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Abstract. *A commercial feedlot study was conducted to determine manure nutrient flow in six feedlots representing 6,366 cattle. On average, cattle involved in this summary were yearlings (BW = 353 kg) and gained 183 kg over 123 d. It was calculated that 11.5% of the feed nitrogen and 16.9% of the feed phosphorus was retained by the animal with the remaining nutrients excreted. On average, 25.6 kg of N and 4.1 kg of P (DM basis) were excreted per fed beef animal. On average, 887 kg total manure (solids and water) were removed per finished animal (7.2 kg/animal/d) averaging 73% total solids. Approximately 28% of the total solids are volatile solids with a wide range of observed volatile solids levels (9 to 63%). Based upon these data, 30.7% of the excreted nitrogen or (7.8 kg/animal fed) and 90.2% of the excreted phosphorus (or 3.7 kg/animal fed) were removed in manure at cleaning.*

These data suggest there is variation in the amount of P harvested from beef feedlots, reflecting the variation between feedlots as a result of individual pen conditions, and requirements for use and handling of the manure in the pen prior to harvesting.

These data suggest that estimates based on the references (ASAE, 2000; USDA, 1992) of P removed in manure are too high, and indicate that acres required for distribution of manure P in NMPs should be 50% of the acres predicted by those references.

Keywords. Phosphorus, Nitrogen, beef cattle feedlots, nutrient mass balance, feedlot manure characteristics, nutrient management plans

Introduction

Little quantitative data exist for manure phosphorus (P) harvested from open lot beef cattle production systems. Previous work at the University of Nebraska suggests 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. Thus, an important objective of this study is to quantify the harvested manure phosphorus and other nutrients from open lot beef cattle production systems, and to conduct a mass balance for P entering and exiting a feedlot. Particularly, can nutrient management plans for feedlots be developed by knowing the amount of P fed?

Literature Review

With the intensification of livestock production, the resultant problems associated with the proper management of the animal manure produced by livestock operations have been magnified. Loehr (1968), Gilbertson et al. (1971), Breeuwsma et al. (1995), and Mallin and Cahoon (2003) are among the many investigators who have studied this problem. Along with nitrogen, phosphorus (P) is implicated in the pollution of our environment (Sharpley et al., 1994; Correll, 1998) through eutrophication of our waters. Animal manure, along with commercial fertilizers, is a source of P in agricultural runoff. Many researchers and regulatory bodies (Sharpley et al., 1994; Parry, 1998; CAST, 2002; Gossin et al., 2003; USEPA, 2003) have offered their perspective on managing agricultural phosphorus for the protection of our water quality. The USEPA (2003) final rule will encourage concentrated animal feeding operations (CAFOs) to effectively manage the 300 million tons of manure produced annually in the US in order to protect the nation's water quality.

Sweeten (1991) concluded that feedlot managers can control water pollution by proper focus on manure and wastewater management in addressing environmental concerns. Erickson et al. (1999) suggested that P supplementation in yearling steers, as well as calf feds (Erickson et al., 2002), is unnecessary. Erickson et al. (2000) concluded that decreasing dietary P will decrease P excretion. Koelsch (2005) observed that decisions relative to protein and phosphorus content of diet can alter the land requirements for managing manure nutrients from beef feedlots. Klopfenstein and Erickson (2002) observed that removal of P supplements is an important nutritional management option to help feedlots become more environmentally sustainable. Geisert et al (2005) also established that P intake is positively correlated to P excretion.

USDA (1992) provides data for estimating manure excretion by beef cattle and manure harvested in open lot production systems. Revised standards proposed by Erickson et al. (2003) for P excretion by feedlot cattle, which are 50% lower than the previous ASAE standards (2000), have recently been accepted by ASAE (R. Koelsch, personal communication). While improvements can be made by incorporating P intake and retention, P removed as manure solids with various feedlot diet scenarios is still unknown. It is important that correct estimates of P removed in manure are utilized by producers if nutrient management plans are based on utilization of manure P. If over-predicted, acres required for appropriate distribution will be inflated.

