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Manure Production, Analysis, and Estimates of Nutrient Excretion in Swine

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Background

Swine producers have modified feed formulations over the past decade in an effort to reduce feed costs and to reduce the quantity of nutrients excreted from swine enterprises. The two primary changes include:

1. The use of Phytase, which enhances the pig's utilization of phosphorus from feed grains and protein supplements. This reduces the need for supplemental, inorganic phosphorus and thus reduces the amount of phosphorus excreted from the pig by 20 to 25%.
2. Increased use of crystalline amino acids, which allows for a reduction in dietary protein. Traditionally, lysine-HCL and D,L Methionine were the only amino acids that could be economically added to the swine diet. Today, the relatively lower costs of other amino acids, such as threonine and tryptophan, have enabled their addition to swine diet formulations. The use of these amino acids can reduce the amount of nitrogen excreted by the pig by at least 20%.

Another change in swine production over the same 10-year time frame has been the adoption of water saving devices, which can reduce manure output (wash water and water waste included) by 20% or more. Note that a reduction in water waste has a direct effect on both manure solids content and nutrient concentrations.

The most recent characterization of the nutrient content of swine manure from Pennsylvania farms was in 1999 before Phytase or additional amino acids were widely used in swine diets (Kephart et al., 1999). The nutrient concentrations reported in that study are used in Table 1.2-13 of the Penn State Agronomy Guide (Beegle, 2007). In recent years, nutrient management planners have reported that the nutrients values for swine manure listed in the current Penn State Agronomy Guide are not in agreement with nutrient values determined by manure analysis. Furthermore, the estimation of total manure output and thus the estimated total nutrient output by pigs is subject to debate. An accurate assessment of manure nutrient concentrations and a reliable estimate of total manure output for various phases of production are warranted. From these two values we can estimate nutrient excretion for a given period of time. Nutrient management planners and reviewers alike can use this information to estimate the total quantity of nutrients excreted and thus verify the validity of values listed in proposed nutrient management plans.

Therefore the objectives of this study were as follows:

1. Determine the average concentration of selected nutrients in swine manure.
2. Estimate the volume of manure produced (including waste water) by pigs.
3. Calculate the quantity of nutrients excreted by pigs per unit of time.

Procedures

Three commercial manure haulers were identified to assist in the collection of swine manure samples from their clients during the spring and summer months of 2008. Haulers were instructed to collect samples during the first, middle, and the last third of the manure removal process and ship them in pre-paid mailers to the Penn State Agriculture Analytical Laboratory. A total of 63 samples were assayed for solids content, total nitrogen, ammonia nitrogen, organic nitrogen (by calculation), phosphorus (P_2O_5 equivalent), potassium (K_2O equivalent), and phosphorus source coefficient (PSC). Note the PSC is a relative measure of phosphorus availability in manure. The values from all samples from each respective phase of production were averaged for this report.

One commercial nutrient management planner also provided nutrient analysis records from 162 samples of swine manure. The analysis of these samples was performed by a commercial laboratory and included solids content, total nitrogen, ammonia nitrogen, phosphorus (P_2O_5 equivalent), and potassium (K_2O equivalent).

The averages from each respective phase of production were compared between the two groups of samples (those collected by the manure haulers and those collected by the nutrient management planner). For the farrow to wean, nursery, and grower finisher phases of production, the differences in nutrient values between the two data sets was less than 25%. Because of the relatively close agreement, farrow to wean, nursery, and grower finisher values from both data sets are included in this report. For the wean to finish phases of production, the difference between the two data sets was more than 100% for most of the nutrient values. Because of the poor agreement only data from the manure haulers are included in this report for the wean to finish phase of production.

Total manure output values for each phase of production were based on personal communication with two Pennsylvania integrated swine producers and Michael Brumm, a swine consultant based in Minnesota. Values are reported as gallons per head per day and gallons per Animal Unit (AU).

Total annual nutrient output for each phase of production was calculated by multiplying the estimated average annual production of manure times the average concentration of each respective nutrient, using the following formula:

$$\text{Annual Nutrient Excretion, lbs} = \frac{(\text{manure nutrient concentration, lbs}) \times (\text{manure production, gal/day}) \times (365 \text{ days/yr})}{1000 \text{ gal}}$$

Results

The average nutrient values are presented in Tables 1 through 4 for each respective phase of production. The estimated manure output values are presented in Table 5 and the estimated nutrient excretion values are presented in Table 6 for each respective phase of production.

Table 1: Nutrient concentrations of **farrow to wean** manure.

Variable	n	Mean	Std Dev	Minimum	Maximum
Solids, %	25	2.4	3.3	0.47	12.8
N, lbs/1000 gal	38	18	11.6	6.2	55.0
NH_4-H, lbs/1000 gal	37	13	5.6	5.2	26.3
Organic N, lbs/1000 gal	16	6	9.7	0.04	32.5
P_2O_5, lbs/1000 gal	38	18	30.3	1.3	143.4
K_2O, lbs/1000 gal	38	11	4.4	2.3	22.2
P source coefficient	16	0.82	0.24	0.32	1.00

Table 2: Nutrient concentrations of **swine wean-finish** manure.

