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Assessing Nitrogen and Phosphorus in Excreta from Grower-finisher Pigs Fed Prevalent Rations in Vietnam*

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ABSTRACT : Livestock production in Vietnam is, as in most Asian countries, increasing rapidly and changing into specialized highly intensified operations. The volume of animal excreta generated exceeds the capacity of the operation land base and cannot be utilized efficiently. As a consequence, there is a loss of plant nutrients from livestock farms that causes environmental pollution. This study carried out a feed and excretion experiment measuring fecal characteristic, daily fecal production, daily nitrogen and phosphorous excretion from grower-finisher pigs fed prevalent rations in Vietnam. Furthermore, equations for assessing the excretion were tested, which can be used in farm models for optimal recycling of manure while focusing on reducing pollution. The results indicated that fecal production and nutrient excretion were affected by the different rations tested. This study showed that five selected equations for predicting excretion from grower-finisher pigs in Danish conditions can also be used with precision in Vietnamese pig farming systems. The equations have been proven valid and can, therefore, be used as a much needed tool for assessing fecal production and nitrogen in excreta on pig farms. The study also showed that about 12% of nitrogen excreted was emitted during housing. Waste water contains more than half of the nitrogen excreted, mainly in ammonium form which has a high potential for gaseous emission. (**Key Words :** Equation, Excretion, Feces, Feed, Urine, Validation)

INTRODUCTION

The government of Vietnam is planning to intensify livestock production to improve production efficiency. However, existing regulations and applied technologies are inadequate to ensure environmentally safe management of manure in highly intensive livestock production systems. In particular, the regulations do not address the recycling of animal manure in agriculture. Nutrient surpluses in fishponds as well as manure volume overloads in biogas tanks have been observed in Vietnam (Vu et al., 2007). Many farmers use manure to fertilize crops or discharge manure directly into fishponds without sufficient knowledge of the nutrient balance of the crop or fish cultures. This problem will become more significant, when the production becomes more intensified and the surplus runoff or discharge will therefore pollute recipient waters. The government does not presently have appropriate tools to address the environmental problem and to ensure a more efficient use of animal manure in agriculture.

The Danish normative system takes into account the flow of nutrients excreted by the animal, during housing and storage (Poulsen et al., 2006). This system is used to regulate the animal production and the rate of manure application on different croplands. The protein and fiber contents of feeds fed to pigs are different between Vietnam and Denmark. Furthermore, the nutrient content of pig feeds varies between household-based productions systems in Vietnam. Feeds higher in protein and lower in fiber content are often used on large-scale farms, while feeds with low protein and high fiber contents are used on small-scale farms in Vietnam (Small Livestock Component, 2003). Fecal characteristics are related to both the fiber and protein content of rations. Therefore, the amount of excreta from pigs fed rations with high contents of low-fermentable fiber is almost twice the amount from pigs fed standard rations containing normal levels of low-fermentable fiber

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(Sorensen and Fernández, 2003).

The intention of this study was, therefore, to provide experimental data on the excretion of nitrogen (N) and phosphorus (P) from grower-finisher pigs under prevalent Vietnamese feeding and manure management practices. Furthermore, the experimental data are used to test equations, developed under Danish conditions for assessing fecal production and N excretion from pigs produced under typical Vietnamese conditions.

MATERIALS AND MEHODS

A feeding and excretion experiment was carried out at the experimental station of the National Institute of Animal Husbandry in Hanoi for a period of 3 months from the beginning of November 2007 to the end of January 2008. The average ambient temperatures during the 3 experimental months were 21°C, 20°C and 15°C, respectively.

Experimental design

The experiment was carried out in accordance with the imbalanced Latin square design with three dietary treatments for each of two growing periods and each of two housing types, which were metabolic cage (cage) and conventional pen (pen). Each of the two growing periods lasted 36 days and included four sampling periods. In the first sampling period, there were 2 pigs for each of the three rations tested for each of two housing methods. Pigs were kept individually in cages or pens for 6-days of adaptation, followed by 5 days of collection of excreta, separated in a feces and urine fraction. In the second sampling period, pigs fed the same ration were exchanged from cages to pens and vice versa. The exchanged pigs were kept for two days of adaptation in their cages or pens, followed by 5 days of separate collection of feces and urine. The third and the forth sampling periods were the same as the first and the second sampling periods, respectively.