Procedure

Feedlot Study

Six central and eastern Nebraska feedlots were recruited during the fall of 2003 to participate in a study to quantify the manure and nutrients harvested from a cross-section of commercial operations found in the mid-west. The six lots ranged in size from less than 5,000 head to more than 20,000 head one-time capacity. Each of the feedlots were asked 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 on a per animal basis will be defined as amount per head (hd). The period of time of data collection from the pens ranged from mid-October 2003 through December 2004.

Feed intake and nutrient profile by diets fed 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 was determined from data supplied by the feedlot for cattle weight in and out, number of animals, and days on feed for each lot of cattle.

All pens that were involved in this study were required to have been initially cleaned prior to entry of study cattle. Manure removal from feedlot pens is typically completed after a pen of cattle is marketed and prior to the next group of cattle arriving. In this study, in some instances, several lots 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 utilized to maintain the integrity of mounds within the pens. During this study, as the manure solids were being harvested out of pens, gross and tare weights of loads of manure removed and representative manure samples for nutrient analysis were collected for all pens of cattle included in the study. Manure was weighed on an as-is basis and either hauled directly for land application, or transferred to stockpile or compost yard.

Nutrient Analyses

Nutrient profile analyses of manure and feed samples were completed by Ward Laboratories, Inc. of Kearney, Nebraska.

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.

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 excreted was calculated by subtracting nutrient retention from nutrient intake. (Figure 1 and Appendix).

Mass balance for N and P was 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 manure nutrient concentration by amount of manure removed (TS) from the pen surface. Total nutrient lost was calculated by subtracting manure nutrient from excreted nutrient. Percentage of nutrient lost was calculated as nutrient lost divided by total nutrient excretion. All nutrient values were expressed on a kg/animal basis. Nutrient mass balance was determined for N and P. Figure 2 illustrates the pen nutrient mass balance concept.

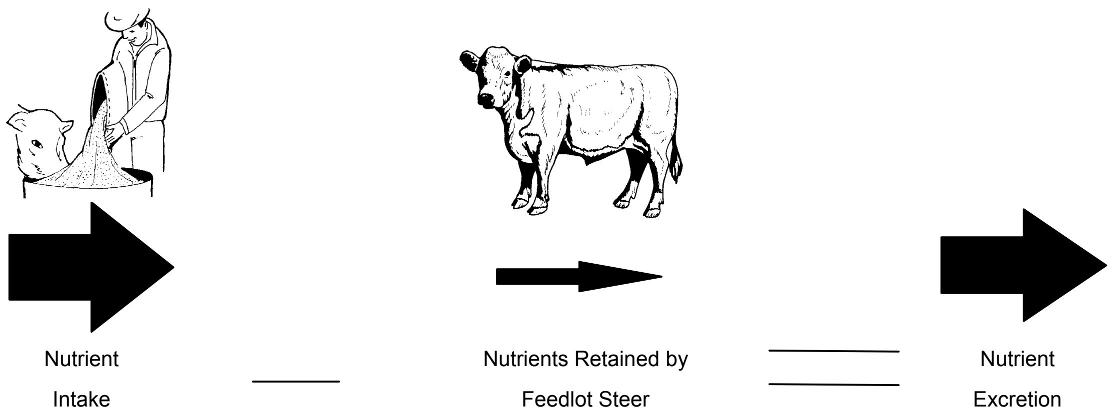

Figure 1. Nutrient balance method was utilized for calculating nutrient excretion by feedlot cattle. This approach incorporates nutrient intake and retention. The general scheme was similar for all nutrients, but specific retention values were based on NRC (NRC, 1996) equations.

