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CHARACTERISTICS OF MANURE HARVESTED FROM BEEF CATTLE FEEDLOTS

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ABSTRACT. *Open lot cattle production systems present unique challenges for nutrient planning processes. Previous estimates of quantities and characteristics of harvested manure from this type of facility are based upon data from the early 1970s. In addition, harvested manure is impacted by weather, feeding program, season, and pen management decisions. The objectives of this study are to characterize under commercial conditions for open lot beef systems: 1) harvested manure quantities and characteristics; 2) impact of factors such as feeding program, season, and management on harvested manure; and 3) mass balance for nitrogen (N) and phosphorus (P). Data from six commercial feedlots (representing 6,366 head of cattle) suggest that 33% of excreted N (65 g/hd/d) and 91% of excreted P (32 g/hd/d) are harvested as manure on average and that current standard estimates published by ASAE (2005) and NRCS (1992a) overestimate harvested manure N and P. Additionally, significant variation was observed among feedlots. This variation is driven by ration nutrient concentration (P only), pen conditions prior to and during manure harvest (N and P), and management choices relative to use of manure in lot maintenance (N and P). The variation would suggest that nutrient planning estimates for open lots would need to be based upon farm specific data as opposed to typical or standard values. Finally, a pen-based mass nutrient balance for a beef cattle feedlot suggests that pen outputs as finished animal, harvested manure, and nutrient losses represent 31%, 23%, and 47%, respectively, of all pen N inputs and 38%, 57%, and 5%, respectively, of all pen P inputs. Inputs include nutrient content of all animals and feed entering a feedlot pen over a grow-out period.*

Keywords. *Animal manure, Beef cattle, Feedlot, Manure characteristics, Nutrient management.*

Revised standards for manure excretion by feedlot cattle have been recently adopted by ASAE (2005). Although nitrogen (N) excretion estimates have changed only modestly, phosphorus (P) excretion is 50% lower than the previous standards (ASAE, 2000). In addition, nutrient excretion in open lot production facilities and harvested manure nutrients can vary significantly. It is important that accurate estimates of N and P removed as manure solids are available for producers to use in developing nutrient management plans. If nutrient content is over-predicted, acres required for appropriate distribution will be inflated. If under-predicted, an inadequate land base can result in increased environmental risk and poor utilization of a valuable nutrient resource.

Multiple factors are likely to impact nutrient removal from open lot beef cattle production systems. Weather will impact the degree of soil mixed with the manure as well as moisture characteristics. Feed ration choices may affect the quantity of nutrients in the manure. Management choices can impact the total quantity of manure that is harvested versus that which is used for lot maintenance. Understanding the impact of some of these changes will improve nutrient management planning associated with open lot systems.

LITERATURE REVIEW

Accurate estimates of harvested manure nutrients are important to the cropping season or annual nutrient planning processes completed by a producer as part of maintaining a permit or cost share agreement. Only a limited number of studies have measured actual harvested manure for beef cattle in open lot production systems (table 1). Multiple studies (Gilbertson et al., 1971a, 1971b, 1974, 1975; Frecks and Gilbertson, 1974) suggested the following conclusions:

- Quantity and quality of material removed from outdoor feedlots is influenced by uncontrollable climatic conditions;
- Significant soil is removed during cleaning contributing to high ash content in manure.
- The quantity of volatile solids and nutrients removed is influenced by animal stocking density but is not affected by lot slope and cleaning frequency. The cleaning period (summer vs. winter) affected manure moisture content.

Sweeten et al. (1985) described a significant variation in manure characteristics based upon vertical location (distance from feed bunk) within the pen. These authors also noted the impact of climatic conditions and seasonal periods on the quality of the manure and ash content. Kissinger (2005) summarized an extensive database of harvested manure under open lot conditions from 11 unique studies. These studies of nutrient and solids balance on open lot pens that have produced a database representing 244 pens of cattle over 10 years. Key findings include:

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- Nearly twice the manure is harvested following a winter feeding period as compared to a summer feeding period (8.8- vs. 4.7-kg total solids/head/day). Only about one quarter of the harvested manure are volatile solids suggesting that significant soil is included in the harvested manure.
- Manure harvested following a winter feeding period produces significantly higher recovery of excreted nitrogen, likely resulting from lower volatilization losses of nitrogen. Manure moisture and volatile solids characteristics also vary with the season.

NRCS (1992a), Lorimor et al. (2000), and ASAE (2005) all provide commonly used estimates of open lot beef cattle harvested manure quantities and characteristics.

Koelsch (2000) suggested that nutrient excretion and land requirements should vary for cattle based upon dietary considerations. Erickson et al. (2003) proposed a mass balance model for beef cattle nutrient excretion which allowed excretion estimates to vary with feed program and animal performance. This model was later adopted as an ASAE standard (*ASAE Standards*, 2005).