Pigs and housing

Twelve growing pigs of Landrace x Yorkshire barrows were included in the experiment and studied during the two growing periods. For the first growing period, the initial bodyweight was 34±2.9 kg (mean and standard deviation) and the final weight 52±3.2 kg. For the second growing period, the mean initial bodyweight was 52±3.2 kg and the final weight 77±3.2 kg.

Six pigs were raised in cages, which facilitated the quantitative and separate collection of faces and urine. The other six pigs were raised in pens, which had fibrocement roofs, concrete floors and natural ventilation. At the lower end of each individual pen a back channel allowed urine and waste water to be drained off and to be collected individually. The waste water was a combination of feces remaining after scraping the floor, urine, the water used for cleaning and the drinking water loss. Drinking water was provided *ad libitum* by drinking nipples. A fixed amount of 20 liters of water was used to clean each pen daily.

Dietary treatments and feeding

Three dietary treatments varied in protein and fiber contents, were applied to 3 groups each of 4 pigs within each growing period. The three rations contained: high protein and low fiber (H-L); medium protein and medium fiber (M-M); and low protein and high fiber (L-H), respectively (Table 1). Pigs in Vietnam, especially during their initial growing period, often have health problems when dietary P content is limited to the recommended level provided by NRC (1998). To avoid this problem, the P level for pigs during the growing period 1 was higher than the NRC-recommendations, while it was reduced to the NRC-recommended level during the growing period 2.

Feed was provided *ad libitum* during the first two days of the adaptation period in the first sampling period in order to estimate average feed intake. Pigs were fed 80% of this estimated average feed intake during the first sampling period and 90% during the second sampling periods. The same feed amounts were given for pigs kept in cages and pens.

Data collection and chemical analysis

Pigs were weighed in the morning before feeding at the beginning of the first sampling period and at the end of the second and the fourth sampling periods. Three feed samples were collected once after the rations were mixed for each of two growing periods. Feed consumption was registered daily for the individual pigs. Feces and urine were collected separately at 08:00 and 15:00. Urine was collected in containers with added sulfuric acid to conserve N. Samples from each day's collection were kept in a freezer at minus 4°C. The samples were subsequently homogenized and representative sub-samples of feces and urine were taken for chemical analysis.

All samples were analyzed in duplicate at Laboratory for Feed and Animal Product Analysis at the National Institute of Animal Husbandry, Hanoi according to standard methods (Association of Official Analytical Chemists, 1990). Feed was analyzed for dry matter (DM), N, crude fiber, Calcium, P, crude fat and ash. Feces were analyzed for DM, crude fiber, N, NH_4-N, P and pH. Urine and waste water were analyzed for N, NH_4-N, P and pH. Total N was measured by Kjeldahl method. The NH_4-N in urine or waste water was determined by distillation. For NH_4-N in feces, samples extracted by dilute HCl (0.05 N) before distillation.

Table 1. Ingredient composition and chemical contents of the experimental rations

	Growing periods	Period 1			Period 2		
Ration	Protein-fiber	H-L	M-M	L-H	H-L	M-M	L-H
Ingredients (%)							
Corn		54.3	46.5	34.9	56.6	49.6	42.2
Rice bran		17.1	18.9	29.5	10.0	16.0	25.0
Cassava residue		0.00	10.0	16.5	10.0	16.0	20.0
Soybean meal		25.0	21.0	15.4	21.9	17.0	11.4
Limestone ($CaCO_3$)		1.03	1.02	1.02	0.74	0.68	0.64
Vitamins mineral premix		0.25	0.25	0.25	0.25	0.25	0.25
Di-calcium phosphate		1.72	1.75	1.76			
Salt (NaCl)		0.50	0.50	0.50	0.50	0.50	0.50
Calculated chemical content (% of DM)							
Crude protein		18.0	16.0	14.0	16.0	14.0	12.0
Crude fiber		4.5	5.5	6.5	6.2	7.2	8.3
Calcium		0.90	0.90	0.90	0.50	0.45	0.45
Phosphorous		0.71	0.71	0.72	0.50	0.55	0.58
Analyzed chemical content (% of DM)							
Crude protein		17.5	15.7	13.8	16.1	13.6	11.6
Crude fiber		4.8	5.7	6.8	5.2	6.6	7.9
Calcium		0.90	0.90	0.99	0.53	0.49	0.46
Phosphorous		0.72	0.76	0.78	0.43	0.44	0.47
Crude fat		3.83	3.92	4.02	3.83	3.55	4.32
Ash		5.90	6.23	6.88	4.43	4.52	4.80
Lysine		0.58	0.49	0.56	0.59	0.50	0.31
Methionine		0.19	0.17	0.14	0.14	0.13	0.11

