VARIABILITY OF MANURE NUTRIENT CONTENT AND IMPLICATIONS FOR MANURE SAMPLING PROTOCOL

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ABSTRACT

The variability of manure nutrient levels within and across farms makes manure sampling and development of reliable tabular values challenging. The chemical characteristics of beef, dairy, horse, sheep, and chicken solid manures in Colorado were evaluated by sampling six to ten different livestock operations for each manure type and comparing the results to values found in the literature. Due to the semi-arid climate of Colorado, manure tends to be drier and have lower ammonium (NH_4-N) levels and higher phosphate (P_2O_5) and potash (K_2O) levels than those reported in the Midwest. Within-farm variability was assessed by analyzing ten sub-samples from each manure source. Coefficients of variation were calculated, and the sample numbers necessary to achieve 10% probable error were determined. On average, about 25 sub-samples are necessary for N, P, and K characterization of solid manures, but determining NH_4-N and nitrate (NO_3-N) concentrations requires over 100 sub-samples to form a representative sample, due to their relatively low concentrations. Until we have adequate sample numbers (>72 farms per manure type) to establish reliable table values based on local data, manure sampling will continue to be recommended.

INTRODUCTION

Land-grant universities throughout the United States recommend that livestock producers sample and analyze animal manure to determine its nutrient content prior to land application. Nutrient management recommendations are dependent on accurate manure nutrient information. Many universities provide table values for use when producers do not have good analyses of their own. However, table values commonly used today are 25 - 30 years old and have been re-published so often, that it is often difficult to ascertain their original source (Rieck-Hinz et al., 1996). Few livestock producers actually do site-specific manure sampling, which has led us to question the rationale behind manure sampling.

Several questions regarding the effectiveness of manure sampling and the use of table values need to be addressed. First, how variable are nutrient contents in manures? How many sub-samples would be required to achieve a representative sample? Can table values provide reasonable estimates when producers do not have analyses from their own operations?

Manure nutrient content is known to be variable (Rieck-Hinz et al., 1996), but the implications of that variability for sampling protocols have not been defined, except in a paper by Dou et al. (2001). Dou et al. (2001) collected serial samples from dairy, swine, and broiler poultry operations when manure was being loaded for field application. They found that when agitation took place prior to loading, coefficients of variation (CVs) were 6 - 8% within farm, and three to five sub-samples were adequate for a representative composite sample. When no agitation was used, CVs ranged from 20 - 30%, and at least 40 sub-samples were required. Dou et al. (2001) concluded that table values were problematic due to the variability of on-farm data.

There is a lack of quantitative information on proper manure sampling procedures and little understanding of the variability that exists. With this in mind, we conducted this study with the following objectives:

1. To measure the variability within stockpiles of various animal manures and determine the number of sub-samples needed to characterize the nutrient content within a 10% probable error, and
2. To compare Colorado manure analyses to the table values we have been using in our publications, which come from Midwestern data.

MATERIALS AND METHODS

This study has been published previously by Davis et al. (2002).

Within-stockpile Variability and Sub-sample Requirements

Ten sub-samples (approximately 0.5 qt each) from each of five manure stockpiles (beef, dairy, horse, sheep, and chicken) were collected in 1996. Each stockpile was sampled from a different farm. Two samples were taken from the top and two from each side of each stockpile (north, south, east, and west). For each pair of samples, one was taken shallowly (1 ft), and one was taken more deeply (3 ft). For the side samples, one of each sample pair was taken from the middle and one from near the bottom of the stockpile. Each sub-sample was analyzed separately for dry matter (D.M.), total nitrogen (N), ammonium (NH_4-N), nitrate (NO_3-N), phosphorus (P), and potassium (K) to determine the variability within the pile or lagoon. Collected data and equation 1 from Upchurch et al. (1988) and Davis et al. (1995) were used to determine the number of sub-samples needed (N_{est}).

$$N_{est} = t^2 CV^2 / p^2 \qquad [\ 1\ ]$$

where t is Student's t value for a specified probability (in this case, for a 95% confidence interval), CV is the coefficient of variation, and p is a percent probable error (in this case, 10%).

Comparison to Midwestern Table Values

Beef, dairy, horse, sheep, and chicken manures were sampled in 1996. Six to ten different livestock operations were sampled for each manure type. Each sample was a composite of six 0.5 qt sub-samples taken from different locations and depths within the stockpile. The D.M., total-N, NH_4, P_2O_5, and K_2O values measured in these samples and manure sample means from each farm tested in the within-stockpile variability experiment were combined into a database. Results were compared to values previously used in Colorado extension publications (Waskom, 1994), which came from Midwestern manure samples (Loudon, 1985).