Objective

The objectives of this study were to characterize under commercial conditions for open lot beef systems: 1) harvested manure quantities and characteristics; 2) impact of factors such as feeding program, season, and management on harvested manure; and 3) mass balance for nitrogen and phosphorus. This information will assist with the annual nutrient planning processes expected of cattle producers and provide insights as the impacts of animal feeding decisions on those nutrient planning processes.

Procedure

Feedlot Study

Six central and eastern Nebraska feedlots ranging in size from less than 5,000 head to more than 20,000 head capacity were recruited during the fall of 2003 to participate in a study to quantify manure and nutrients harvested from pens during cleaning. Each of the feedlots assigned three cattle feeding pens for this study, and to share information for

Table 1. Comparison of estimates of excreted and harvested manure from beef cattle production facilities.

Reference	Animal Characteristics	Housing / Ration	Moisture (% wet basis)	TS	VS	N	P	K
				kg/head/day unless otherwise indicated				
Excreted Manure								
Gilbertson et al., 1974	420-kg feeder, Eastern NE	Hi energy		1.76	1.65			
NRCS, 1992a	420-kg feeder	Hi forage	88	2.84	2.53	0.13	0.046	0.10
	420-kg feeder	Hi energy	88	2.48	2.28	0.13	0.039	0.088
	272-kg calf	Calf	87	2.05	1.74	0.082	0.027	0.054
ASAE, 2005	446-kg feeder	High energy	92	2.4	1.9	0.16	0.022	0.11
Lorimor et al., 2000	499-kg feeder	High energy	92	2.8	2.6	0.24	0.042	0.12
	340-kg feeder	High energy	92	1.9	1.8	0.17	0.028	0.083
	499-kg feeder	High forage	92	3.8	3.4	0.28	0.042	0.14
	340-kg feeder	High forage	92	2.6	2.4	0.19	0.028	0.094
	204-kg calf		92	1.5	1.3	0.063	0.020	0.041
Harvested Manure								
NRCS, 1992a	454-kg feeder	Open lot	45	4.35	2.18	0.095	0.063	0.014
		Surfaced – hi forage	53	2.49	1.75			
		Surfaced – hi energy	52	1.13	0.79			
ASAE, 2005	446-kg feeder	High energy	33	7.5	2.3	0.088	0.038	0.094
Gilbertson et al., 1974	420-kg feeder	Roofed – hi energy	78	1.81	1.56	0.058	0.014	0.026
	408-kg feeder	Eastern NE open lot – hi energy	55	6.37	2.37			
Gilbertson, 1972	18.5 m^2/hd Eastern NE	Eastern NE open lot	54	6.0–7.1	1.5	0.062–0.070	0.0048–0.0056	0.017–0.020
Kissinger, 2005		Eastern NE open lot	[a]	[b]	[b]	[b]		
	Summer – 467 kg (132 pens)		30±15	4.7±4.4	1.1 ± 1.0	0.059±0.057		
	Winter – 465 kg (112 pens)		39±21	8.8±8.6	2.2 ± 1.5	0.100±0.066		
Sweeten et al., 1985	15.5 m^2/hd	TX open lot – Heifers – 152 day feeding period	[a] 22–40%		[c] 26–72%	[c] 2.6%		
Sweeten et al., 1985	20-23 m^2/hd	Eastern CO open lots – 152 day feeding period	[a] 48±19%		[c] 65±24%	[c] 2.6±0.5%		
	17-20 m^2/hd		38±26%		37±35%			
Sweeten et al., 1985		Eastern CO feedlot – 152 day feeding period	[a] 52±10%		[c] 62±11%	[c] 2.7±0.4%	[c] 1.5±0.6%	

[a] Mean ± 2 standard deviation expressed as a % wb.
[b] Mean ± 2 standard deviations expressed as kg/head/day.
[c] Mean ± 2 standard deviations expressed as a % db.

approximately one year on the cattle fed in each pen. The completed study represents 15 feeding pens, 40 separate lots of cattle fed in those pens, and 6,366 head of cattle in those lots. For this study, both steers and heifers were fed. All calculations are reported as an amount per head (hd) per day (kg/hd/d or g/hd/d). The data collection period ranged from mid-October 2003 through December 2004.

Originally, the intent was to evaluate nutrient balances for cattle fed two significantly different diets, one based on a corn diet and a second that included some ethanol by-product replacement of corn. Due to the recent growth in ethanol production in Nebraska and the economics of feeding by-products, the project investigators were unsuccessful in identifying feedlots that were not using by-products.

Feed intake and dietary nutrient profile were furnished by the feedlot staff or consulting nutritionist. Bunk samples were collected for additional documentation of feed nutrient profile. Animal performance on each lot of cattle fed in each pen including weight in and out, number of animals, and days on feed for each lot of cattle was collected from the feedlot records. Random manure samples were collected from within the study pens either just prior to, or at the time of manure harvest. These representative samples were obtained from the manure piles resulting from the mechanical scraping of the pens. Multiple samples (minimum of six) were taken, pooled, and then sub-sampled for the final sample to be analyzed. Samples were sealed in a plastic bag, placed on ice in a cooler for transport, and then frozen until time of analysis.

