Nutrient management planning for sow operations using extant and new feed consumption models and manure analysis

FINAL REPORT

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Executive Summary

Successful nutrient management planning of sow operations depends on accurate estimation of nutrient output from the animal. The objective of the study was to evaluate an empirical model that predicts phosphorus (P) and nitrogen (N) output and used to calculate land base requirement for manure spreading by Manitoba Conservation. In addition, the effect of microbial phytase supplementation on land base requirement was investigated. The model was originally developed for Quebec, Canada and implemented in Manitoba, Canada. An experiment was conducted at the T.K. Cheung Centre, University of Manitoba, Winnipeg, MB. Eighteen sows were randomly allocated to receive a diet that meets NRC requirement for P (6.0 g total P/kg; NOPHYTASE) or reduced P (5.1 g P/kg) supplemented with microbial phytase at 500 FTU/kg (PHYTASE). Samples of feed, feces and urine were collected for five days after seven days of acclimatization. Urine was collected using urinary catheters. The results were a composite of three collection periods. Reducing P intake by nearly 2 g/d and supplementing phytase resulted in numerically higher P and N retentions in the sows. Furthermore, there was a tendency for the sows to excrete less P and N in manure. Measured total P in manure (feces + urine) was compared to model predicted values. Evaluation was based on mean square prediction error (MSPE) which was further decomposed into error of prediction due to variation from regression line, central tendency (or deviation from the mean) and random (unexplained error). The MSPE analysis showed that root MSPE as percentage of observed mean was 10% in NOPHYTASE and 30% in PHYTASE treatments. This was further confirmed in the decomposition of sources of error with only 26% and 50% coming from random variation in NOPHYTASE and PHYTASE diets, respectively. This means that the model predicted P excretions from the standard diet better than the phytase supplemented diet. The annual land base requirement for manure spreading based on the P content of manure from sows fed NOPHYTASE and PHYTASE diets were 0.24 and 0.23 ha/sow, respectively. However, the model predicted land requirements of 0.32 and 0.28 ha/sow, respectively. The overestimation by the model, which was directly linked to P output predictions, has a significant implication to producers in determining the amount of animals they are allowed to keep. Therefore, it is recommended that the model should be refined to reflect local conditions if it were to be used as nutrient management planning and monitoring tool. It is particularly important to revise the model if producers are using microbial phytase to reduce P intake and output. The project results can

be used as a benchmark to the amount of P and N expected to be excreted from non-lactating dry sows in Manitoba.

INTRODUCTION

Sustainable production is one of the most pressing challenges facing the swine industry. Major concerns of pressure on the environment from swine operations include excess nutrient load, mainly P and N, which affect soil, water and air surrounding swine facilities (Fernández *et al.* 1999a; Nahm 2002). Sows contribute the highest proportion of both P and N with 26 and 22% of the total outputs, respectively from swine industry after growing-finishing pigs (Fernández *et al.* 1999b). Sows consume diets that are comprised mainly of seeds (cereal grains) or their products (oil seed meal and grain by products) that contain about two-thirds of the P in the form of phytate-P which has a low bioavailability due to lack of the enzyme phytase in the gastro-intestinal tract of these animals (Simons *et al*. 1990; Kies *et al*. 2005). This results in a higher excretion of P in manure increasing the risk of P loss from land surrounding swine facilities. Manure applications to meet N requirement of crops increase the concentration of soil P. This is because the N:P ratio of manure is lower than that for crop removal leading to the application of more P than removed by crops (Daniel et al. 1994). When the inherent threshold of soils to retain P is exceeded, coupled with the various transport factors in the soil, an increase in runoff P with detrimental effects on surface waters is observed (Sharpley et al. 1999), with eutrophication of surface water being the major consequence (Smith et al. 1999). Various mitigation strategies have been studied extensively that can assist the swine industry to achieve a sustainable production practice while maintaining profitability. Among those mitigation strategies, the use of microbial phytase has shown a promising opportunity by improving the digestibility of phytate-P in sows and reducing output to the environment (Jongbloed *et al.* 2004; Liesegang *et al.* 2005). A comprehensive nutrient management planning (NMP) where the amount of imported and exported nutrients can be quantified on the farm can provide an essential tool for understanding the flow of nutrients in the life cycle of animals. A rapid and accurate on-farm determination of swine slurry nutrient concentrations can minimize potential environmental damage to water bodies while providing crops with nutrients for optimal yields (Higgins *et al.* 2004).

Mathematical models have been used for understanding and predicting the flow of nutrients in various categories of pigs including sows (e.g. Aarnink *et al.* 1992; Dourmad *et al.* 1992; Carter *et al.* 2003), and can be valuable tools because obtaining representative samples of stored manure for analysis of nutrients are difficult and sometimes impossible

(Powers & Van Horn 2001). Furthermore, with the common use of phytase to optimize bioavailability of P in swine, NMP strategies should consider nutrient outputs in farms where microbial phytase use is a common practice.