H-L = High protein and low fiber concentration ration; M-M = Medium protein and medium fiber concentration ration; L-H = Low protein and high fiber concentration ration.

Calculation and statistical analysis

Gaseous N loss during housing was determined by total N excretion measured from pigs kept in cages subtracted by total N excretion measured from pens. Gaseous N loss in the cages was assumed to be zero. The data were analyzed using ANOVA in MINITAB software version 13.31 (Minitab, 2000). Animal performance, feed consumption and excretion data were analyzed by the General Linear Model as follows:

$$\text{Model}: Y_{ij} = \mu+T_i+S_j+(T\times S)_{ij}+\varepsilon_{ij}$$

Where: μ equals overall mean; T_i equals effect of dietary treatment i (H-L; M-M and L-H) and S_j equals effect of sampling period j (1,2,3 and 4) or T_i equals effect of housing treatment i (cage and pen) and S_j equals effect of sampling period j (1,2,3,4,5 and 6); $(T\times S)_{ij}$ equals effect of the interaction between treatment i and sampling period j; and ε_{ij} equals effect of error.

As treatment and sampling period interactions were non-significant, they were removed from the model.

The experimental data were used as test set for assessing whether the equations developed by Vu et al. (2009) could be used under Vietnamese conditions. The equations selected for validation have parameters generated from this study, and there were no significant differences ($p>0.05$) between predicted and observed means. Performance of the equations was calculated by their prediction error in terms of root mean square error of prediction (RMSEP) and by testing any systematic differences (bias) between the average values of the test dataset (Esbersen, 2002; Jørgensen and Lindberg, 2006). The t-test was used for the equation validation process.

RESULTS AND DISCUSSION

Feed consumption and animal performance

Nutrient composition of the rations calculated based on the Vietnamese Feedstuff Table (Composition and Nutrients value of Animal feeds in Vietnam, 1995) and measured in the laboratory are presented in Table 1. The calculated values were close to the data from the laboratory analysis except for a minor deviation for P in the growing period 2.

No health problems were observed during the experimental periods. The different rations did affect the

Table 2. Animal performance, feed consumption, fecal production and characteristics (n = 24 for each growing period)

	Growing periods	Period 1				Period 2			
Ration	Protein-fiber	H-L	M-M	L-H	SE[1]	H-L	M-M	L-H	SE[1]
Animal performances									
Average body weight (kg)		40.5	40.3	40.8	0.81	64.3	64.9	63.7	1.14
Live weight gain (kg/d)		0.62[a]	0.52[b]	0.50[b]	0.03	0.74[a]	0.68[ab]	0.57[b]	0.04
Feed consumption and digestibility									
Dry matter intake (kg DM/d)		1.16	1.17	1.16	0.00	1.89	1.90	1.91	0.04
Digestibility organic matter (%)		83[a]	80[b]	78[b]	0.01	84[a]	82[b]	80[c]	0.37
Fecal production (kg/d)									
Fresh feces		0.63[a]	0.80[b]	0.94[c]	0.03	1.15[a]	1.26[a]	1.41[b]	0.04
Dry matter feces		0.20[a]	0.24[b]	0.26[b]	0.01	0.31[a]	0.34[b]	0.38[c]	0.01
Fecal characteristics									
Dry matter (%)		32.6[a]	29.0[b]	27.1[b]	0.71	26.9	27.1	27.2	0.55
Crude fiber (% of DM)		16.4[a]	19.7[b]	23.0[c]	0.47	21.4[a]	25.1[b]	28.2[c]	0.65
N (% of DM)		2.97[a]	2.92[a]	2.52[b]	0.06	2.72[a]	2.54[ab]	2.29[b]	0.08
NH_4-N (% of DM)		0.38	0.34	0.36	0.03	0.41	0.40	0.39	0.03
P (% of DM)		1.78	1.92	1.67	0.09	1.30	1.38	1.26	0.06
pH		6.91	6.94	6.90	0.07	5.99	6.20	6.28	0.08

[1] Pooled standard error.