Each pen in the study was initially cleaned prior to entry of cattle. Manure from feedlot pens is typically removed after a pen of cattle is marketed and prior to the next group of cattle arriving. In some instances in this study, more than one cycle of cattle were fed in a pen between manure harvestings. Subsequently, feedlot personnel scraped and harvested the manure following normal management procedures of the respective feeding operations. Manure was scraped and piled into central piles within each pen. In some instances, scraped manure was utilized to maintain the integrity of mounds within the pens. As the manure was harvested, gross and tare weights of truck or tractor and spreader loads were recorded and representative manure samples were collected for nutrient analysis at a commercial laboratory. Manure was either hauled directly to fields for land application, or transferred to a stockpile or compost yard. An independent commercial laboratory (Ward Labs, Kearney, Neb.) completed all nutrient and solids concentration analyses of manure and feed samples following procedures described by Peters (2003) and Herlich (1990), respectively.

Nutrient Balance

Nutrient intake was calculated using dietary nutrient concentration of each diet fed multiplied by DMI. Cattle nutrient retention was calculated according to the retained energy and protein equations established by the National Research Council (1996) for beef cattle. Nutrient excreted was calculated using mass nutrient balance procedures that involved subtracting nutrient retention from nutrient intake (fig. 1) using procedures detailed by ASAE (2005).

In addition, a mass balance for N and P was completed for each pen in the study for each period of time between manure harvesting. Manure nutrients were quantified by multiplying manure nutrient concentration by the amount of manure removed (TS) from the pen surface. Total nutrient loss was calculated by subtracting measured manure nutrients harvested from calculated excreted nutrients. Percentage of nutrient loss was estimated as nutrient loss divided by total calculated nutrient excretion. All nutrient values were expressed on a g/finished head basis. Nutrient mass balances were completed for N and P (see fig. 2) that involved field measurements of the two inputs, animals and feed, and two of the three outputs, animals and manure. The third output was calculated by difference.

Statistical Analyses

Statistical analyses were conducted using MIXED and MEANS procedures of SAS (2004). Model effects included feedlot and season with pen as the experimental unit for that cleaning period. Only variables significant at the 0.15 level remained in the models considered in stepwise selection. In the correlation procedure, all variables were entered, resulting in the production of Pearson Correlation Coefficients.

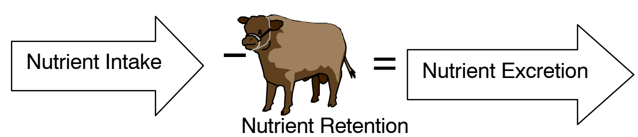

Figure 1. A nutrient mass balance method was used to estimate nutrient excretion following procedures from ASAE (2005).

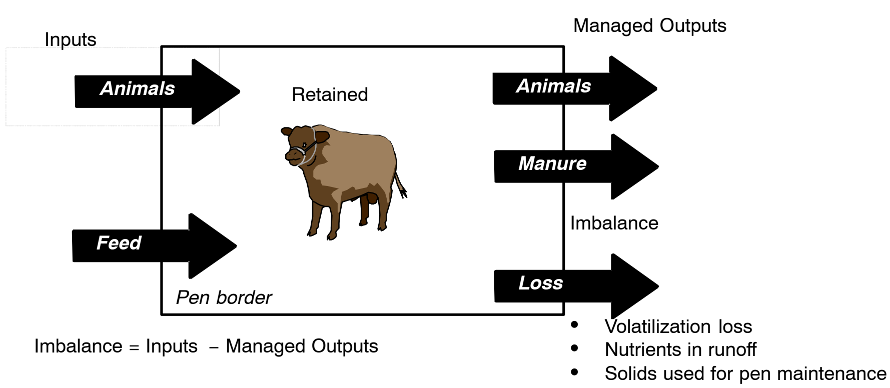

Figure 2. A mass nutrient balance procedure for a feedlot pen was used to calculate the imbalance of N and P as a difference between the measured inputs and managed outputs.

Results and Discussion

Animal Performance

On average, cattle involved in this study started as yearlings (BW = 355 kg) and gained 187 kg over 127 days (ADG = 1.47 kg/day) [BW = Body weight (kg); ADG = Average daily gain (kg of BW per day); F:G = feed per unit of gain (kg feed per kg of gain); DMI = Dry matter intake (kg of feed per day)]. This compares to a typical beef feeder defined by ASAE (2005) which initially weighs 338 kg and gains 216 kg over 153 days (ADG of 1.42 kg gain per day). Average DMI was slightly higher (10.3 kg/hd/d) than for a typical beef feeder defined by ASAE (8.92 kg/hd/d). The cattle involved in this study were less efficient in their conversion of feed to body weight gain (F:G of 7.1 kg /kg for trial vs. 6.3 kg /kg for typical animal in ASAE standard). Macken et al. (2004) reported an average midpoint BW, ADG, and DMI of 461 kg, 1.78 kg, and 11.3 kg/hd/d, respectively. Compared to Macken's results, the cattle in our study exhibited a slightly lower average weight (4489 kg), lower ADG (1.46 kg), and a lower average DMI as summarized in tables 1 and 2.