RESULTS AND DISCUSSION

Within-stockpile Variability and Sub-sample Requirements

The variability of samples within a manure stockpile or lagoon differed for the various constituents. Ammonium and nitrate had the greatest coefficients of variation due to their relatively low concentrations. The greater the coefficients of variation, the greater the number of sub-samples required for useful analysis (Table 1). For example, to achieve probable error within 10% for a beef manure stockpile, one would need 17 sub-samples to characterize total N, 20 sub-samples for P, 32 for K, 121 for NH_4-N, and 692 sub-samples for NO_3-N·

For solid manures, it seems possible to estimate the total N, P, and K in a stockpile within 10% probable error with a moderately intensive sampling plan (collecting 21-27 sub-samples and combining them to form one composite sample). However, to characterize the NH_4-N and NO_3-N levels in order to predict N availability to crops, the required sub-sample number becomes impractical (> 100). Rieck-Hinz et al. (1996) used four sub-samples per farm in their study, and Dou et al. (2001) suggested a minimum of 40 sub-samples for unagitated manures.

In addition to CVs, another measure of similarity is the confidence interval (C.I.), which is a measure of the probability that a sample will fall within an upper and lower limit. For the one case in which we had over 100 samples (solid beef manure), the 90% C.I.s were quite narrow. For example, the mean total N content was 23 lb/ton, with a C.I. of 21 - 24 lb/ton. We can interpret this to mean that nine out of ten beef manure stockpiles will have a N content between 21 and 24 lb/ton.

Rieck-Hinz et al. (1996) created a database for a sub-region of Iowa with 14 farms. Based on our information, we recommend a minimum of 25 farms for manure database creation in the Mountain West in order to achieve 90% C.I. ranges of 10% D.M. and 10 lb/ton for the nutrients. Including 72 farms in each database (for each manure type) would reduce the ranges in the 90% C.I.s to 5% D.M. and 5 lb/ton for each of the nutrients.

Comparison to Midwestern Table Values

The solid manures sampled from Colorado operations differed in comparison with those we previously used in our extension publications (Waskom, 1994), which originated from sources in the Midwest (Loudon, 1985). The dry matter contents of the Colorado manures were consistently higher than those reported from the Midwest (Table 2). On a wet weight or "as is" basis, the Colorado manures had higher total N contents in four out of five cases. Ammonium (NH_4-N) was lower in all of the Colorado manures on a wet weight basis. Colorado P_2O_5 and K_2O contents were higher than Midwestern data for all manure types, when evaluated on a wet weight basis.

The semi-arid and windy climate of Colorado probably leads to greater evaporation of water and volatilization of NH_3° from manure stockpiles, resulting in the higher dry matter values and lower contents of NH_4-N in all of the manures. Phosphate and K_2O contents are probably greater in Colorado manures because of the concentration effect from the greater loss of water. This concentration effect also occurs with organic N, causing the increase in total N content in most of the manures.

SUMMARY AND CONCLUSIONS

- Average dry matter contents varied from 0.54 to 0.78 among manure types. Nutrient contents also varied among manure types; within types there were large ranges in concentrations.
- Twenty to thirty subsamples are required to characterize a manure stockpile, within 10% error, for total N, P, and K.
- To characterize NH_4 or NO_3 would require hundreds of subsamples and is impractical.
- Colorado manure stockpiles were drier than the Midwest manures that we have used for our extension recommendations. Colorado manures had much lower ammonium contents. On a fresh-weight basis, Colorado manures contained higher levels of P and K; most Colorado manure types contained slightly higher levels of total N. Therefore, we have updated our extension publications appropriately (Waskom and Davis, 1999).

- We challenge the common practice of separating organic and inorganic N forms for prediction of mineralization rates due to the large variability in NH_4 levels and the very low NH_4 contents. Based on our limited dataset, it appears that nutrient management planners will achieve greater accuracy in semi-arid areas using total N values alone for predictions of N availability to crops.
- We have developed a database of Colorado manures to assist growers who are not able to collect representative samples due to the cost of analyses, difficulty of sampling, and the large number of subsamples required. Using book values and regular soil testing may be the best management option for optimum crop production and environmental protection.

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Table 1. Number of sub-samples needed to characterize selected characteristics of Colorado animal manure stockpiles within 10% error at 95% confidence level.

Manure type	N	P	K	NH_4-N	NO_3-N	D.M.[1]
	-------------number of sub-samples needed------------					
Beef	17	20	32	121	692	3
Dairy	19	49	14	255	1914	22
Horse	17	11	14	211	802	12
Sheep	13	23	19	360	688	7
Chicken	55	31	27	443	147	43
Mean	**24**	**27**	**21**	**278**	**849**	**17**

[1] D.M. = dry matter

Table 2. Comparison of selected characteristics of solid animal manures from Colorado and the Midwest (wet weight basis).

Manure type	Source	n	D.M. [1]	Total N	NH_4-N	P_2O_5	K_2O
			--%--	------------------lb/ton------------------			
Beef	Colorado	11	68	23	3	24	41
	Midwest[2]		52	21	7	14	26
Dairy	Colorado	8	54	13	2	16	34
	Midwest		18	9	4	4	10
Horse	Colorado	9	78	19	1	14	36
	Midwest		46	14	4	4	14
Sheep	Colorado	9	69	29	2	26	38
	Midwest		28	18	5	11	26
Chicken	Colorado	9	60	30	8	64	39
	Midwest		45	33	26	48	34

[1] D.M. = dry matter.
[2] Midwestern values come from Loudon (1985).

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