

PROPOSED BEEF CATTLE MANURE EXCRETION AND CHARACTERISTICS STANDARD FOR ASAE

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ABSTRACT

A committee was formed consisting of both animal scientists and agricultural engineers to evaluate and update current ASAE standards. An intake minus retention model was developed to estimate nutrient excretion. This approach allows users (producers, engineers, etc.) to develop site specific information based on known variables such as protein or phosphorus content of diets and cattle performance. This approach illustrates the importance of nutrition on nutrient excretion in livestock operations. Our focus is for feedlot cattle and updates excretion of dry matter (DM or total solids), organic matter (OM or volatile solids), N, P, Ca, K, Na, Mg, S, Cu, Fe, Se, Zn, Mn, Co, and I.

Based on survey data of 19 nutritionists that control formulation for approximately 50% of the cattle fed in the U.S., the average diet contains 13.3% crude protein (2.13% N) and 0.31% P. Based on performance of approximately 14 million cattle fed from 1996 to 2002, the "average" steer is fed 153 days. This steer weighs 338 kg at arrival, finishes at 554 kg, gains 1.42 kg per day and consumes 8.84 kg of DM each day. With the "average" diet concentrations and consumption amounts for feedlot steers fed in the U.S, we can accurately estimate nutrient intake. Retention of nutrients in the animal during growth is the other critical component to using an intake minus retention based model for excretion. Retention of nutrients was calculated from gains using the 1996 National Research Council Nutrient Requirements of Beef Cattle to calculate N, P, and Ca retention. Retention of other minerals was based on 10% of intake being retained when fed at requirements.

Average excretion values for DM, OM, N, P, Ca, K, Na, Mg, S, Cu, Fe, Se, Zn, Mn, Co, and I expressed for the entire 153 day period or per finished steer are 270 kg, 220 kg, 24.8 kg, 3.2 kg, 7.8 kg, 9.2 kg, 1.8 kg, 2.7 kg, 2.4 kg, 19.4 g, 68.9 g, 0.27 g, 96.1 g, 49.1 g, 0.31 g, and 0.93 g, respectively. In some cases, the new values are much lower than current standards. For example, P excretion is 6.3 kg for the average steer weighing 446 kg (average live weight) fed 153 days based on the previous standard. The revised P excretion based on intake minus retention is 3.2 kg or 50.8% of the previous standard. The proposed excretion values should allow for more accurate planning and allow users to tailor excretion to site-specific situations by incorporating cattle performance, days on feed, weights, and nutrient content of diets.

While the previous standard does not account for variation, considerable agreement was found between the current intake minus retention model for excretion and the previous standard. Excretion of DM, OM, P, and Ca were identical between the average excretion estimate using the current model and the previous standard for calves gaining 0.9 kg per day, weighing 295 kg.

KEYWORDS. ASAE standards, manure, nutrient excretion, beef cattle, modeling

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INTRODUCTION

Engineers, producers, and regulators use the ASAE Manure Production and Characteristics standard to determine nutrient output from livestock operations. Greater attention to nutrient management is occurring. Precise values for manure nutrients are needed to estimate land needed to recycle nutrients. An important first-step is to accurately define nutrient excretion by cattle. If overestimated, then acres and size requirements are inflated which increases operator costs. If underestimated, then access to acres and sizing for manure storage will be an environmental liability. In recent years, animal nutritionists have become more aware of the environmental challenges facing producers and focus has been placed on methods to decrease the nutrient intake, thereby decreasing nutrient output. The amount of nutrient excreted is directly proportional to nutrients consumed. If nutrients are underfed, then performance is hindered. Therefore, formulation practices used by producers and nutritionists should meet nutrient requirements while minimizing excesses. The objective of this paper is to summarize efforts of the committee to update ASAE standards for beef cattle, using available data on diet formulation practices, performance of cattle, and a unique approach of estimating nutrient excretion by measuring intake and subtracting the amount of nutrient retained by the feedlot steer during growth. The approach will be outlined and nutrient excretion from this new model compared to previous standards.