LS Means values within a row of a growing period with the same letter are not significantly different at $p<0.05$.

H-L = High protein and low fiber concentration ration; M-M = Medium protein and medium fiber concentration ration; L-H = Low protein and high fiber concentration ration.

pigs' growth rate. As shown in Table 2, the pigs fed H-L rations had higher rates of gain in both growing periods than those fed the other rations. As expected, the digestibility of organic matter (diOM) was significantly different among rations ($p<0.05$). The diOM was negatively correlated to dietary crude fiber. This result was at the same level as found by Just et al. (1983b) and Fernández and Jørgensen (1986), who in a comprehensive study showed that dietary crude fiber, was the very best crude nutrient predictor of metabolic energy (Just et al., 1984).

Fecal production and characteristics

As shown in Table 2, both fresh and dry amounts of the feces excreted were highest by L-H rations. Reduction of dietary protein levels resulted in decreased amounts of manure excreted per animal (Portejoie et al., 2004). However, as the result of a higher dietary fiber content, the fecal volume of ration L-H was about 20% and 50% higher than that of ration H-L in the growing periods 1 and 2, respectively. This finding is supported by studies of Sørensen and Fernández (2003) and Vu et al. (2009), which showed that the amount of fecal excretion was positive related to the amount of fiber intake. For diOM, pigs fed L-H ration had the lowest values (Table 2). Previous studies have shown that rations with high fiber contents result in lower feed digestibility (Jørgensen et al., 1996; Len et al., 2007).

Regarding fecal characteristics, dry matter concentration was lowest in the L-H rations during growing period 1 due to the highest level of fecal fiber, which has a high water holding capacity (Eastwood, 1973; Serena et al., 2008). No significant differences were observed in fecal dry matter concentration among rations in growing period 2. These findings are surprising and no explanation could yet be given for this pattern.

The fecal N concentration was highest in the H-L ration and lowest in the L-H ration, which supports the concept that the fecal N concentration is positively related to dietary N concentration, provided that N digestibility is constant. The fecal NH_4-N concentration, which is readily available for plant uptake was not affected by the rations. There were no significant differences in the fecal P concentrations excreted among rations in both growing periods, as dietary P contents were similar in each growing period. Fecal pH levels were similar for the three rations in each growing period. This is in agreement with Mroz et al. (2000) and Shriver et al. (2003), who reported that no significant change in fecal pH was found as a result of adding fiber to low crude protein rations.

These findings suggest, that manure storage capacity and application rates can be planned for different feeding practices.

Nutrient excretion

Table 3 shows that the daily excretion of fecal N and NH_4-N, in contrast to the daily excretion of urinary N and NH_4-N, were not influenced by the rations. This result agrees with findings by Canh et al. (1998), who reported

Table 3. Daily nutrient intake and excretion, nutrient excretion in percentage of intake, N intake and excretion per kg weight gain (n=24 for each growing period)