On several occasions, a pen of cattle was started within a pen monitored by the study but only remained for a few days to a few weeks before transfer to a different pen. Because manure was not harvested as the group of cattle was removed, the animal performance and manure data for these partial-finishing periods were included in the study. This resulted in a lighter average weight and shorter average finishing period than is common. The 6,366 cattle involved in this study are representative of typical commercial conditions with the exception that the average observed 127-day feeding period is lower than common industry practices. Estimates for harvested manure and other performance characteristics should be adjusted from the observed 127-day feeding period to a more typical 150-day period for data reported on a per animal finished basis. Most data presented in this article will be reported on a per head per day basis to minimize the influence of the shorter than normal feeding period.

Feed input (table 2) is a critical nutrient input for estimating nutrient excretion (ASAE, 2005). The average nutrient intake was 230 g N/animal/day (29.4 kg/finished animal) and 41 g P/animal/day (5.3 kg/animal fed). All feedlots were using corn and corn-milling byproduct-based diets. The dietary crude protein content averaged 14.3% (DM basis), but ranged from 13.4% to 16.6%. The P content averaged 0.40% (DM basis), but ranged from 0.34% to 0.48%. Mineral P was not added to these finishing diets, but dietary P was elevated relative to diets containing only corn grain. The rate of corn milling byproduct inclusion in diets was primarily responsible for the observed variation in dietary P.

Harvested Manure Characteristics

Field measures were used to determine total manure mass harvested and concentration of solids, moisture, and nutrients (table 3). The dry matter content of harvested manure averaged 74% as compared to the original excreted manure that is approximately 10% (ASAE, 2005). This would suggest that more than 95% of the original excreted moisture has evaporated. The ash content of harvested manure is approximately 66% as compared to a 20% ash content in excreted manure (ASAE, 2005). This data suggests that more than 50% of the harvested manure is soil mixed with the manure.

The characteristics of manure collected in spring (following a winter and spring feeding period for 13 separate collection periods) and late summer through fall (following a summer and fall feeding period for 13 separate collection periods) were very similar on average. Harvested manure moisture content, contribution of ash to total manure, and nutrient and micronutrient concentrations varied very little between the two feeding periods. Variation in N concentration might be expected due to potential differences

Table 1. Performance data collected by cleaning period after two feeding periods for cattle fed in six Nebraska feedlots.

Variable	Average Performance[a]				Performance for Feeding Period[b]	
	Mean	CV[c] (%)	Minimum	Maximum	Winter/Spring	Summer/Fall
Cattle per pen	160	25	81	262	164	156
Days on feed	127	34	42	213	146	107
Initial BW (kg)	355	13	231	459	337	372
Final BW (kg)	542	134	373	666	544	540
ADG (kg)	1.46	11	1.23	1.78	1.41	1.52
F:G (DMI/ADG)	7.14	11	5.70	8.78	7.32	6.96

[a] Values are for 26 cleaning periods.
[b] Values are average for 13 cleaning periods each within the winter/spring and summer/fall feeding periods.
[c] CV = Coefficient of Variation.

Table 2. Feed nutrient intake data for cattle fed in six Nebraska feedlots.

Variable	Average Nutrient Intake[a]				Nutrient Intake for Feeding Period[b]	
	Mean	CV (%)	Minimum	Maximum	Winter/Spring	Summer/Fall
DMI (kg/hd/d)	10.3	11	8.5	13.2	10.0	10.6
CP (%)	14.3	8	13.4	16.6	13.9	14.6
N (kg/hd/d)	0.23	13	0.18	0.29	0.22	0.25
P (%)	0.40	14	0.34	0.48	0.40	0.40
P (g/hd/d)	41	22	30	62	40	43

[a] Values are for 26 cleaning periods.
[b] Values are average for 13 cleaning periods each within the winter/spring and summer/fall feeding periods.

in volatilization of ammonia under summer and winter conditions. This study observed higher nitrogen content of harvested manure in spring (77 g N/hd/d) versus late summer or fall (54 g N/hd/d). Previous research has suggested similar trends (Erickson et al., 2001a; Adams et al., 2003). Time of year and season should influence volatile N losses. Other nutrient and micronutrient concentrations exhibited little change.