MATERIALS AND METHODS

Feedlot cattle

Diet formulation and concentration of nutrients such as crude protein, N, P, and others are critical factors in determining the amount of nutrients excreted (CAST, 2002). Therefore, evaluation of feed inputs must play a role in accurate determination of nutrient excretion, and accounting for variation from operation to operation. The nutrient concentration must be combined with consumption (dry matter intake or DMI is commonly used) to calculate the amount in kg, g, or mg of nutrient intake per animal. The feedlot steer will retain some (usually small amounts relative to intake) of the nutrients in the body, whereas the remainder is excreted in either urine or feces. The difference between amount consumed and amount retained in the body is equivalent to the nutrient excreted (Figure 1). This is the approach utilized to update the nutrient excretion standards for beef cattle.

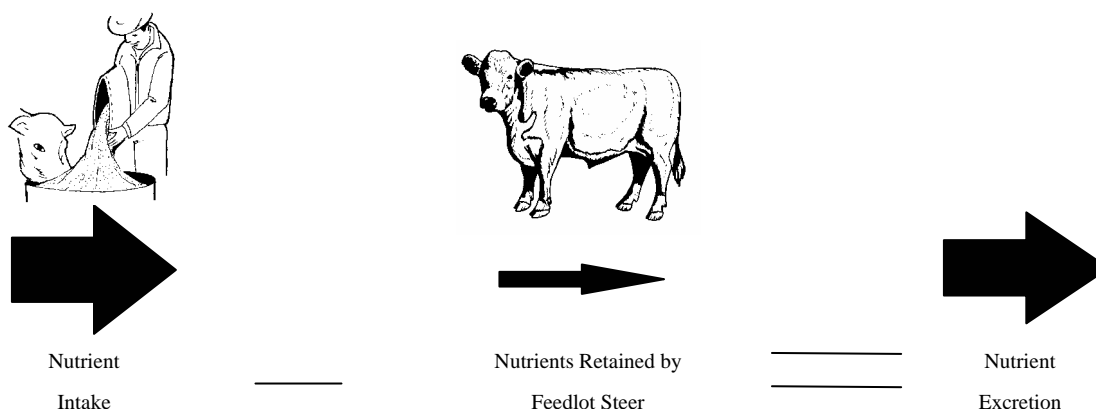


Figure 1. Nutrient balance method was utilized for calculating nutrient excretion by feedlot cattle. This approach incorporates nutrient intake and retention. The general scheme was similar for all nutrients, but specific retention values were based on NRC (NRC, 1996) equations.

Average Diet

For accurate determination of intake, both DMI and nutrient concentration must be known. Concentrations of various nutrients used by feedlots were evaluated using a survey of 19

nutritionists (Galyean and Gleghorn, 2001). While small in number, these 19 nutritionists formulated diets for approximately 14 million head fed per year or 50% of beef feedlot cattle. The average concentrations with minimum and maximum values that were formulated are provided in Table 1. One deviation was assumed for P because of common experience with byproduct feeding common in certain regions of the U.S. The maximum concentration for P was assumed to equal 0.50% of diet DM.

Average Performance

To calculate the amount consumed, these concentrations were multiplied by DMI. Therefore, we must know "average" performance for feedlot cattle today. This becomes very important for calculation of retention as well. Average performance was based on data collected by Professional Cattle Consultants as part of eMerge Interactive. Data were summarized from 1996 to 2002 for feedlot steers fed in the northern, central, and southern plains regions as closeout summaries from member feedlots. The dataset included 13.94 million head of steers with the "average" animal fed in the U.S. weighing 338 kg initially, gaining 1.42 kg per day, consuming 8.84 kg of DM per day, weighing 554 kg at market, and requiring 153 days "on feed" (eMerge/Professional Cattle Consultants, Weatherford, OK). These were the input data used for calculating retention of N, P, and Ca, and the days for calculation of total excretion. While performance of feedlot cattle is not constant, the large number of cattle represented in this dataset should accurately represent the performance for the past six years. For individual operations, performance should be used that fits their specific operation.

Table 1. Assumed dietary concentration of nutrients (adapted from Galyean and Gleghorn, 2001).