The project addresses the short-term priority areas of 'Phosphorus Management' and 'Nitrogen Management on Sandy Soils' identified by MLMMI. Agriculture has been identified as a contributor to water quality problems related to eutrophication of surface water, especially Lake Winnipeg. The livestock industry in particular has been subject to much scrutiny due to the expansion of the pig industry in Manitoba and the environmental risks associated with manure. Concurrently, producers are becoming increasingly cognizant of the need to optimize their feeding regimes for efficient production and to manage manure to obtain the benefits that come with its proper use (e.g. replacement of costly synthetic fertilizer, improvement of soil quality, etc.).

Nutrient management planning by livestock producers aims to maximize the value of and optimize the use of an operation's resources (e.g. feed, manure and soil) while minimizing environmental risk. Annual planning is needed to properly use manure nutrients based on the circumstances of a given year (field conditions, crop rotation), while long-term planning (principally calculation of land base required for manure application) is critical to ensure the sustainability of an operation. For this planning to be effective, precise and accurate data are required for several parameters. There are two principal methods for estimating the total amount of nutrients to be managed in a given operation, one that uses manure nutrient contents and manure volume (traditionally employed in Manitoba) while the other relies on production factors such as livestock characteristics and feeding programs (a new approach known as a feed consumption model employed elsewhere). These two methods can be used in combination to ensure that a final estimate is reasonable given the nature of the operation.

A project is needed to begin the validation of the feed consumption model under Manitoba conditions so that it can be used by producers in on-farm nutrient management planning and by government staff in extension activities and in the regulation of manure management. Ultimately, producers are expected to adopt innovative feeding practices or refine existing ones to optimize nutrient inputs to livestock and minimize nutrient outputs in manure that must then be managed as a source of crop fertility in an environmentally sustainable way. A simplified approach for estimating land base requirements for new swine operations, developed based on data from Quebec is currently being employed by Manitoba Conservation in its administration of the Livestock Manure and Mortalities

Management Regulation. Absence of Manitoba data for this land base estimation has serious implications for producers if estimates are high and may be overly restrictive.

Thefore, the objective of this project was (1) conduct experiments under highly controlled conditions based on common feeds used in sow operations in Manitoba, (2) collect detailed data on feed composition, animal productivity, and manure composition and volume, (3) evaluate an extant feed consumption and land base requirements model for sow operations in Manitoba.

MATERIALS AND METHODS

Animals and Diets

Six sows were blocked in to two treatment diets with three sows per treatment and repeated over three periods with different sows, so a total of 18 sows were used. Animals were randomly assigned to the two diets; one control diet where the level of P in the diet was formulated to meet the requirement of the animals according to NRC (1998) (No-phytase) and the second diet with the P level in the diet reduced by 0.1 percentage units (Phytase). Feed composition of the experimental diets are given in Table 1. The animals were fed for seven days of adaptation period before the actual collection periods were started. On the eighth day, the sows were fit with urinary catheters for a total urine collection of five days, and total fecal collection was also performed. During these five days of collection, feed consumption, water consumption, water spillage and room temperature were recorded. Samples of urine and feces were taken for laboratory analysis of P and N contents. The remaining excreta were pooled along with the water spillage to store manure in a drum container for the determination of manure volume. Body weight of sows was aslo measured at the start and end of collection days.

Fecal and feed samples were oven dried and ground to pass through a 1 mm screen and thoroughly mixed and sent to Central Testing Laboratory Ltd. (Winnipeg, MB. Canada) along with urine samples for the determination of total P (AOAC 923.03) and N (Leco Version 2.2). Dry matter was determined according to AOAC 934.01 (AOAC 1990). Nutrient content in the manure was obtained by combining the nutrient content in the feces and urine of individual pigs.

All experimental procedures were reviewed and approved by the University of Manitoba Animal Care Protocol Management and Review Committee, and pigs were handled according to the guidelines described by the Canadian Council on Animal Care (CCAC, 1993).

Table 1. Composition of sow experimental diets used in the study.

Ingredients	No-phytase	Phytase
Barley, 6r	15.1	16.3
Wheat HRW	44.9	44.9
Canola meal	15.1	15.1
SBM 48%	14.1	14.1
Veg. oil	4.80	4.40
Limestone	0.98	0.69
Biophose	0.80	0.30
Iodized Salt	0.25	0.25
Vit-Min Premix	3.50	3.50
Lys-HCl	0.20	0.20
DL-Methionine	0.04	0.04
Threonine	0.24	0.24
Phytase, FTU/kg	-	500
Calculated nutrient content in diet:		
ME, kcal/kg	3265	3265
CP, %	19.7	19.8
Ca, %	0.75	0.56
tP, %	0.60	0.50
Av. P, %	0.32	0.22
Lys, %	1.20	1.20
Met, %	0.36	0.36
Determined nutrient content of diet:		
tP, %	0.60	0.51
CP, %	19.9	20.9

FTU= phytase units.

Mathematical Model Description

The model evaluated was empirical and the inputs were feed intake, body weight and number of animals. The model predicted P and N in the manure at the moment it is produced by the animal using the difference between the quantity consumed and retained in the body of pigs.

