Revision of ASAE Standard D384.1: a new approach to estimating manure nutrients and characteristics

A.S. Leaflet R1923

Wendy J. Powers, Associate Professor of Animal Science

Summary and Implications
A nutritional approach to estimating manure excretions allows producers to evaluate the impact of dietary strategies in their operation; considering nutrients that will be land applied as well as those that may volatilize during storage. A national effort is nearing completion that will take a nutritional or mass-balance approach to estimating excretions by revising the current table values of manure composition and characteristics.

Introduction
Over-application of any source of fertilizer nutrients will likely promote losses that threaten environmental quality, especially with respect to water quality. For this reason, livestock producers are often held accountable for their manure nutrient production and utilization. In Iowa, accountability requires that a producer formulate a manure management plan. The plan includes number of animals to be produced, estimated nutrient excretion in manure, manure nutrients recovered and applied for fertilizer (based on manure analyses), and a plan to export nutrients off-farm if there is excess manure production relative to on-farm crop production needs. Actual farm data and analyses are necessary for accurate nutrient budgeting for that farm, however, published book values provide helpful estimates of manure nutrient excretions, nutrient losses, and crop removals to use in planning new facilities or until accurate farm data are generated. Most frequently, table values are used to estimate nutrient excretions. However, these values are often outdated, not representing modern animals and production practices, and do not allow for site-specific management practices to be incorporated. A mass balance approach that considers animal diet and performance, proven to be an accurate means of predicting manure excretion composition and quantity, offers the advantage of tailoring a plan to reflect individual farm characteristics of what is produced despite not reflecting nutrient transformations that occur post-excretion excretion.

A National Initiative to Update the ASAE Standard
For the past two years, agricultural engineers and animal scientists have been working together to update the current ASAE Standard D384.1 Manure Production and Characteristics such that it will reflect modern animals and production practices. This standard is widely used, nationwide, by regulators to estimate manure production and its composition. Recent environmental and regulatory emphasis on nutrient issues requires that this standard be useful in developing site-specific Comprehensive Nutrient Management Plans. A key component to such a plan is the integration of animal feeding practices into manure mass and nutrient excretion and reasonable estimates of nutrients removed from manure storages. The revised standard will take a nutritional approach to estimating manure production and characteristics such that excretions can be estimated on a site-by-site basis.

A joint Federation of Animal Science Societies (FASS) and ASAE committee was established in fall 2001. Overarching goals of the committee were identified:

- As Excreted - Feed Intake Summary: Characteristics of excreted manure will be defined based upon a mass balance approach using estimates of feed intake and animal retention and calculation of excretion by difference or other appropriate relationships.

- As Excreted – Average Summary: A review and modification of the existing ASAE D384.1 tables will define characteristics of excreted manure for typical feed programs.

- As Removed – Average Summary: An update or modification of MWPS-18 (Section 1; 2000) on Manure Characteristics will summarize typical manure characteristics as removed from common animal housing and manure storage systems.

Working groups were formed and involvement from additional scientists solicited. To date, over 30 scientists are involved in this activity with an anticipated completion and approval date of early 2004.

The Nutrition-Based Model Approach to Excretion Prediction
Manure is what is excreted in the form of urine and feces after the animal has digested and utilized all that it is going to from the ration provided, plus the endogenous losses from various metabolic processes. Knowing digestibility and, hence, indigestibility of the ration dry matter (DM) and organic matter (OM), plus quantity consumed, permits us to estimate the amounts of DM and OM excreted; components that determine manure volume.

If animals are consuming dietary nutrients at maintenance levels, e.g., N, P, and K, they will excrete, on-average over time, the same amount of N, P, and K they consumed except for small amounts of nutrients in shed hair and sloughed tissues that usually are collected with manure. When animals are accumulating N, P, and K in body weight gain, offspring, milk, eggs, or wool (products), the amount of those nutrients excreted in manure (feces plus urine) differ from what is fed by the amounts in products produced.

Thus, nutrient content of intake coupled with good estimates of the content of the same nutrients in food products leaving the farm permit accurate estimation of total nutrient excretions in feces plus urine by difference.