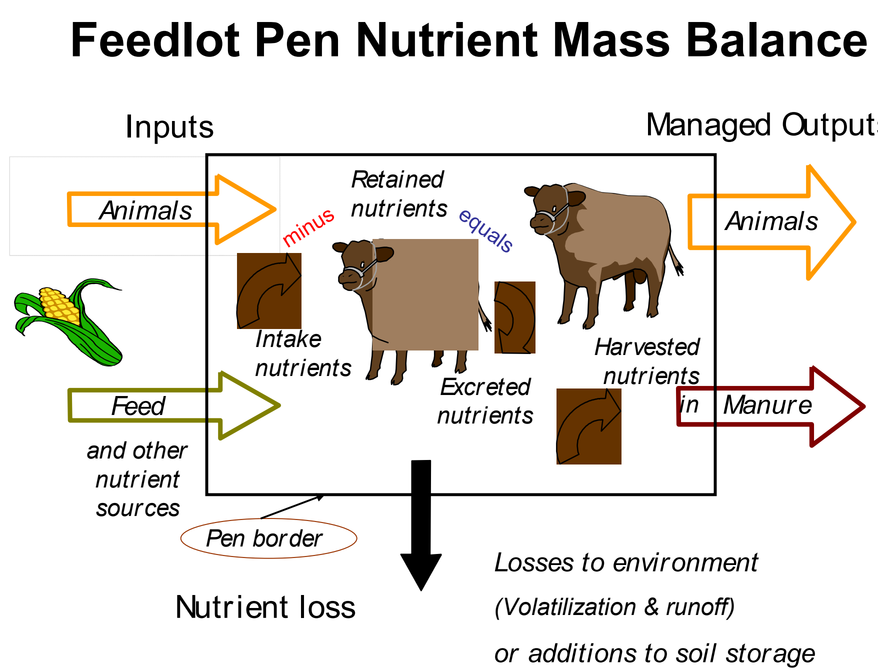

Figure 2. Feedlot pen nutrient mass balance concept was utilized for pens of feedlot cattle for determining nutrient mass balance for N and P.

Results

Data summarized in Table 1 are for cattle fed from October 2003 through December 2004. On average, cattle involved in this summary were yearlings (BW = 353 kg) and gained 183 kg over 123 d. The data was partitioned into two feeding periods: winter/spring and summer/fall feeding periods, and subsequent manure harvesting for each of these periods, in order to illustrate any differences between the average values for the two feeding periods.

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

	Performance[a]				*Feeding period*[b]	
Variable	*Mean*	*CV*[c]*, %*	*Minimum*	*Maximum*	*Winter/spring*	*Summer/fall*
Cattle, n	*167*	*28*	*94*	*262*	*182*	*151*
Days	*123*	*34*	*45*	*199*	*145*	*102*
Initial BW[d]*, kg*	*353*	*14*	*230*	*459*	*339*	*367*
Final BW[d]*, kg*	*536*	*12*	*378*	*635*	*553*	*518*
ADG, kg	*1.47*	*9*	*1.24*	*1.75*	*1.47*	*1.47*
F:G (DMI/ADG)	*7.03*	*9*	*5.70*	*8.04*	*6.83*	*7.22*

[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.

[c]CV = Coefficient of Variation.

[d]BW = Body weight

Feed input is a critical nutrient input evaluated by this study. The average nutrient intake was 0.23 kg N/animal/day (28.9± 3.5 kg/animal fed) and 40.2 g P/animal/day (4.9 ± 1.0 kg/animal fed) for the 123 d average feeding period (Table 2). For an industry average 153 d feeding period, this would amount to 35.9 kg N/animal fed and 6.2 kg P/animal fed. All feedlots were using a corn and byproduct based diet with an average P of 0.39% (DM basis), but ranged from 0.34 to 0.48%. 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 by-product replacement of corn. Due to the recent growth in ethanol production in Nebraska and the economics of feeding by-products, we were unsuccessful in identifying feedlots that were not using by-products.

Based upon these data, a summary of manure solids and related nutrient content is generated (Table 3). On average, 887 kg total manure (solids and water) were removed per finished animal (7.2 kg/animal/d). The harvested manure averaged 73% total solids (TS), (71% during the winter and spring; 77% during the summer and fall). Approximately 28% of the total solids are volatile solids (VS) with a wide range of observed volatile solids levels between individual cleanout periods (9 to 63%). Feedlot surface conditions during manure harvest and pre-harvest periods substantially impact the amount of soil that is mixed with the manure. Percent ash (100 - % VS) is a potential marker for amount of soil contamination at the time of cleaning.

Table 2. Feed nutrient intake data collected by cleaning period after two feeding periods for cattle lots fed in six Nebraska feedlots.