	Growing periods	Period 1				Period 2			
Rations	Protein-fiber	H-L	M-M	L-H	SE[1]	H-L	M-M	L-H	SE[1]
Intake									
N (g/d)		32.4[a]	29.2[b]	25.6[c]	0.22	48.7[a]	41.5[b]	35.3[c]	0.21
P (g/d)		8.35[a]	8.87[b]	9.05[c]	0.02	8.12[a]	8.38[b]	8.97[c]	0.03
N (g/kg gain)		53.0	60.4	54.8	3.20	67.0	61.7	63.2	3.62
Excretion (g/d)									
Fecal N		5.97	6.82	6.37	0.23	8.39	8.58	8.67	0.29
Fecal NH_4-N		0.74	0.81	0.88	0.07	1.29	1.37	1.48	0.09
Fecal P		3.44[a]	4.39[b]	4.23[ab]	0.24	3.96[a]	4.65[ab]	4.75[b]	0.21
Urinary N		11.5[a]	9.08[b]	7.14[b]	0.58	17.5[a]	15.3[ab]	12.4[b]	0.91
Urinary P		1.12	0.95	1.39	0.13	0.00	0.00	0.13	0.05
Total N		17.5[a]	15.9[a]	13.5[b]	0.53	25.9[a]	23.9[ab]	21.0[b]	0.89
Total P		4.56[a]	5.34[b]	5.62[b]	0.20	3.96[a]	4.65[ab]	4.88[b]	0.22
Excretion/intake (%)									
Fecal N		18.5[a]	23.2[b]	25.1[b]	0.71	17.1	20.6	24.5	0.70
Fecal P		42.5	50.4	46.9	2.41	48.8	55.7	53.3	2.61
Urinary N		35.0[a]	31.1[ab]	27.7[b]	1.72	36.1	37.0	34.9	2.06
Urinary P		12.8	10.3	15.3	1.43	0.00	0.00	1.46	0.53
Total N		53.5	54.3	52.8	1.67	53.1	57.7	59.4	1.97
Total P		55.2	60.7	62.2	2.18	48.8	55.7	54.7	2.73
Excretion per kg weight gain (g/kg gain)									
Fecal N		9.78[a]	13.9[b]	13.9[b]	0.69	11.5[a]	12.8[ab]	15.5[b]	0.99
Urinary N		18.6	18.6	15.0	1.46	23.9	22.9	22.1	1.71
Total N		28.4	32.5	28.9	1.89	35.5	35.7	37.6	2.36

[1] Pooled standard error.

LS Means values within a row of a growing period with the same letter are not significantly different at $p<0.05$.

H-L = High protein and low fiber concentration ration; M-M = Medium protein and medium fiber concentration ration; L-H = Low protein and high fiber concentration ration.

that the relationship between daily urinary N excretions and dietary protein content was closer than that of daily fecal N excretion and dietary protein content.

Regarding N excretion as percentage of N intake, urinary N excretion tended to increase while fecal N excretion decreased in H-L rations (Table 3). This result agrees with finding by Just et al. (1982), that pigs fed protein above their nutrient requirements or fed a ration with an unbalanced amino acid composition excrete more N into the urine. Furthermore, increasing the content of dietary fiber will shift the N excretion from urine to feces (Zervas and Zijlstra, 2002; Vu et al., 2009).

The total N intake and total N excretion per kg weight gain were not affected by the rations. The fecal N excretion per kg weight gain was lowest in the H-L ration and highest in the L-H ration. In contrast, the urinary N excretion per kg weight gain was low in the L-H rations and high in the H-L rations, even though this tendency was not significant ($p>0.05$). This finding implicates that the H-L ration may be considered environmentally detrimental in terms of gaseous N losses, as urinary N is the precursor of NH_3 (Sommer et al., 2006).

As Table 3 shows, the daily P excretion was mainly presented in the solid fraction. This result is in agreement with previous studies (Fernández et al., 1999) and suggests that there will be less environmental impact with the waste water in terms of P, when feeding pigs at their minimal P requirements. The total daily P excretions increased by increasing dietary P, whereas the total P excretion as a percentage of P intakes in both growing periods was not significantly different between rations ($p>0.05$). A slight increase in fecal P was found by lowering dietary protein and increasing fiber content, but this was not the case with urinary P excretion. Changes in biochemistry were observed with a very low daily urinary P excretion during growing period 1 and almost no daily urinary P excretion during growing period 2 (Table 3). The explanation may be that dietary P either fulfilled the pigs' minimum P requirements or was perhaps slightly lower than their physiological requirement (Fernández et al., 1999).