Nutrient	Average concentration	Minimum concentration	Maximum concentration
DM digestibility	80	70	85
OM digestibility	83	73	88
CP, % of DM	13.31	12.50	14.00
P, % of DM	0.31	0.25	0.50
Ca, % of DM	0.70	0.60	0.90
K, % of DM	0.74	0.60	1.00
Mg, % of DM	0.21	0.15	0.30
S, % of DM	0.19	0.10	0.34
Na, % of DM	0.138	0.098	0.197
Cu, mg/kg	14.8	6.0	20.0
Zn, mg/kg	74	50	150
Se, mg/kg	0.21	0.10	0.30

Retention

Retention of N was based on protein retention equations and retained energy equations using the 1996 National Research Council "Nutrient Requirements of Beef Cattle" (NRC, 1996). Combined equations are listed in the appendix along with simplified versions for N and P. The complex equations take into account weights and gain. As gain increases, retention of N, P, and Ca increase. The retention values used for the standard excretion values are based on performance of the "average" animal described initially.

Also included are more simplified equations for N and P assuming a constant retention for weight change. These were back calculated from retention data and compared to literature values available. Retention for all other nutrients besides N, P, and Ca were calculated assuming 10% of the nutrient intake was retained when fed at requirements recommended by NRC. This assumption was used because of lack of data on retention values for all other minerals.

Beef Cows and Growing Calves

During certain times of year, cows are fed in confinement due to low quality or quantity of forage for grazing. Calves are also commonly fed lower energy diets to grow in confinement systems prior to entering the feedlot or being finished. Therefore, the group wanted to provide

nutrient excretion values, expressed as amount per day, for both cows and growing calves. More variation exists in production practices for cows and calves in confinement than with feedlot production practices. We caution the reader that numbers provided are only as accurate as the assumptions regarding diet, weights, etc.

The assumptions we used are: 1) cows weigh 544 kg, 2) DMI is 2.3% of BW, and 3) diet digestibility averages 52% for DM and 55% for OM. Diets in these situations are forage or silage based with 90% OM and 10% ash or mineral. Diets range from 45 to 60% digestible for DM and 48 to 63% for OM digestibility. Nitrogen and P retention were assumed to be zero: Cows are maintaining themselves and not depositing protein in body tissue. We recognize that fetal growth will require some protein retention, but we did not account for fetal growth. Therefore, N and P intake equal N and P excretion.

For growing calves, gain was assumed to be 0.9 kg per day. Diet digestibility ranged from 55 to 70% for DM and 60 to 75% for OM, with the average growing calf weighing 295 kg. Retention of N and P were calculated similar to feedlot cattle.

Calves and cows in these systems may be in confinement for different durations of time. There is no clear endpoint such as marketing with feedlot cattle. Therefore, excretion data are presented as amount per day. Grazing production systems are not presented. A similar approach could be used for grazing cattle if intake and forage nutrient quality (consumed not available) are known. These are very difficult to measure and tremendous variation exists across the U.S. Intake and nutritive quality are simpler measures in confinement systems. Making assumptions on grazing selection and intake would allow for excretion to be estimated using the nutrient intake minus retention model proposed for feedlot cattle. With cows grazing pastures, calf production, i.e. weight gain, would be the only nutrient retention.

RESULTS

Feedlot Cattle

The average consumption of nutrients was based on performance and will be expressed as amount per finished animal. This assumes 153 days fed in the feedlot and will be consistent for presenting retention and excretion values. Assuming 8.84 kg per day for 153 days, total DM, OM, N, and P intakes were 1353, 1300, 28.8, and 4.2 kg, respectively. All excretion values proposed using the intake minus retention model are provided in Table 2. A minimum and maximum excretion was provided to offer insight into variation due to dietary concentration. These values represent the range probable for feedlot cattle today.

Excretion of DM (total solids) was based on an average DM digestibility of 80%. The new value was 270 kg with a range of 210 to 410 depending on diet digestibility ranging from 70 to 85%. Average DM excretion of 270 kg is only 46.6% of the 580 kg as in the previous standard. Excretion of OM followed a similar trend as DM, with current recommendation averaging 220 kg over the 153 days, or 45% of the ASAE standard of 491 kg. This assumes OM digestibility is 83%. The observed range in digestibility is 75 to 88%.