Variable	n	Mean	Std Dev	Minimum	Maximum
Solids, %	17	4.2	2.3	1.4	9.5
N, lbs/1000 gal	17	37	9.9	20.2	60.1
NH_4-H, lbs/1000 gal	17	26	4.7	16.5	32.7
Organic N, lbs/1000 gal	17	11	7.9	0.8	30.8
P_2O_5, lbs/1000 gal	17	23	15.4	5.9	55.1
K_2O, lbs/1000 gal	17	21	3.8	14.0	27.5
P source coefficient	17	0.45	0.11	0.29	0.73

Table 3: Nutrient concentrations of **swine grow-finish** manure.

Variable	n	Mean	Std Dev	Minimum	Maximum
Solids, %	118	3.9	3.0	0.5	13.8
N, lbs/1000 gal	141	31	13.6	3.4	65.8
NH_4-H, lbs/1000 gal	140	23	8.8	2.0	53.1
Organic N, lbs/1000 gal	16	11	9.6	0.4	31.5
P_2O_5, lbs/1000 gal	142	24	20.0	1.1	94.3
K_2O, lbs/1000 gal	142	22	7.3	7.5	40.3
P source coefficient	16	0.67	0.27	0.27	1.00

Table 4: Nutrient concentrations of **swine nursery** manure.

Variable	n	Mean	Std Dev	Minimum	Maximum
Solids, %	16	1.4	1.0	0.6	4.0
N, lbs/1000 gal	18	19	9.5	9.5	42.2
NH_4-H, lbs/1000 gal	18	14	5.1	7.2	20.6
Organic N, lbs/1000 gal	14	6	6.0	2.1	21.7
P_2O_5, lbs/1000 gal	18	8	6.1	2.2	24.4
K_2O, lbs/1000 gal	18	14	5.8	7.8	28.4
P source coefficient	14	0.71	0.21	0.41	1.00

Table 5: Estimated manure production by swine in various phases of production.

	Manure Production		
Phase of Production	Gal/day	Gal/yr	Gal/AU/day[c]
Farrow to wean[a]	4.5 - 5.5	1600 - 2000	10 - 13
Nursery [b]	0.40 - 0.60	150 - 220	11 - 17
Grow finish [b]	1.0 - 1.2	370 - 440	6 - 8
Wean to finish [b]	0.7 - 0.9	260 – 330	5 - 6

[a] Gal/sow.
[b] Gal/pig.
[c] AU is an animal unit (1000 lb).

Table 6: Estimated annual nutrient excretion by swine in various phases of production.

	Nutrient Excretion[a]		
Phase of Production	N	P_2O_5	K_2O
Farrow to wean[b]	33	33	20
Wean to finish [c]	11	7	6
Grow finish [c]	12	10	9
Nursery [c]	3.5	1.5	2.6

[a] Calculated from the following formula:

$$\text{Nutrient Excretion} = \frac{(\text{manure nutrient concentration, lbs}) \times (\text{manure production, gal/day}) \times (365 \text{ days/yr})}{1000 \text{ gal}}$$

Note: Manure nutrient concentrations obtained in Tables 1-4; Manure production obtained in Table 5.

[b] lb/sow.
[c] lb/pig.

Discussion

The categories of production listed in Table 1.2-13 of the Penn State Agronomy Guide (Gestation, Lactation, Nursery, Grow-Finish, Farrow-to-Feeder) do not accurately reflect today's production or manure storage conditions. For example, manure in gestation and lactation is usually stored together. Today's farrowing operations generally do not

include a large-scale nursery as these pigs are generally raised off-site. Thus, the previous categories of farrow to feeder, gestation, and lactation have been collectively replaced with a single category – farrow to wean. Many of today's farrowing operations include a small number of replacement females that are kept onsite from the nursery through the finishing phases; the values in the present report do reflect the waste contributions of these replacement females. The other change in production since the previous report is the industry's adoption of wean to finish facilities; thus, we have included this new category in the present report.

The two phases of production common to both report is nursery and grow finish. For these phases of production, manure production values in the present report are similar to those of the previous report; however, the nutrient concentration values in the present report are roughly half of those reported previously.

Table 6 presents estimates of annual nutrient excretion for each phase of production. These values can be used as a guide for evaluating the validity of manure production and manure nutrient analyses in nutrient management plans. Reviewers can multiply the manure production values by the manure nutrient analyses to estimate nutrient excretion (over a given period of time); the result of that calculation should be within 25-35% of the values listed in Table 6.

References

Kephart, K., Berrang, B., Mikesell, R. 1999. Nutrient content of swine manure. Department of Dairy and Animal Science. Pennsylvania State University.

Beegle, D. B. 2007. Soil Fertility Management, In: Penn State Agronomy Guide. Crop Management Extension Group. College of Agricultural Sciences. Pennsylvania State University.