These results suggest that dietary P allowances for the growing period 2, as recommended by NRC (1998) are

Table 4. Daily fecal production, N excretion and total gaseous N losses from pigs with average weight varied from 41 to 78 kg as affected by the housing types (n = 72)

Methods	Metabolic cages	Conventional pens	SE[1]
Fecal production (kg/d)			
Fresh feces	1.16[a]	1.26[b]	0.03
Dry feces	0.32	0.33	0.01
Urine/ waste water amount	2.72[a]	20.06[b]	0.27
Nitrogen excretion (g/d)			
Fecal N	8.18[a]	8.97[b]	0.18
Fecal NH_4-N	1.21[a]	1.50[b]	0.04
Urinary/ waste water N	13.9[a]	10.4[b]	0.55
Urinary/ waste water NH_4-N	2.79[a]	7.65[b]	0.33
Total N	22.0[a]	19.3[b]	0.54
Total NH_4-N	4.00[a]	9.14[b]	0.33
Total gaseous N losses:		12% of total N excretion	

[1] Pooled standard error.

LS Means values with the same letter are not significantly different at $p<0.05$.

sufficient and probably can be even further reduced before pigs reach slaughter weight. This is in agreement with Kanakov et al. (2005). However, he also reported that lowering the P level to 4.3 g/kg DM in the late finishing stage seemed to have an effect on dry and ash bone weight. Therefore, the most appropriate time for reducing dietary P before reaching the slaughter weight, and by how much before any deficiencies develop, and do so without having any detrimental effect on performance or carcass traits, requires further investigation.

Fecal production, N excretion and emission by housing types

Daily dry fecal production was not different between pigs kept in cages or in pens, even though fresh amounts of feces from pigs kept in cages were lower than those of pigs kept in pens (Table 4). This larger fresh amount of feces from pigs in pens is due to urine and cleaning water got mixed with feces. Urine mixed with feces also results in higher daily amounts of fecal N and NH_4-N from pigs kept in pens compared to that of pigs kept in cages during both growing periods. The data shows that almost half of the N was present in the solid fraction and over half of N, mainly in the form of NH_4-N, was present in the waste water. In the Asian context, waste water is often applied to fish ponds and to vegetable gardens. However, a very large amount of the unused waste water is discharged into water sheds or streams and obviously will cause serious pollution due to its high N content.

The total N excretion from pigs kept in pens was lower than that from pigs kept in cages due to gaseous N losses (Table 4). Ammonia emission is enhanced because feces are mixed with urine and waste water after cleaning the pen floors. Urease is present in feces but not in pure urine (Aarnink and Verstegen, 2007), so that the conversion of urea to NH_4^+ only begins, when urine becomes mixed with feces. The net percentage of N emitted during housing from pigs in pens was estimated at 12.2% of total N excretion. These figures may be even higher, because total N excretion from pigs kept in cages may be underestimated due to emission of N during collection time before it was kept in fridge for storing. The gaseous N loss is high compared to

Table 5. Validation of equations for daily fecal production and N excretion developed by Vu et al. (2009)

N°	Equations	Bias	RMSEP	P
Fecal production (kg/d)				
5.7	Feces = 5.405-6.31 diOM+0.505 DM intake	-0.03	0.02	0.15
5.8	Feces = 5.469-6.20 diOM+0.0105 BW	0.04	0.03	0.18
N in Feces (g/d)				
6.8	Fecal N = 25.37-33.5 diOM+0.0163 dPROT+4.678 DM intake	-0.29	0.10	0.01
N in urine (g/d)				
7.8	Urine N = -20.34+0.133 dPROT+0.239 BW	0.41	0.42	0.34
7.9	Urine N = -28.50+0.143 dPROT+13.23 DM intake	-0.63	0.34	0.07

Bias: accuracy of the prediction (difference between measured and predicted values); RMSEP: residual mean square error of prediction using the test data (experimental data, n = 48); P: probability of a significant difference between measured and predicted values; BW: body weight (kg); DM intake: dry matter intake (kg/d); diOM: digestibility of organic matter (coefficient); dPROT: dietary crude protein (g/kg DM).

emission in earlier studies of housing, where the floor is scraped daily (Sommer et al., 2006), due to the natural ventilation in this experiment.

Validation of equations from a Danish study

Table 5 shows a comparison of the experimental results with predictions obtained by applying the equations developed by Vu et al. (2009). In general, the measured and predicted average values of daily fecal production and N excretion are in close agreement. The negative bias values indicate that the predicted values are overestimated, and *vice versa*. When the dry matter intake (DMI) was included in the equations as one of the predictors, the average predicted values became overestimated. In contrast, the average predicted values became underestimated, when body weight (BW) was included. This may be explained by virtue of the different feed ingredients, pig breeds and production environments between Vietnam and Denmark. RMSEP values from equations including the DMI variable were lower than those including the BW variable.