	Nutrient intake[a]				*Feeding period*[b]	
Variable	*Mean*	*CV*[c]*, %*	*Minimum*	*Maximum*	*Winter/spring*	*Summer/fall*
DMI, kg/hd/d	*10.22*	*9*	*8.74*	*11.18*	*9.88*	*10.56*
CP, %	*14.35*	*8*	*13.35*	*16.58*	*14.17*	*14.53*
N, kg/hd/d	*0.23*	*12*	*0.19*	*0.29*	*0.22*	*0.25*
P, %	*0.39*	*13*	*0.34*	*0.48*	*0.38*	*0.41*
P, g/hd/d	*40.2*	*20*	*30.2*	*52.4*	*37.2*	*43.2*

[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.

[c]CV = Coefficient of Variation

Table 3. Manure harvested data collected by cleaning period after two feeding periods for cattle lots fed in six Nebraska feedlots.

	Manure characteristics[a]				*Feeding period*[b]	
Variable	*Mean*	*CV*[c]*, %*	*Minimum*	*Maximum*	*Winter/spring*	*Summer/fall*
As-is, kg/hd/d	*7.2*	*79*	*0.8*	*27.7*	*7.9*	*6.5*
TS, %	*73.2*	*13*	*58.8*	*94.4*	*70.6*	*76.5*
TS, kg/hd/d	*5.3*	*83*	*0.6*	*21.5*	*5.6*	*4.9*
VS, %	*27.8*	*55*	*8.8*	*63.0*	*33.5*	*34.6*
VS, kg/hd/d	*1.5*	*45*	*0.2*	*2.8*	*1.3*	*1.61*
N, %	*1.21*	*55*	*0.44*	*2.51*	*1.40*	*1.53*
N, kg/hd/d	*0.06*	*47*	*0.01*	*0.13*	*0.06*	*0.07*
P, %	*0.57*	*60*	*0.21*	*1.18*	*0.66*	*0.76*
P, g/hd/d	*30.1*	*49*	*2.7*	*58.1*	*25.4*	*34.9*

[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.

[c]CV = Coefficient of Variation.

Based upon averages (Tables 4 and 5) from the 6,366 head of cattle, 11.6% of the feed nitrogen and 16.9% of the feed phosphorus was retained by the animal with the remaining nutrients excreted. On average, 25.6 kg of N and 4.1 kg of P (DM basis) were excreted per fed beef animal.

Table 4. Nitrogen balance data by cleaning period for cattle lots fed in six Nebraska feedlots.

	Nitrogen balance[a]				Feeding period[b]	
Variable	*Mean*	*CV[c], %*	*Minimum*	*Maximum*	*Winter/spring*	*Summer/fall*
N intake, g/hd/d	*234.6*	*12*	*188.5*	*291.1*	*224.0*	*245.2*
N retain, g/hd/d	*27.0*		*14.1*	*36.8*	*28.6*	*25.5*
N excrete, g/hd/d	*207.6*		*157.4*	*264.9*	*195.4*	*219.7*
N manure, g/hd/d	*63.7*	*47*	*6.2*	*125.9*	*56.4*	*71.0*
N lost, g/hd/d	*143.9*		*62.2*	*193.6*	*139.0*	*148.8*
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.

[c]CV = Coefficient of Variation.

Table 5. Phosphorus balance data by cleaning period for cattle lots fed in six Nebraska feedlots.

	Phosphorus balance[a]				Feeding period[b]	
Variable	*Mean*	*CV[c], %*	*Minimum*	*Maximum*	*Winter/spring*	*Summer/fall*
P intake, g/hd/d	*40.2*	*20*	*30.2*	*52.4*	*37.2*	*43.2*
P retain, g/hd/d	*6.8*		*5.4*	*9.0*	*7.0*	*6.6*
P excrete, g/hd/d	*33.4*		*22.7*	*50.4*	*30.2*	*36.6*
P manure, g/hd/d	*30.1*	*49*	*2.7*	*58.1*	*25.4*	*34.9*
P lost, g/hd/d	*3.3*		*-21.4*	*24.4*	*4.8*	*1.7*
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.

