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Managing Phosphorus in Beef Feedlot Operations

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Summary

A commercial feedlot study determined manure nutrient flow in six feedlots using a corn and by-product based diet with an average P content of 0.39% (DM basis), and a range of 0.34 to 0.48%. Mass balances for N and P were conducted on each pen. The average feed nutrient intake was 0.52 lb N/head/day (64.0 ± 7.6 lb/animal fed) and 0.09 lb P/head/day (10.9 ± 2.2 lb/animal fed). Based upon averages from the 6,366 head of cattle, 11.5% of the feed nitrogen and 16.9% of the feed phosphorus were retained by the animal with the remaining nutrients excreted. The harvested manure averaged 73% dry matter and 28% organic matter. A wide range of observed organic matter levels (9 to 63%), reflected soil being hauled out of pens along with the manure solids. Based upon these data, 31% of the excreted nitrogen or (17.2 lb/animal fed) and 90% of the excreted phosphorus (or 8.1 lb/animal fed) were removed in manure at cleaning.

Introduction

Revised standards for phosphorus (P) excretion by feedlot cattle have recently been accepted by ASAE, which are 50% lower than the previous standards. It is important that correct estimates of P removed as manure solids are available for producers to use in developing nutrient management plans that are based on utilization of manure P. If P content is over-predicted, acres required for appropriate distribution will be inflated. If under-predicted, P levels in the soil may be elevated and excess P may leave fields in runoff.

Few data exist for manure P harvested from feedlots. Previous work at the University of Nebraska suggested that less than 100% of P excreted is removed in manure. It is imperative to monitor P flow in the feedlot to determine how much is removed in manure in commercial feedlots compared to the amount excreted by cattle. The objectives of this study were to quantify the phosphorus and nitrogen in manure harvested from open lot beef cattle production systems, and to conduct a mass balance for P entering and exiting a feedlot. This information will help determine if nutrient management plans for feedlots can be developed by knowing the amount of P fed.

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 was to assign three cattle feeding pens for this study, and to share information for 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 were made on a per animal basis and results were presented as amount per head. The period of time of data collection from the pens ranged from mid-October 2003 through December 2004.

Feed intake and the nutrient profile of each diet fed were furnished by the feedlot staff or consulting nutritionist. Bunk samples of delivered feed were collected for additional documentation of nutrient profiles. Animal performance on each lot of cattle fed in each pen was determined from data supplied by the feedlot staff for cattle weights in and out, number of animals, and days on feed for each lot of cattle.

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 during 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 used to maintain the integrity of mounds within the pens. As the manure was harvested, gross and tare weights of truck 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.

Nutrient Balance

Nutrient intake was calculated using dietary nutrient concentration from the nutrient profile 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 excretion was calculated by subtracting nutrient retention from nutrient intake.

Mass balances for N and P were conducted as a group on those lots of cattle in residence during the period of time between manure harvesting for each pen in the study. Manure nutrients were quantified by multiplying the nutrient concentration of harvested manure by the amount of manure removed (DM) from the pen. Total nutrient loss was calculated by subtracting the mass of harvested manure nutrient from the amount of excreted nutrient. Percent nutrient loss was calculated as nutrient loss divided by total nutrient excretion. All nutrient values were expressed on a lb/head

Table 1. Nutrient intake of cattle fed in six Nebraska feedlots.

	Nutrient intake[a]				Feeding period[b]	
Variable	Mean	CV, %	Minimum	Maximum	Winter/spring	Summer/fall
DMI, lb/head/day	22.5	9	19.3	24.6	21.8	23.3
CP, %	14.4	8	13.4	16.6	14.2	14.5
N, lb/head/day	0.52	12	0.42	0.64	0.49	0.54
P, %	0.39	13	0.34	0.48	0.38	0.41
P, lb/head/day	0.09	20	0.07	0.12	0.08	0.10

[a]Values are for 22 cleaning periods.
[b]Values are average for 11 cleaning periods each within the winter/spring and summer/fall feeding periods.

Table 2. Analysis of harvested manure for cattle fed in six Nebraska feedlots.

	Manure characteristics[a]				Feeding period[b]	
Variable	Mean	CV, %	Minimum	Maximum	Winter/spring	Summer/fall
As-is, lb/head/day	15.9	79	1.9	61.0	17.5	14.3
DM, %	73.2	13	58.8	94.4	70.6	76.5
DM, lb/head/day	11.6	83	1.2	47.4	12.4	10.9
OM, %	27.8	45	8.8	63.0	33.5	34.6
OM, lb/head/day	3.2	45	0.3	6.1	2.9	3.6
N, %	1.21	45	0.44	2.51	1.40	1.53
N, lb/head/day	0.14	47	0.01	0.28	0.12	0.16
P, %	0.57	48	0.21	1.18	0.66	0.76
P, lb/head/day	0.07	49	0.01	0.13	0.06	0.08

[a]Values are for 22 cleaning periods.
[b]Values are average for 11 cleaning periods each within the winter/spring and summer/fall feeding periods.