Nutrient concentration varied significantly for individual samples as illustrated by the large coefficients of variations for individual characteristics (table 3). A two standard deviation range for most nutrient and micronutrient concentrations commonly equaled 70% to 90% of the magnitude of the average value. The only characteristics with lower variations included pH, DM, ash, and C:N and N:P ratios.

The quantity of harvested manure varied with season (table 4). On average, 7.2-kg total manure (solids and water) was removed per animal per day. For a typical 150-day feeding period, one would expect to remove about 1100 kg per finished animal. Spring cleaning harvested about 20% more manure than fall cleaning. Most of that increase can be attributed to the 30% increase in harvested ash from the spring cleaning. A greater amount of ash (soil) is being hauled out of pens in the spring.

Feedlot surface conditions during manure pre-harvest and harvest periods is a likely contributor to the total solids harvested as well as the amount of soil that was mixed with the manure. Wet feedlot surface conditions, more common during winter and spring, produce more mixing of manure and soil resulting from animal activity. Wet conditions at harvest create challenges for equipment operators to harvest manure only. High soil inclusion with the manure solids may cause total mass of harvested manure P to exceed excreted P. With the continuous addition of soil to pens in many feedlots to offset the soil loss during manure harvest, it is possible for solids and P in manure to exceed solids and P from excretion. Feedlot surface conditions are likely to impact solids and nutrients harvested in manure.

The variation in harvested manure between individual feedlots (tables 5 and 6) was much greater than the seasonal variation (table 4). Based upon the 40 lots of cattle fed in the six feedlots (table 5), average manure harvested values for TS, VS, N, and P are 5.3 kg, 1.5 kg, 65 g, and 32 g per head per day, respectively. However, as noted by the range of values for individual feedlots as well as the large coefficients of variation, substantial variation exists between individual feedlots. For example, harvested manure ranged from 1.6 to 9.5 kg/head/day for the six feedlots. Management choices are the more likely primary factor controlling the quantity of harvested manure. Based upon visual observations and interviews with producers, harvested manure is used by some feedlots for mound construction and feedlot surface maintenance resulting in less harvested manure (e.g. feedlots I and VI, table 5). This management choice contributes to the variation between feedlots in total harvested manure solids and nutrients harvested. Nutrient management plans and reporting requirements must recognize that average or typical values can produce significant variations in the quantity of manure handled and land requirements for managing manure nutrients. The feedlot is unique among livestock systems in that feedlot managers have alternative uses for manure solids besides land application often resulting in less than 100% of the manure being harvested.

Similar to other livestock systems, typical or average manure nutrient concentrations are not good predictors for individual farms (table 6). Likely sources of variation in nutrient concentration between individual farms can be related to:

- differences in harvested manure dry matter content (range of 59% to 94% TS observed for individual pen cleanings) typically driven by weather factors.

Table 3. Concentration of harvested manure characteristics summarized by feeding period for cattle fed in six Nebraska feedlots.

	Winter/Spring[a]		Summer/Fall[a]	
Manure Characteristic	Mean	CV (%)	Mean	CV(%)
pH	7.55	11	8.03	7
DM (% wb)	71.8	7	76.1	13
Ash (% db)	69.9	20	69.9	18
OM (% db)	30.1	45	30.1	42
Organic carbon (% db)	17.5	45	17.5	42
C : N ratio	13.5	9	13.2	9
Organic N (% db)	1.23	41	1.29	47
Ammonium (ppm db)	494	97	529	91
Nitrate N (ppm db)	4.0	42	20.3	137
Total N (% db)	1.28	43	1.35	47
Phosphorus (% db)	0.64	48	0.64	53
N : P ratio	2.10	18	2.18	15
Potassium (% db)	1.35	39	1.52	39
Sulfur (% db)	0.43	40	0.46	44
Calcium (% db)	1.71	36	1.89	34
Magnesium (% db)	0.59	33	0.62	29
Sodium (% db)	0.33	53	0.32	55
Zinc (ppm db)	276	39	284	58
Iron (ppm db)	10200	36	10900	37
Manganese (ppm db)	320	26	384	31
Copper (ppm db)	65	30	60	52
Soluble salts (mmho/cm)	23.37	44	20.53	35

[a] Values are for 24 and 29 manure samples collected from Winter/Spring (April – June) and Summer/Fall (July – December) cleaning periods, respectively.

Table 4. Total mass of manure and nutrients harvested by cleaning period after two feeding periods for cattle fed in six Nebraska feedlots.

	Manure Characteristics[a]				Feeding Period[b]	
Variable	Mean	CV (%)	Minimum	Maximum	Winter/Spring	Summer/Fall
As-is (kg/hd/d)	7.2	74	0.8	27.0	9.6	4.8
TS (kg/hd/d)	5.3	78	0.6	21.5	6.9	3.7
VS (kg/hd/d)	1.5	46	0.1	2.8	1.8	1.2
N (g/hd/d)	65	48	6.2	126	77	54
P (g/hd/d)	32	52	2.7	74	37	26

[a] Values are for 26 cleaning periods.
[b] Values are average for 13 cleaning periods each within the winter/spring and summer/fall feeding periods.