[c]CV = Coefficient of Variation.

These data also provide an indication of nutrients harvested from feedlots for land application. Based upon these data, 31% of the excreted nitrogen or (7.8 kg/fed animal) and 90% of the excreted phosphorus (or 3.7 kg/fed animal) were recovered. The nitrogen unaccounted for by these measurements can likely be explained by nitrogen that volatilizes as ammonia and other nitrogen forms, and the dissolved or suspended nitrogen in feedlot runoff. However, less than 5% of excreted nitrogen is generally lost via surface runoff while manure is in pens (Bierman et al., 1999; Clark et al., 1975; Erickson and Klopfenstein, 2001a; Erickson and Klopfenstein, 2001b).

These data suggest a positive correlation between P intakes and manure P (Figure 3). 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.

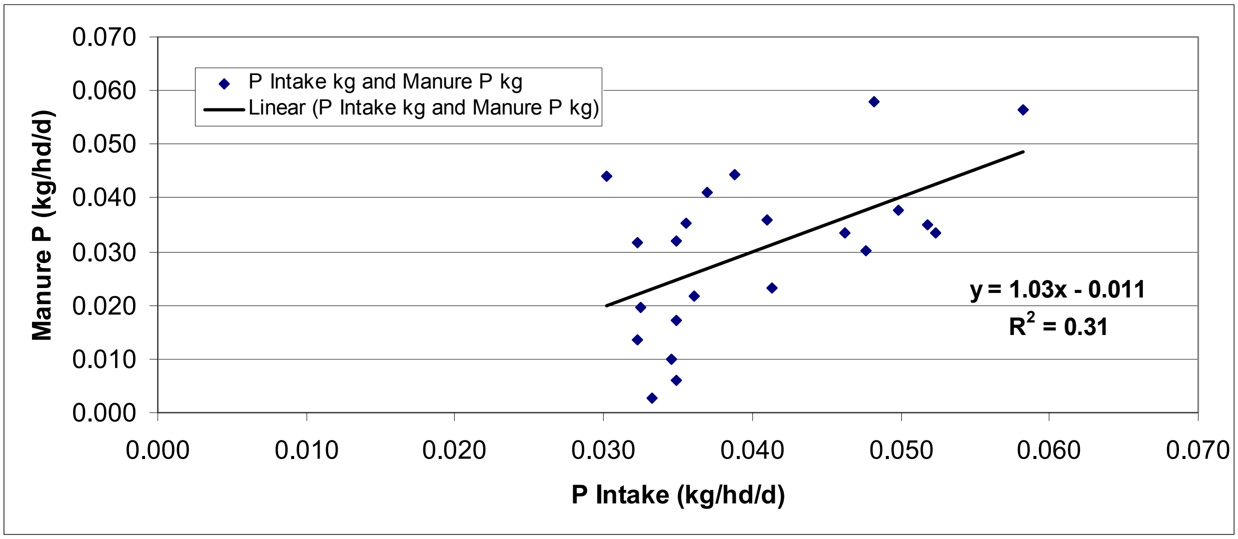

Figure 3. Relationship between P intake and manure P (kg/hd/d) for cattle in Nebraska feedlots.

Discussion of Results

The only anticipated P loss would be from P contained in the runoff, which is 5% or less of excreted phosphorus (Clark et al., 1975; Erickson and Klopfenstein, 2002). Thus, an estimate of P recovery of slightly less than 100% would be anticipated. These data (Table 5) indicate an average of 9.8% P loss. Although there is variation, one factor that might explain variation in P lost 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 manure P to P excreted.

Another factor that might explain the variability in P loss is that in some instances, scraped manure is utilized 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 manure from the amount excreted. However, these data in Table 5 suggest that most (90.2%) of the P excreted is hauled away in manure, at least eventually, and may be a good indicator for predicting P needing distribution in nutrient management plans required for feedlots. But, pen to pen variation should be expected with a coefficient of variation as high as 49%.

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 6 summarizes average values for N, P, total solids and volatile solids for feedlot manure from these Nebraska feedlots. These values are likely to improve on typical values currently used in nutrient planning processes by producers, regulators, and planners.