Table 1 presents a nutrition-based approach to estimating manure N, P, and K excretions based on ration content less amounts estimated to be in milk, eggs, or animal gain (from Powers and Van Horn, 2001). This table was derived from a spreadsheet-based model developed by Powers and Van Horn (2001) using a 'feed input minus excretion in product' approach. The rations shown in table 1 for the different food animal species, i.e., dry matter intake (DMI) and content of crude protein, phosphorus, and potassium, are representative of rations fed to these animals nationally to produce expected yields of milk, eggs, and body weight gain (kg/d) for dairy cows, hens, and beef steers and the gain/life cycle grow-out for broilers, turkeys, and pigs. Note that production units for hens in table 1 are per 1000 hens. Calculations within the table predict amounts consumed of N, P, and K, the amounts in exported food animal products such as milk, eggs and live animal gains, and, by difference, the amounts excreted in manure.

Variation in nutrient intake by animals is the most important single contributor to variation in nutrient excretions. Utilization of an input-output model as used in Table 1 adjusts for the variation in intake and the amounts of nutrients that are converted to the products produced. As an example, excretions by a dry cow and an early lactation cow producing 45 kg of milk per day varied from 4.5 kg to 9.8 kg of DM/d (DM equals total solids, TS), from .165 to .467 kg N/d, and from .046 to .094 kg P/d (Van Horn et al., 1994). These differences were expected and predictable based on ration parameters and performance. Although widely used excretion estimates such as *ASAE Standards* (1994) fall in the cited ranges, the estimates tend to be for average performance, are not farm specific, and do not provide a method for producers to evaluate consequences of overfeeding given nutrients.

Using nutrition based input-output methods to estimate solids and nutrient excretions when nutritional data are available eliminates most of the variation in estimated manure production found in the literature and the method permits calculating what the effects of dietary changes would be on excretions. Nutrition managers on large animal-food production units, who have computerized records of feed nutrient deliveries to animals, can provide key nutrient intake information to tailor nutrient excretion estimates to actual input-output data for a specific farm. Records of food product sales off-farm along with measured or estimated nutrient content of the products provide the other component needed to accurately estimate total manure nutrient excretions.

Pre- vs. Post-Excretion Composition
Nutrition based models predict the amounts of nutrients in fresh manure excretions more accurately than collections from animal pens because of the dynamic state of manure after excretion whereby losses of nutrients and manure volume occur. Using the input-output method to predict manure nutrient composition on a dry basis (Table 1) suggests that there is less variation in freshly excreted manure composition than usually reported in collected manures. It is much more difficult to predict either the amounts or the composition of manure that is recovered for use because of many differences from farm to farm in manure management procedures. Stored manure amounts and composition vary with manure handling system and housing. Feed and bedding spilled into the manure collection areas contribute to variability. Faulty watering facilities which drip or overflow dilute manure solids and nutrient content, as does moving manure from housing facilities to storage facilities by flushing alleys with water. Nutrient losses occur during manure storage and treatment, especially volatilization of ammonia and the amount volatilized varies with type of storage (covered vs. uncovered, stirred) and pH. Manure mineral content will vary in response to dietary inputs as well. Macro- and micro-mineral contents of manures reflect the dietary levels of these elements.

Advantages of the Input-Output Model
The major advantage of showing that manure nutrient production is a function of ration and performance (Table 1) is that it is easy to visualize the importance of ration management to minimize excretions. For example, supplementation of limiting amino acids permits reduction of total dietary protein and, hence, reduces excretion of N. For every percentage unit that dietary protein can be reduced, Table 1 calculations predict that excretion of N by different species would be reduced by 8 to 10% (average of 8.5%) which would reduce manure N to manage. Reducing dietary crude protein percentage (CP) for dairy cows from 18 to 15 to 12% reduced urinary N excretion from 228 to 138 to 99 g/d while fecal N was reduced from 199 to 179 to 158 g/d (Tomlinson et al., 1996). By reducing urea (urinary) excretion, the percentage of excreted N lost to ammonia volatilization also will be reduced.

Surveys indicate that dairy and beef producers usually feed more dietary P than animals require and, thus, excretions can be reduced by dietary reduction. For example, if ration P as percent of dry matter were reduced 0.1% in all rations in table 1, a 12-25% relative reduction in ration P, the amounts of P in manures from confined livestock operations nationally could be reduced by 193,000 Mg. Changing the P content of ration dry matter for the average dairy cow in table 1 to 0.35% of dietary dry matter lowers estimated P excretion from 81 g/d to 48 g/d, changes estimated P% in manure excreted from 0.93% to 0.56% of DM and P% in manure DM collected from 1.16% to 0.69%.

