19^{ns}	-0.21^{ns}	0.08^{ns}	-0.03^{ns}
N		0.52^{*}	0.74^{**}	0.25^{ns}	0.45^{**}	-0.33^{*}
P_2O_5			0.58^{**}	0.21^{ns}	0.46^{**}	-0.13^{ns}
K_2O				0.24^{ns}	0.37^{**}	-0.25^{ns}
NH_4-N					0.77^{**}	-0.80^{**}
N-sol. H_2O						-0.62^{**}

(1) n= 165 for N, P_2O_5 and K_2O; n=50 for pH, N-sol. H_2O and NH_4-N. ^{ns}: not significant; ** and *: significant at 1 and 5 % of probability by the t test, respectively.

There was a positive correlation between the contents of NH_4^+-N and water soluble N, especially because NH_4^+-N is part of the water soluble N. On the other hand, there was a negative correlation between these two N forms and the pH of the poultry litter (Table 2), which may be a result of ammonia volatilization losses caused by the increase in the waste pH (Oliveira et al., 2003; Carvalho et al., 2011). Thus, the addition of calcium oxide, which is normally used to disinfect poultry barns (Wolf et al., 2014), may decrease the fertilizer value of the organic waste by decreasing the amount of NH_4^+-N that is readily available to the plants.

CONCLUSIONS

Samples of poultry litter from more than 30 confined systems in the states of Rio Grande do Sul and Santa Catarina presented large physico-chemical variability. The mean dry matter was 64 % and the averages for total N, P_2O_5, and K_2O (dry base) were 2.2, 3.0 and 2.9 %, respectively.

More than 90 % of the N in the poultry litter is in the organic fraction, which must be mineralized to become available to plants.

Due to the natural variability of the poultry litters, it is wise to determine their moisture and contents of N, P_2O_5 and K_2O to ensure adequate use as soil fertilizer with no risk of environmental pollution.

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