Calculating N intake using the average protein content of 13.3% and intake of 8.84 kg per day results in 28.8 kg of N consumed. Using these body weights and gain, retention of N is only 4.2 kg or 14.5% of intake. Nitrogen excretion was similar to previous ASAE standard at 108% the previous value. Phosphorus retention was low as a % of intake, averaging 24%. P intake averaged 4.2 kg, retention was 1.0 kg, and subsequent excretion was 3.2 kg. This assumes NRC (1996) retention equations are accurate (appendix). The new recommendation for average P excretion of beef cattle is considerably lower than the previous ASAE standard (52%). The lower P excretion standard would markedly decrease the amount of P estimated at feedlots.

Considerable variation exists for P excretion due to variation in dietary P. Dietary P varies from no supplemental P (0.25% diet P and 2.1 kg excreted) to diets that contain byproducts high in P

(0.50% diet P and 6.4 kg excreted). The previous ASAE standard is similar to the maximum excretion values predicted in diets containing elevated dietary P.

The real advantage of using the intake minus retention model proposed is accounting for changes in dietary concentrations and the subsequent effect on excretion. In the Appendix, NRC equations are provided to calculate N and P retention so producers and engineers can calculate excretion for a specific operation. A simplified equation is also provided for calculating retention based on change in weight while cattle are fed in feedlots. While less sensitive to different weight gains and weights, this method is acceptable because the impact on excretion is small. For example, if retention for P is actually 10% lower (0.9 kg compared to 1.0 kg), then excretion is overestimated by .1 kg. The new excretion number would be 3.3 instead of 3.2, or 3% higher. The most critical factor is accurately measuring nutrient intakes. As a general rule, beef feedlots monitor DMI daily and nutrient composition of diets to ensure optimum performance. This should allow for accurate determinations of nutrient intakes in most beef feedlots.

The remaining minerals in Table 2 were updated using average intakes and assumptions on retention. Similar to P, the retention values may be less precise; however, the impact on excretion is quite small. For all minerals except Zn, the updated excretion values are lower than the previous ASAE standard. However, because the range in dietary concentrations is variable in the feedlot industry, so too is excretion. Except for K and Fe, the previous standard is within the range that might be expected with feedlot diets being fed today.

Table 2. Nutrient excretion standards calculated using an intake minus retention model for beef finishing cattle. Units are expressed as amount per finished animal^a, either kg or g.

Nutrient	Units	Average excretion	Minimum excretion	Maximum excretion	Previous standard ^b
Total solids, DM	kg	270	210	410	580
Volatile solids, OM	kg	220	160	330	491
Nitrogen, N	kg	24.6	21	29	23.2
Phosphorus, P	kg	3.2	2.1	6.4	6.3
Calcium, Ca	kg	7.8	5.8	11.0	9.6
Potassium, K	kg	9.2	7.3	12.7	14.3
Magnesium, Mg	kg	2.7	1.9	4.0	3.3
Sodium, Na	kg	1.8	1.2	2.6	2.1
Sulfur, S	kg	2.4	1.2	4.4	3.1
Zinc, Zn	g	96.1	63.6	198.9	75.1
Iron, Fe	g	68.9	60.9	196.2	532.3
Copper, Cu	g	19.4	7.6	26.5	21.2
Manganese, Mn	g	49.1	24.3	105.5	81.9
Selenium, Se	g	0.27	0.12	0.39	--
Cobalt, Co	g	0.31	0.12	0.78	--
Iodine, I	g	0.93	0.60	1.95	--

^aSteer fed from 338 to 554 kg over 153 days, consuming 8.8 kg per day, and diet assumptions in Table 1
^bCalculated from ASAE standard D384.1 DEC99 assuming average body weight of 446 kg and 153 days

Beef Cows and Growing Calves

Excretion amounts for DM, OM, N, P, and Ca are provided in Table 3 for beef cows and growing calves fed in confinement. Amounts are expressed on a per day basis due to varying lengths of times that cows or calves may be held in confinement. Not all minerals were evaluated for beef cows and growing calves because no data exists on the "average" diet fed to these animals or the "average" animal. Calculating excretion of all other minerals is very difficult for these beef animals because the diets consist primarily of forage. Forages can be quite variable in mineral composition from region to region across the U.S.