Table 3. Nitrogen balance data for cattle fed in six Nebraska feedlots. Values expressed in lb/head/day unless noted.

	Nitrogen balance[a]				Feeding period[b]	
Variable	Mean	CV, %	Minimum	Maximum	Winter/spring	Summer/fall
N intake	0.52	12	0.42	0.64	0.49	0.5
N retain	0.06	—	0.03	0.08	0.06	0.06
N excrete	0.46	—	0.35	0.58	0.43	0.48
N manure	0.14	47	0.01	0.28	0.12	0.16
N lost	0.32	—	0.14	0.43	0.31	0.33
N lost, %	69.6	—	39.5	96.5	70.6	68.6

[a]Values are for 22 cleaning periods.
[b]Values are average for 11 cleaning periods each within the winter/spring and summer/fall feeding periods.

Table 4. Phosphorus balance data for cattle fed in six Nebraska feedlots. Values expressed in lb/head/day unless noted.

	Phosphorus balance[a]				Feeding period[b]	
Variable	Mean	CV, %	Minimum	Maximum	Winter/spring	Summer/fall
P intake	0.089	20	0.07	0.12	0.08	0.10
P retain	0.01	5	0.01	0.02	0.02	0.02
P excrete	0.074	--	0.05	0.11	0.07	0.08
P manure	0.066	49	0.01	0.13	0.06	0.08
P lost	0.007	--	-0.05	0.05	0.01	0.00
P lost, %	9.8	--	-94.3	89.9	13.1	6.4

[a]Values are for 22 cleaning periods.
[b]Values are average for 11 cleaning periods each within the winter/spring and summer/fall feeding periods.

basis. Nutrient mass balances were determined for N and P.

Statistical Analyses

Statistical analyses were conducted using procedures of SAS (2004). 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.

Results

Data summarized are for cattle fed from October 2003 through December 2004. Cattle involved in this summary were typically yearlings (BW = 778 lb) and on average gained 403 lb over 123 days. The data were partitioned into two feeding periods: winter/spring and summer/fall feeding periods, in order to illustrate any differences between the average values for the two feeding periods.

Feed input is the critical nutrient input evaluated in this study. The average nutrient intake was 0.52 lb N/head/day (64.0 ± 7.6 lb/animal fed) and 0.09 lb P/head/day (10.9 ± 2.2 lb/animal fed) for the 123-day average feeding period (Table 1). For an industry average 153-day feeding period, this would amount to 79.1 lb N/animal fed and 13.6 lb P/animal fed. All feedlots were using corn and by-product based diets. The P content averaged 0.39% (DM basis), but ranged from 0.34 to 0.48%.

Based upon averages (Tables 3 and 4) from the 6,366 head of cattle, 11.6% of the feed N and 16.9% of the feed P was retained by the animal with the remaining nutrients excreted. On average, 56.3 lb of N and 9.1 lb of P (DM basis) were excreted per fed beef animal.

Based upon collected data, manure solids contents and nutrient contents of harvested manure were generated (Table 2). On average, 1.0 ton of manure (as-is) was removed per finished animal (15.9 lb/head/day). The harvested manure averaged 73% dry matter (71% during the winter and

(Continued on next page)

spring; 77% during the summer and fall) and 28% organic matter (OM). The wide range of observed organic matter levels (9 to 63%) reflected the amount of soil that was being hauled out of pens. Feedlot surface conditions during manure harvest and pre-harvest periods substantially impacted the amount of soil that was mixed with the manure. Percent ash (100 - % OM) is a potential marker for amount of soil contamination at the time of cleaning. Typically, without the addition of soils, 10-20% ash content of the manure would be expected.

The data from this study provide an indication of nutrients harvested from feedlots and available for land application. After 123 days in the pen on average, 31% of the excreted N or (17.2 lb/fed animal) and 90% of the excreted P (or 8.1 lb/fed animal) were recovered in harvested manure. The N unaccounted for by these measurements can likely be explained by N that volatilizes as ammonia and the dissolved or suspended N in feedlot runoff (5% or less of excreted N).

The only anticipated P loss would be from P contained in the runoff, which is 5% or less of excreted P. Thus, an estimate of P recovery of slightly less than 100% would be anticipated. These data (Table 4) indicate an average of 9.8% P loss. Although there is variation, one factor that might explain variation in P loss is feedlot conditions prior to and during manure harvesting. 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. Higher soil inclusion with the manure solids may cause 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 P in manure to exceed P excretion. P in manure would also be greater than P excretion if some P was removed at cleaning that was remaining in the pen from a previous group of cattle. If cleaning differences exist, it is challenging to match harvested P to P excreted.