Table 5. Summary of average amounts and characteristics of manure harvested from six Nebraska feedlots.

Feedlot Summary	TS (kg/hd/d)	VS (kg/hd/d)	VS/TS Ratio	Manure N (g/hd/d)	Manure P (g/hd/d)	N/P Ratio
I	1.8	0.69	0.37	31	19	1.6
II	3.5	1.9	0.55	82	37	2.2
III	5.0	1.6	0.33	72	43	1.7
IV	5.8	1.8	0.32	77	34	2.3
V	9.5	1.5	0.19	62	26	2.4
VI	1.6	0.32	0.19	15	6.4	2.3
Average	5.3	1.5	0.34	65	32	2.1

- differences in ash (primarily soil) content (range of 37% to 91% observed for individual pen cleanings) which is likely related to weather factors and differences in operators of manure scraping equipment. This factor would appear to be more influential on the observed variation than moisture content.
- possible differences in feed nutrient intake and excretion (to be discussed in the next section). Although the total nutrients harvested varied substantially between lots, the observed variation in N to P ratio (table 5) was smaller than that observed for other manure characteristics.

These observations further substantiate a common recommendation for site-specific manure samples for nutrient planning purposes.

A comparison of harvested manure data collected from this study with standard values suggests several differences (table 7). The NRCS and ASAE reference values for total solids were 82% and 142%, respectively, of the observed values in this study. ASAE and NRCS reference values estimate manure nitrogen to be 135% to 140% of nitrogen measured in the 6 feedlots. Similarly, ASAE and NRCS reference values estimate manure phosphorus to be 119% to 197% of observed values. The reference values over-estimated farm specific measured values for harvested manure in spite of cattle diets for these farms (14.4% crude protein and 0.39% P) that were greater than conventional finishing diets used in the other regions of the United States. The inaccuracies resulting from use of published standards could result in regulatory permits requiring two times more land than necessary for the farms observed in this study. Even greater errors would be anticipated for feedlots feeding a traditional corn-based ration. Similar errors for total and volatile could also prove significant for planning of systems including combustion and treatment technologies.

Table 6. Characteristics of manure samples collected at six Nebraska feedlots.

Feedlot	No. of Samples	Total N % (% db)	P (% db)	pH	Ash (% db)	VS (% db)	TS (% wb)
I	3	1.72	1.06	7.3	62.6	37.4	71.1
II	8	2.42	1.13	7.3	46.0	54.0	76.2
III	9	1.50	0.89	7.6	66.9	33.1	74.0
IV	11	1.33	0.59	8.1	68.3	31.7	70.6
V	15	0.77	0.31	8.1	81.4	18.6	71.3
VI	7	0.84	0.39	7.8	82.0	18.0	84.9
Avg.		1.28	0.64	7.6	69.9	30.1	71.8

Table 7. Comparison of alternative estimates of solids and nutrients harvested from feedlots.

Source	TS (kg/hd/d)	VS (kg/hd/d)	Manure N (g/hd/d)	Manure P (g/hd/d)
Feedlot summary	5.3	1.5	65	32
NRCS[a]	4.3	2.2	95	63
ASAE[a]	7.5	2.3	88	38

[a] Estimate from NRCSa (1992), table 4–9, and ASAE (2005) corrected to an average body weight of 445 kg.

NUTRIENT BALANCE

The 6,366 head of cattle involved in this study retained, on average, 12.3% of the feed nitrogen and 15.4% of the feed phosphorus (table 8). The remainder of N and P were assumed to be excreted (ASAE, 2005). On average, it was estimated that the cattle excreted 210 g of N and 35 g of P per animal per day. The harvested manure N represented 32% of the excreted N or 65 g/hd/d and 91% of the excreted P or 32 g/hd/d. Total manure nutrient recovered in the spring were generally greater than in the fall. Observed losses of nitrogen were found to be on the upper end of commonly accepted values (NRCS, 1992b).

The amount of N recovered in harvested manure is minimally impacted by increases in dietary N and excreted N (fig. 3). Increasing feed N intake from 190 to 290 g/hd/day, as illustrated in figure 3, would result in a 100 g/hd/day increase in excreted N. This increase produced approximately a 30-g/hd/day increase in the N in harvested manure. Most of the increase in excreted N is lost either as runoff or volatilization. This would suggest that excess feeding of dietary nitrogen is increasing the excretion of primarily urea nitrogen, more susceptible to volatilization and runoff losses, and producing only small changes in N recovered in manure.

The amount of P recovered in harvested manure is more directly related to P fed. Increasing dietary P increased excreted P without influencing losses (fig. 4). The regression equation comparing harvested manure P and feed intake P

Table 8. Nutrient balance data by cleaning period for cattle fed in six Nebraska feedlots.