The intake, retention, and subsequent excretion may change for each individual operation, pen of cattle, or individual animal. Producers, engineers, and others can use this approach for specific situations to accurately predict nutrient excretion of N, P, and Ca. The other nutrients including DM, OM, and minerals may be calculated for specific operations if the correct digestibility (DM

and OM) or retention (other minerals) values are utilized and the intake and diet concentration are known.

For many of the major nutrients (OM, N, and P), average excretion given the animal and diet assumptions used agrees with the previous standard. Interestingly, the previous standard may be based on growing calves fed forage-based diets gaining less than feedlot cattle. The excretion values are identical between the average growing calf data using intake and retention compared to the previous standard for DM, OM, P, and Ca.

Table 3. Nutrient excretion standards calculated for beef cows and growing calves in confinement. Nutrients were limited to only DM, OM, N, P, and Ca. Units are expressed as amount per day, either kg or g.

Nutrient	Units	Average excretion	Minimum excretion	Maximum excretion	Previous Standard ^a
Beef cows weighing 544 kg, consuming 2.3% of BW, with zero retention					
Total solids, DM	kg	6.0	5.1	7.0	4.6
Volatile solids, OM	kg	5.1	4.2	5.9	3.9
Nitrogen, N	g	190	170	250	185
Phosphorus, P	g	44	35	63	50
Calcium, Ca	g	89	--	--	76
Growing calves weighing 295 kg, consuming 2.3% of BW, gaining 0.9 kg per day					
Total solids, DM	kg	2.5	2.0	3.0	2.5
Volatile solids, OM	kg	2.1	1.6	2.5	2.1
Nitrogen, N	g	130	120	140	100
Phosphorus, P	g	25	20	30	27
Calcium, Ca	g	40	--	--	41
^a Calculated from ASAE standard D384.1 DEC99 assuming average body weights given for cows and calves					

Standard deviation can be calculated if the data are normally distributed and the range is assumed to be 6 standard deviations (mean \pm 3 standard deviations). For example, N excretion averages 24.6 kg with a range of 21 to 29 kg. Therefore, the standard deviation is 1.3 kg or 8/6. By separating feedlot cattle, beef cows, and growing calves, the excretion values for the updated standard should be more accurate and precise than one standard value for all beef cattle.

CONCLUSION

Using an intake minus retention model to calculate nutrient excretion by feedlot cattle is more accurate than previous standards for most nutrients. Another advantage of this method is that the impact of diet formulation or performance for individual operations can be evaluated quickly. The impact on nutrient excretion emphasizes the importance of nutrition and formulation practices to help beef feedlots become more sustainable. With growing calves and cows kept in confinement, values agree with previous standard values, suggesting that previous data were based on cattle fed forage-based diets quite different than typical feedlot diets fed today.

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APPENDIX

Definition of Input Variables

Variable	Description	Units	Source for Input Data*
<i>Animal performance characteristics</i>			
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
<i>Feed program characteristics</i>			
DMI	Dry matter intake	kg / day	NRC 1996, page 85
DMD	Dry matter digestibility of total ration	%	NRC 1996, Table 11-1, use TDN value
OMD	Organic matter digestibility of total ration	%	
ASH	Ash concentration of total ration	%	For individual feeds use NRC 1996, Table 11-1, page 134
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		

* Data specific to individual herd performance or feed analysis should be used when data is available. If situation specific information is not available, a default value from the Assumptions Table for Typical Manure Characteristics, As-Excreted may be the next best alternative.

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
DME	Dry matter excretion	kg of dry matter/day/animal
DME _T	Total dry matter excretion per finished animal	kg of dry matter/finished animal

Equations for Calves and Finishers in Confinement

Dry Matter Excretion Equation

$$DME = DMI * (1 - DMD/100) \quad (1)$$

$$DME_T = \sum_{x=1}^n DMI_x * DOF_x * (1 - DMD_x/100) \quad (2)$$

Organic Matter Excretion Equation

$$OME = [DMI * (1 - ASH/100)] * (1 - OMD/100) \quad (3)$$

$$OME_T = \sum_{x=1}^n [DMI_x * DOF_x * (1 - ASH_x/100)] * (1 - OMD_x/100) \quad (4)$$