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

	Summary manure samples (DM basis)							
Feedlot	*# of samples*	*Total N %*	*[a]P %*	*pH*	*Ash %*	*VS %*	*TS %*	*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*	*46.0*	*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.

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 7 summarizes average quantitative values for each feedlot for total solids (TS), volatile solids (VS), N and P on a hd/d basis for harvested manure. Also shown are the average characteristics for percent VS, N, and P. On average, manure harvested values from the six feedlots for TS, VS, N, and P expressed per head per day fed are 5.3 kg, 1.5 kg, 0.06 kg, and 30.1 g, respectively.

Table 7. Summary of average amounts and characteristics of manure harvested from six Nebraska feedlots.

	--Manure Harvested--						
Feedlot Summary	TS kg/hd/d	VS %	VS kg/hd/d	Manure %N	N manure kg/hd/d	Manure % P	P manure g/hd/d
I	1.1	37.8	0.4	1.72	0.02	1.06	12.0
II	3.4	54.9	1.9	2.34	0.08	1.06	36.4
III	4.6	32.7	1.5	1.47	0.07	0.88	40.4
IV	5.8	32.0	1.8	1.33	0.08	0.59	34.2
V	9.3	19.3	1.8	0.72	0.07	0.30	27.6
VI	1.5	19.1	0.3	0.89	0.01	0.38	5.9
Average[a]	5.3	27.8	1.5	1.21	0.06	0.57	30.1
CV[b]	83	55	45	55	47	60	49

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

[b]CV = Coefficient of Variation.

These data in Table 7 further illustrate the variation which exists between individual feedlots. For example, feedlots II, III, and IV averaged relatively close in TS, ranging in average values from 3.4 kg/hd/d to 5.8 kg/hd/d. Feedlot V averaged 9.3 kg/hd/d TS harvested with average VS at 19%. The high ash content, in conjunction with the relatively high TS, indicates that a relatively large amount of soil was removed from this feedlot.

In comparison, feedlots I and VI harvested below average amount of TS, 1.1 kg/hd/d and 1.5 kg/hd/d, respectively, illustrating the difference in management technique, and other possible differences in pen conditions and maintenance. This may have resulted in more manure remaining on the pen surface compared to the average in feedlots II, III, IV, and V. These two feedlots also were below average in amounts of VS, N, and P harvested. The variation in harvested values for VS, N, and P between the six feedlots should be expected with coefficient of variation ranging from 45% to 49%. The coefficient of variation for TS for the six feedlots is also relatively large at 83%.

As a group, feedlots II, III, IV, and V were relatively close to the average value of 30.1 g/hd/d manure P. Feedlots I and VI were well below the average, with values of 12.0 g/hd/d and 5.9 g/hd/d manure P, respectively. These data effectively illustrate the variation between feedlots in manure P harvested. From these data, suggested recommendations for average manure TS, VS, N, and P estimates which could be used in a nutrient management plan (NMP) are 5.3 kg/hd/d, 1.5 kg/hd/d, 0.06 kg/hd/d, and 30.1 g/hd/d, respectively. However, these data 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 is in Table 8. These data compare the average values for harvested manure nutrients from the 6,366 cattle fed in six Nebraska feedlots with dirt pens to values calculated from the NRCS reference (USDA, 1992) for beef waste characteristics for feedlot manure from an unsurfaced lot.

Table 8. Comparison of quantity of manure nutrients (kg/hd/d) from beef cattle.

Source	TS kg/hd/d	VS kg/hd/d	N manure kg/hd/d	P manure kg/hd/d
Feedlot Summary[a]	5.3	1.5	0.06	0.03
NRCS[b]	4.3	2.1	0.09	0.06

[a]Animals fed from 353 to 536 kg over 123 days, consuming high concentrate diet.

[b]Calculated from reference USDA-NRCS (1992) AWMFH, Table 4-9, assuming average body weight of 445 kg.

The average total solids in the six feedlots of 5.3 kg/hd/d was 23% higher than the 4.3 kg/hd/d TS calculated from the NRCS reference, while the average volatile solids recorded for the feedlots was 71% of the calculated VS from the NRCS reference.