	Balance[a]	Balance for Feeding Period[b]	
Variable	Mean	Winter/Spring	Summer/Fall
N intake (g/hd/d)	234	223	245
N retain[c] (g/hd/d)	28	28	28
N excrete[c] (g/hd/d)	206	196	217
N manure (g/hd/d)	65	77	54
N lost (g/hd/d)	141	119	163
N lost (% of excreted)	67	61	75
P intake (g/hd/d)	41.4	40.1	42.7
P retain (g/hd/d)	6.5	6.2	6.7
P excrete (g/hd/d)	34.9	33.9	36.0
P manure (g/hd/d)	31.8	37.2	26.4
P lost (g/hd/d)	3.1	-3.3	9.6
P lost (% of excreted)	9	-13	27

[a] Values are for 26 cleaning periods.
[b] Values are average for 13 cleaning periods each within the winter/spring and summer/fall feeding periods.
[c] Nutrients retained and excreted are estimated from procedures defined in NRC (1996) and ASAE (2005), respectively.

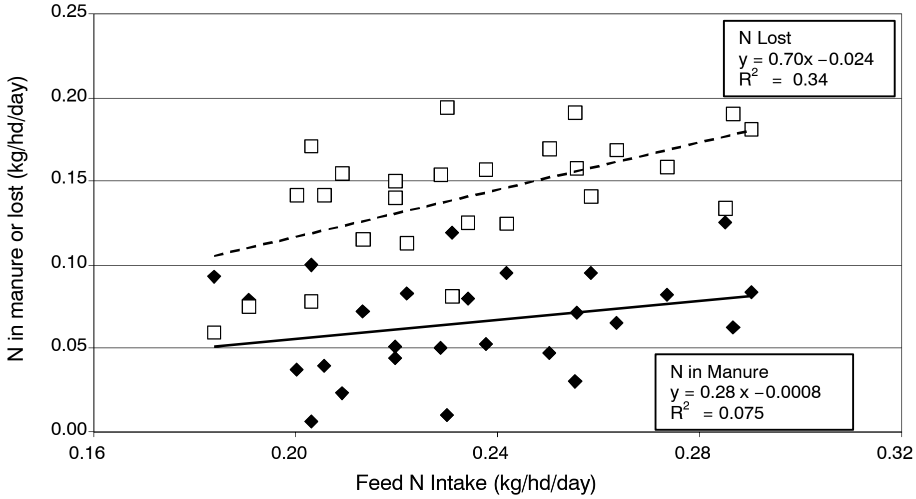

Figure 3. Relationship between N intake and N in manure and lost for six Nebraska feedlots.

suggests that 81% of the increase in P intake was observed in the harvested manure. However, the lost P did not vary with increases in P intake. Other factors also influenced harvested and lost P as seen by the scatter in data presented in figure 4.

Based upon results from this study, a typical mass nutrient balance is presented for our observed 127-day feeding period (fig. 5). It was observed that 53% of the nitrogen and 95% of the phosphorus entering a cattle pen as animals and feed was recovered as meat products or manure. The N lost (fig. 5), as volatilization of ammonia, as dissolved or suspended N in feedlot runoff, or retained in manure not removed from pens, represented less than half of the total pen nitrogen inputs. N lost was also equivalent to 67% of excreted N. Since 5% or less of excreted N is lost via surface runoff (Clark et al., 1975; Bierman et al., 1999; Erickson and Klopfenstein, 2001a, 2001b), the balance would be attributed to N volatilization.

The primary anticipated P loss would be from P contained in the runoff, typically 5% or less of excreted phosphorus (Clark et al., 1975; Kissinger, 2005). Some loss resulted from manure use for pen maintenance and is not a true loss. This study observed that P loss represented about 9% of excreted manure and about 5% of total feed and animal P inputs into a pen of cattle.

Conclusions

Open lot systems produce unique challenges for recommendations of average or typical amounts of manure and nutrients harvested. The unique interactions of weather, soil, and management decisions result in ash and moisture content of harvested manure for individual farms that are difficult to predict. The large coefficients of variation reported for manure nutrient concentrations and for harvested manure mass illustrate the variation between individual feedlots. Farm managers may become aware of patterns in nutrient concentration and mass harvested based upon experience. However, variations between farms make use of average or typical values are problematic when applied to individual farm planning processes for open lot systems.