The predicted and observed values of fecal production, fecal and urinary N excretion are illustrated in Figure 1, 2 and 3, respectively. These show that the measured and predicted average values of daily fecal production, fecal and urinary N excretion were closely related with high r^2 values at 0.88, 0.86 and 0.78, respectively.

These validation results implicate that the equations selected from previous study on grower finisher pigs in Danish conditions are suitable for predicting the fecal production and N excretion in Vietnamese context.

IMPLICATIONS

The manure storage capacity should be calculated in relation to the dietary fiber content of the pig feed. As excreta are normally separated into liquid and solid fractions in Vietnamese pig production systems, this experiment shows that the waste water has high nitrogen and low phosphorus contents and the solid fractionhas high phosphorous and low nitrogen contents, which has implications for crop fertilization. Gaseous N loss during housing was about 12% of total N excretion. The selected equations developed by Vu et al. (2009) under Danish conditions could be applied under Vietnamese conditions. Further research needs to focus on the efficient use of N excretion in the liquid excreta fraction.

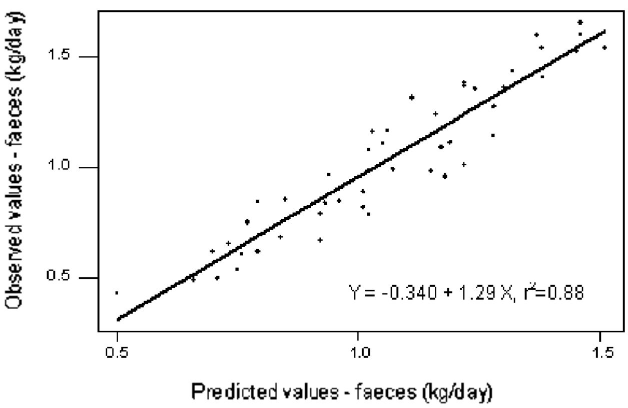

Figure 1. Plot the predicted values and observed values of daily fecal production (n = 48), when equation 5.7 from Table 5 has been used.

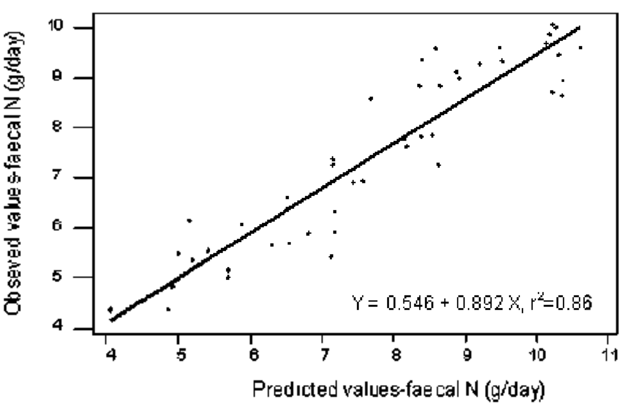

Figure 2. Plot the predicted values and observed values of daily fecal N excretion (n = 48), when equation 6.8 from Table 5 has been used.

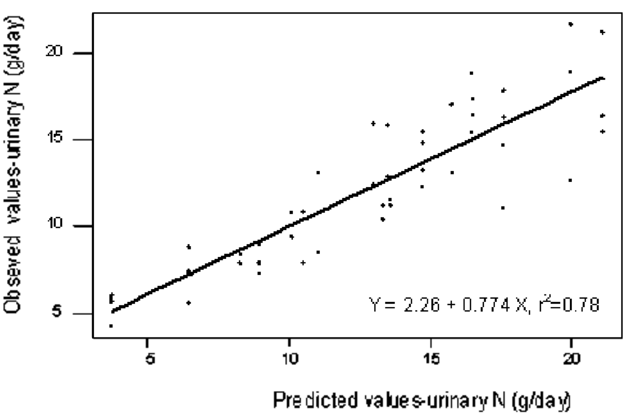

Figure 3. Plot the predicted values and observed values of daily urinary N excretion (n = 48), when equation 7.9 from Table 5 has been used.

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