Conclusions
Nutrient and/or manure management planning is an essential component for management of livestock

operations. To develop plans that adequately reflect practices of an operation, an accurate method to estimate nutrient flows, including nutrient excretions, is needed. Predicting nutrient excretions can best be accomplished by using a mass balance approach, which considers nutrient inflow, via dietary intake and nutrient outflow via absorption and utilization (in the form of product: milk, growth, eggs). This approach also serves as a check for manure sampling to determine if calculated losses and recoveries are feasible. A current national initiative is moving present table values, non-specific towards operational differences, in the direction of using a mass balance approach to estimate nutrient excretions. Producers interested in employing this approach in their whole-farm nutrient plan should include a nutritionist on their nutrient management team in order to provide a nutrition-based estimate without compromising animal performance. While we may not want to think about it, the day is coming when producers will be held accountable for all nutrients generated by their operation, and not just the nutrients that make it to the field. A nutritional approach to estimating nutrient production is the logical step to forming a plan to address nutrient losses to both the air and soil.

Table 1. Estimates of N, P, and K excretions based on ration and products produced[1].

Herd or Flock information	Units	Numbers below expand from daily averages to years			Numbers below based on life cycle grow-out		
		Dairy cows	Beef steer	Hens	Broilers	Turkeys	Pigs
Animals/day or animals/grow-out	No.	1	1	1000	1	1	1
Average DMI kg/day =	kg	21.8	9.53	94.8	3.91	24.3	298.0
Average diet crude protein (CP) % (DM basis) =	%	17.0	12.0	16.4	20.0	20.0	16.5
Average diet N % = CP % x .16 =	%	2.72	1.92	2.62	3.20	3.2	2.64
Average diet total P % (DM basis) =	%	0.50	0.40	0.65	0.80	0.80	0.57
Average diet K % (DM basis) =	%	1.20	0.80	0.60	0.60	0.60	0.66
Milk yield or egg yield kg/d =	kg	27.2		47.6			
Milk or egg protein percentage	%	3.2		10.4			
Milk or egg N%	%	0.496		1.664			
Milk or egg P%	%	0.10		0.21			
Milk or egg K%	%	0.15		0.12			
Average net body weight gain kg/day or grow-out	kg	0.09	1.41	0.839	2.18	10.80	115.2
Average N % of weight gain	%	1.20	1.60	2.20	2.60	2.10	2.32
Average P % of weight gain	%	0.70	0.70	0.60	0.60	0.60	0.72
Average K % of weight gain	%	0.20	0.20	0.20	0.20	0.20	0.20
Average diet DM digestibility %	%	65	80	83	84	82	82
Ratio: Feed DM:(milk, doz eggs, or gain)	Ratio	0.80	6.76	3.16	1.79	2.25	2.59

Daily or grow-out balances[2]:

Nitrogen (N):

	Units	Dairy cows	Beef steer	Hens	Broilers	Turkeys	Pigs
Input: g DMI x N/DMI =	g	593	183	2488	125	778	7867
Export: g milk or eggs x N% =	g	135		793			
g gain x N/gain =	g	1	23	18	57	227	2673
Difference (manure estimate) = input - export	g	457	160	1677	68	551	5195
Yearly or grow-out manure N =	g	166764	58552	611946	68	551	5195

Phosphorus (P):

	Units	Dairy cows	Beef steer	Hens	Broilers	Turkeys	Pigs
Input: g DMI x P/DMI =	g	109	38	616	31	194	1699
Export: g milk or eggs x P% =	g	27		100			
g gain x P/gain =	g	1	10	5	13	65	829
Difference (manure estimate) = input - export	g	81	28	511	18	130	869
Yearly or grow-out manure P =	g	29621	10311	186569	18	130	869

Potassium (K):

	Units	Dairy cows	Beef steer	Hens	Broilers	Turkeys	Pigs
Input: g DMI x diet K%/100	g	262	76	569	23	146	1967
Export: g milk or eggs x K%/100	g	41		57			
g gain x K%/100	g	0	3	2	4	22	230
Difference (manure estimate) = input - export	g	221	73	510	19	124	1736
Yearly or grow-out manure K =	g	80518	26798	186138	19	124	1736

[1] From Powers, W.J. and H.H. Van Horn. 2001. Nutritional implications for manure nutrient management planning. Appl. Engng in Agric. 17(1):27-39.
[2] Expanded from daily averages above to annual or life cycle grow-out balances