The knowledge and experience gained with estimating feedlot nutrient balances on six beef cattle feedlots suggests that:

- An average manure TS, VS, N, and P of 5.3 kg/hd/d, 1.5 kg/hd/d, 65 g/hd/d, and 30 g/hd/d, respectively, was harvested from six beef cattle feedlots representing 33% of the excreted nitrogen and 92% of the excreted phosphorus. Current standards published by NRCS and ASAE

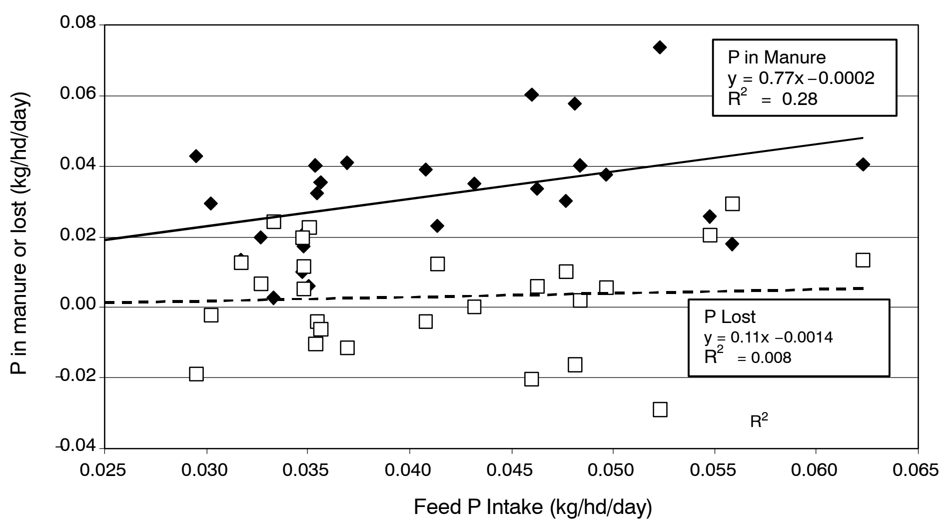

Figure 4. Relationship between P intake and P in manure and lost for six Nebraska feedlots.

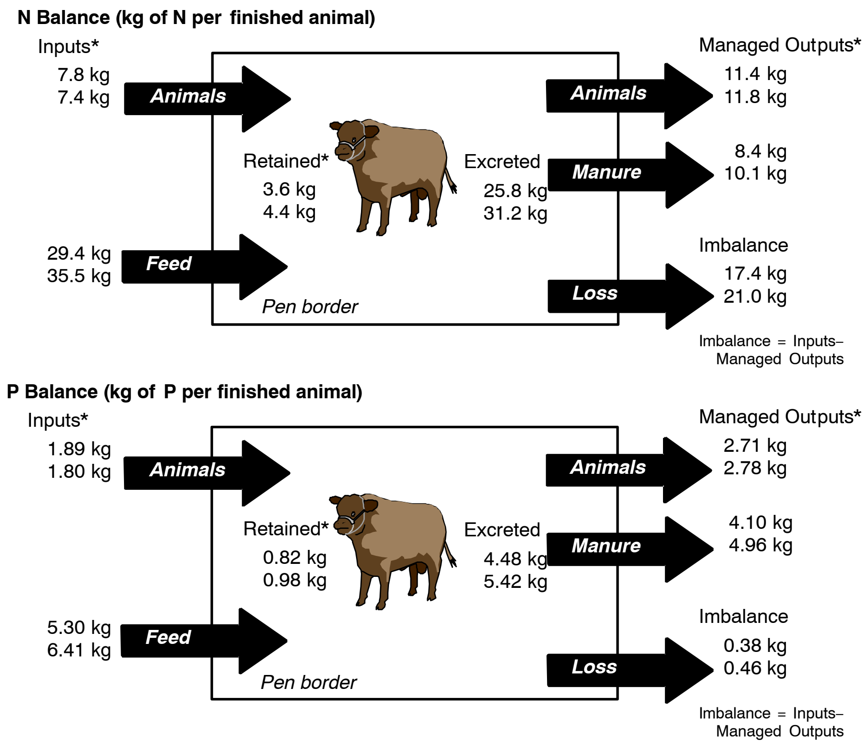

Figure 5. A mass nutrient balance for a feedlot pen for a 127-day measured finishing period (top entry) and 153-day typical finishing period (bottom entry) based upon observations from six Nebraska feedlots. * N and P content and retention by animals estimated from procedures defined by ASAE (2005).

over-estimated average harvested N and P. Nutrient planning procedures may need adjustment to better reflect the manure nutrient recovery rates.

- Due to the wide variation between individual feedlots, both over and under estimates were common when based upon these same standards. Farm specific estimates may be critical to nutrient planning processes for open lot systems.
- The amount of P harvested in manure from beef feedlots varies with level of P in the diets. The amount of N harvested in manure shows less variation with the level of crude protein in the diet. Field observations suggest that individual pen conditions prior to and at time of manure harvesting and management choices specific to use of manure solids for lot surface maintenance or crop fertilization also influence harvested N and P.
- A feedlot pen-based mass nutrient balance for a beef cattle feedlot suggested that pen outputs as finished animals, harvested manure, and nutrient losses represent 31%, 22%, and 47%, respectively, of all pen N inputs and 38%, 57%, and 5%, respectively, of all pen P inputs.

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