These data suggest the amount of N and P (kg/hd/day) in harvested manure to be less than the values calculated from the NRCS reference for comparable weight beef cattle. On average, these data indicate approximately 67% of the manure N (0.06 kg/hd/d) and 50% of the manure P (0.03 kg/hd/d) were harvested from these six Nebraska feedlots, compared to the amounts calculated from the NRCS reference (0.09 kg/hd/d manure N and 0.06 kg/hd/d manure P).

Although the average 0.39% P concentration (Table 2) of the diets fed in this study was higher than a conventional corn based diet, the quantity of P removed (kg/hd/d) 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 that estimates based on the references (ASAE, 2000: USDA, 1992) of P removed in manure are too high, and indicate that acres required for distribution of manure P in NMPs should be 50% of the acres predicted by those references.

Conclusion

- These data suggest that the amount of P harvested in manure from beef feedlots varies with 1) level of P in the diets 2) individual pen conditions prior to and at time of manure harvesting, and 3) requirements for use of manure solids for surface maintenance prior to harvesting.
- These data indicate a positive correlation between P intake and P in harvested manure, and should assist in the determination of quantities of P in harvested manure in individual beef feeding operations.
- 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.
- It is important that correct estimates of P excretion are utilized by producers if NMPs are based on utilization of manure P. It is recommended that producers, regulators, and planners use revised ASAE standards to estimate P excretion.
- From these data, suggested recommendations for average manure TS, VS, N, and P estimates which could be used in a NMP are 5.3 kg/hd/d, 1.5 kg/hd/d, 0.06 kg/hd/d, and 30.1 g/hd/d, respectively. However, these data 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.
- These data suggest that estimates based on the references (ASAE, 2000; USDA, 1992) of P removed in manure are too high, and indicate that acres required for distribution of manure P in NMPs should be 50% of the acres predicted by those references.

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Appendix

Definition of Input Variables

Variable	Description	Units	Source for Input Data*
Animal performance characteristics			
LW	Live weight	kg	
LW_f	Live weight at finish of feeding period (market weight)	kg	
LW_s	Live weight at start of feeding period (purchase weight)	kg	
SRW	Ideal shrunk weight for preferred body fat	kg	NRC 1996, page 116
Feed program characteristics			
DMI	Dry matter intake	kg / day	NRC 1996, page 85
C_{cp}	Concentration of crude protein of total ration	%	
C_P	Concentration of phosphorus of total ration	%	
DOF	Days on feed for individual ration	days	
DOF_t	Days on feed for entire feeding period	days	
x	Ration number		
n	Total number of rations fed		

Definition of Output Variables

Variable	Description	Units
N_E	Nitrogen excretion	kg of nitrogen/day/animal
N_{E-T}	Total nitrogen excretion per finished animal	kg of nitrogen/finished animal
P_E	Phosphorus excretion	kg of phosphorus/day/animal
P_{E-T}	Total phosphorus excretion per finished animal	kg of phosphorus/finished animal

Equations for Calves and Finishers in Confinement[1]

Nitrogen Excretion Equation

$$N_{E-T} = \sum^{n}_{x=1} (DMI_x * C_{cp-x} * DOF_x * / 6.25) - [0.0412 * (LW_f - LW_s)] + [0.000243 * DOF_t * [(LW_f + LW_s) / 2]^{0.75} * (SRW / (LW_f * 0.96))^{0.75} * [(LW_f - LW_s) / DOF_t]^{1.09} \quad (1)$$

$$N_E = N_{E-T} / DOF_t \quad (2)$$

Phosphorus Excretion Equation

$$P_{E-T} = \sum^{n}_{x=1} (DMI_x * C_{P-x} * DOF_x) - [0.0100 * (LW_f - LW_s)] + \{5.92 * 10^{-5} * DOF_t * [(LW_f + LW_s) / 2]^{0.75} * (SRW / LW_f * 0.96)^{0.75} * [(LW_f - LW_s) / DOF_t]^{1.097}\} \quad (3)$$

$$P_E = P_{E-T} / DOF_t \quad (4)$$

[1]Erickson et al., 2003.