Table 5. Characteristics of manure samples collected at six Nebraska feedlots.

	Summary manure samples (DM basis)							
Feedlot	# of samples	Total N %	P %[a]	pH	Ash %	OM %	DM %	N:P
I	3	1.72	1.06	7.3	62.6	37.4	71.1	1.6
II	8	2.42	1.13	7.3	46.1	54.0	76.2	2.1
III	9	1.50	0.89	7.6	66.9	33.1	74.0	1.7
IV	11	1.33	0.59	8.1	68.3	31.7	70.6	2.3
V	15	0.77	0.31	8.1	81.4	18.6	71.3	2.4
VI	7	0.84	0.39	7.8	82.0	18.0	84.9	2.2
Total/average	53	1.32	0.64	7.8	69.9	30.1	74.1	2.1

[a]P = Elemental Phosphorus. In order to convert to P_2O_5, multiply elemental P values by 2.29.

Table 6. Summary of average amounts and characteristics of manure harvested from six Nebraska feedlots.

	Manure harvested						
Feedlot Summary	DM lb/head/day	OM %	OM lb/head/day	Manure % N	Manure N lb/head/day	Manure % P	Manure P lb/head/day
I	2.5	37.8	0.9	1.72	0.04	1.06	0.026
II	7.6	54.9	4.2	2.34	0.18	1.06	0.080
III	10.2	32.7	3.3	1.47	0.15	0.88	0.089
IV	12.7	32.0	4.1	1.33	0.17	0.59	0.075
V	20.4	19.3	3.9	0.72	0.15	0.30	0.061
VI	3.4	19.1	0.7	0.89	0.03	0.38	0.013
Average[a]	11.6	27.8	3.2	1.21	0.14	0.57	0.066
CV	83	55	45	55	47	60	49

[a]Values are average for the 22 cleaning periods.

Another factor that might explain the variability in P loss is that in some instances, scraped manure is used in maintenance of the mounds in the pens. Manure solids are not removed from the pen, resulting in a lower average quantity of harvested manure from the feedlot. Therefore, it may be difficult to always predict P in harvested manure from the amount excreted. However, these data in Table 4 suggest most (90.2%) of the excreted P is hauled away in manure, at least eventually, and may be a good indicator of the P needing distribution to crop land in nutrient management plans. But, pen-to-pen variation should be expected with a coefficient of variation as high as 49%.

These data suggest a positive correlation between P intakes and manure P. With an increase in P intake, manure P increased in these Nebraska feedlots, and was positively correlated ($r = 0.56$; $P < 0.01$) to P intake.

One additional source of information that will add to our ability to manage manure nutrients is the database of feedlot manure samples. Few summaries of typical feedlot manure characteristics exist especially for cattle fed by-products of corn processing. Based upon a database of 53 samples, Table 5 summarizes average values for N, P, total solids and volatile solids for feedlot manure from these Nebraska feedlots.

Another source of information is the comparative summary of average quantities of manure solids harvested from the feedlots in the study. Based upon the 40 lots of cattle fed in the six feedlots, Table 6 summarizes average quantitative values for each feedlot for DM, OM, N and P on a per head/day basis for harvested manure. Also shown are the average characteristics for percent OM, N, and P. On average, manure harvested values from the six feedlots for DM, OM, N, and P are 11.7, 3.2, 0.14, and 0.066 lb/head/day, respectively. The data in Table 6 further illustrate the variation which exists between individual feedlots and emphasize the need for determining individual values of P harvested from individual feedlots under individual management and pen conditions, if accurate and realistic NMPs are to be implemented.

An interesting comparison of quantity of manure nutrients from beef cattle can be made. The average values for harvested manure N and P from the 6,366 cattle fed in six Nebraska feedlots with dirt pens were compared to values calculated from the NRCS reference (USDA, 1992) for beef feedlot manure from an unsurfaced lot, and were well below NRCS projections. These data indicated an average 0.14 lb N/head/day and 0.066 lb P/head/day in harvested manure. This compared to values of 0.21 lb N/head/day and 0.137 lb P/head/day in manure nutrients calculated from the 1992 NRCS reference for the same average weight animal (980 lb) fed over the 123 days.

Although the average 0.39% P concentration (Table 1) of the diets fed in this study was higher than a conventional corn-based diet, the quantity of P removed (lb/head/day) in the manure harvested in these feedlots was 50% less than the amount obtained from calculation based on the 1992 NRCS reference for comparable weight animals.

These data suggest estimates based on the current NRCS reference (USDA, 1992) of P removed in manure are too high, and indicate acres required for distribution of manure P in NMPs should be 50% of the acres predicted by the NRCS reference. The characteristic and quantitative summary values of the feedlot manure harvested from these Nebraska feedlots are a significant improvement over existing standard values currently used in nutrient planning processes by producers, regulators, and planners.

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