Nitrogen Excretion Equation

$$N_{E-T} = \sum_{x=1}^n (DMI_x * C_{cp-x} * DOF_x * / 6.25) - [0.0412 * (LW_f - LW_s)] + [0.000243 * DOF_t * [(LW_f + LW_s) / 2]^{0.75} * (SRW / (LW_f * 0.96))^{0.75} * [(LW_f - LW_s) / DOF_t]^{1.097}] \quad (5)$$

$$N_E = N_{E-T} / \text{DOF}_t \quad (6)$$

$$N_{E-T\text{-simple}} = \sum_{x=1}^n (\text{DMI}_x * C_{\text{cp-x}} * \text{DOF}_x / 6.25) - 0.019 * (\text{LW}_f - \text{LW}_s) \quad (7)$$

Phosphorus Excretion Equation

$$P_{E-T} = \sum_{x=1}^n (\text{DMI}_x * C_{\text{P-x}} * \text{DOF}_x) - [0.0100 * (\text{LW}_f - \text{LW}_s)] + \{5.92 * 10^{-5} * \text{DOF}_t * [(LW_f + LW_s) / 2]^{0.75} * (\text{SRW} / \text{LW}_f * 0.96)^{0.75} * [(\text{LW}_f - \text{LW}_s) / \text{DOF}_t]^{1.097}\} \quad (8)$$

$$P_E = P_{E-T} / \text{DOF}_t \quad (9)$$

$$P_{E-T\text{-simple}} = \sum_{x=1}^n (\text{DMI}_x * C_{\text{P-x}} * \text{DOF}_x) - 0.0046 * (\text{LW}_f - \text{LW}_s) \quad (10)$$

N, P, and Ca retention estimates are based upon NRC, 1996.

Example

Yearlings enter a feedlot at 320 kg and are fed to an average weight of 567 kg. Their average daily gain is 1.4 kg/day (days on feed of 176 days). Two separate rations are used as illustrated below:

- 1) Receiving and adaptation diet fed for an average of 10 days (20 total days) at rate of 6.6 kg/animal/day, 14.5% crude protein, and 88% DMD,
- 2) Finishing diet fed for 166 days at rate of 9.1 kg/animal/day, 13% crude protein, and 88% DMD.

Based upon this information, estimate the N, P, and dry matter excretion using the equations above.

Dry Matter Excretion Equation

$$\begin{aligned} \text{DME}_T &= \sum_{x=1}^n \text{DMI}_x * \text{DOF}_x * (1 - \text{DMD}_x / 100) \quad (2) \\ &= 6.6 \text{ kg/d} * 10 \text{ d} * (1 - 88/100) + 9.1 \text{ kg/d} * 166 \text{ d} * (1 - 88/100) \\ &= 189 \text{ kg of dry matter per finished animal} \end{aligned}$$

Nitrogen Excretion Equation

$$\begin{aligned} N_{E-T} &= \sum_{x=1}^n (\text{DMI}_x * C_{\text{cp-x}} * \text{DOF}_x * / 6.25) - [0.0412 * (\text{LW}_f - \text{LW}_s)] + [0.000243 * \text{DOF}_t * [(LW_f + LW_s) / 2]^{0.75} * (\text{SRW} / (\text{LW}_f * 0.96))^{0.75} * [(\text{LW}_f - \text{LW}_s) / \text{DOF}_t]^{1.097}] \quad (5) \\ &= (6.6 * 0.145 * 10 \text{ d} + 9.1 * 0.13 * 166) / 6.25 - [0.0412 * (567 - 320)] + [0.000243 * 176 * [(567 + 320) / 2]^{0.75} * (478 / (567 * 0.96))^{0.75} * [(567 - 320) / 173]^{1.097}] \\ &= 32.95 - 10.18 + 5.54 = 28.3 \text{ kg N per finished animal} \end{aligned}$$

$$\begin{aligned} N_{E-T\text{-simple}} &= \sum_{x=1}^n (\text{DMI}_x * C_{\text{cp-x}} * \text{DOF}_x / 6.25) - 0.019 * (\text{LW}_f - \text{LW}_s) \quad (7) \\ &= 32.95 - 0.019 * (567 - 320) = 32.95 - 4.69 = 28.3 \text{ kg N per finished animal} \end{aligned}$$

Results of simplified estimate of nitrogen excretion matches with more complex estimate.