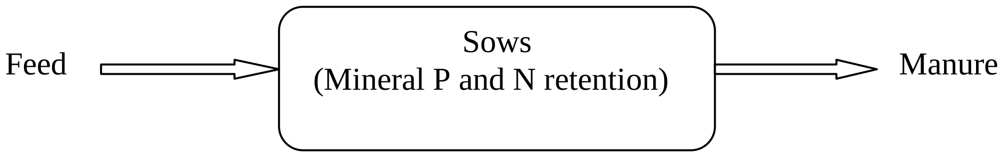

Figure 1. Schematic representation of the determination of mineral P and N in the manure of sows.

$$\text{Intake P (kg)} = P_f\ (\%) \times \text{FC (kg)} \qquad \textbf{[1]}$$

where P_f is the percentage of P in feed; FC is the total daily feed consumption.

The model assumes a total retained nutrient of 5.3 g of P and 25 g of N for every kg of body weight gain in pigs in all phases of production:

$$P = 0.0053\ W_G \qquad \textbf{[2]}$$

$$N = 0.025\ W_G \qquad \textbf{[3]}$$

where W_G is the daily weight gain (kg).

The body composition of sows on a g/kg basis was similar to the study of May and Rozeboom (2008) who reported the average P and N content of sows to be 5.63 and 24.9 g/kg.

The model predicted the land base required (LBR) for optimal application of manure (ac/yr/pig) using the following formula:

$$\text{LBR} = P_2O_5 \text{ application} / P_2O_5 \text{ removal} \qquad \textbf{[4]}$$

where P_2O_5 application is annual P_2O_5 application (lb), and P_2O_5 removal is the average crop removal rate for P_2O_5 (lb/ac).

$$P_2O_5 \text{ rem.} = X_1\ (X_{1yield}\ \ X_{1rem.}) + X_2\ \ (X_{2yield}\ \ X_{2rem.}) + X_n\ (X_{nyield}\ \ X_{nrem.}) \qquad \textbf{[5]}$$

where X_1 is the % of cropland occupied by crop 1; X_{1yield} is the ‘crop 1’ yield (bu/ac); $X_{1rem.}$ is P_2O_5 removal rate by ‘crop 1’ (lb P_20_5/ac); X_2 is the % cropland occupied by crop 2; X_{2yield} is the ‘crop 2’ yield (bu/ac); $X_{2rem.}$ is P_2O_5 removal rate by ‘crop 2’ (lb P_20_5/ac); X_n is the % of cropland occupied by crop n; X_{nyield} is the ‘crop n’ yield (bu/ac); $X_{nrem.}$ is P_2O_5 removal rate by ‘crop n’ (lb P_20_5/ac).

The land base requirement values determine the optimal spread of manure to a land base without a significant accumulation of nutrients, mainly P and N, and reduced runoffs in to surface waters thereby minimizing the hazardous effects of nutrients on aquatic systems.

The model predicted values were compared to the experimentally observed values for P, N and calculated land base requirements to assess the adequacy of the mathematical model for its intended purpose of P and N management as a nutrient management plan strategy for swine production in Manitoba. The land base requirement was calculated based on model calculations with inputs of observed and predicted P outputs.

Statistical Procedures

Statistical analysis was perfomed using the MIXED procedure in SAS (SAS, 2002). The period effect was analyzed for its significance. All observations within a treatment diet were pooled for the assessment of the adequacy of the model. If the ANOVA was significant for a given class variable, then 1-df contrasts were conducted to compare specific treatment means. All tests were considered significant at $P < 0.05$. Shapiro-Wilk's W (Shapiro & Wilk 1965) test was used to ensure the normal distribution of both the observed and predicted data.

Model Evaluation

Dependability and accuracy of models is critical before they can be used with greater confidence. Such a method also provides the mechanism to evaluate if sensible reductions in dietary inputs can sufficiently balance nutrient budgets when manure nutrients exceed the amounts that can be utilized for crop production on farm (Powers & Van Horn 2001). As truthfulness of a model is a difficult task to assess, usefulness of the model for its intended purpose should be the main objective of model evaluation process (Reynolds *et al.* 1981).

For a perfect model, N and P predicted will be equal to N and P observed. An assessment of the error of prediction was made by calculation of the mean square prediction error (MSPE):

$$\text{MSPE} = \sum_{i=1}^{n} (O_i - P_i)^2 / n$$

where n is the number of runs and O_i and P_i are the observed and predicted N or P excretions, respectively. The MSPE was decomposed into error due to overall bias of prediction, error due to deviation of the regression slope from unity, and error due to the disturbance (random variation; Bibby and Toutenburg, 1977). Root MSPE (RMSPE) was used as a measure of accuracy of prediction.

Concordance correlation coefficient or reproducibility index (CCC; Lin, 1989) was also used to evaluate the precision and accuracy of N and P predicted excretion against observed values. The CCC can be represented as a product of 2 components. The first component is the correlation coefficient (r) that measures precision. This coefficient may vary from 0 to 1, where 1 indicates perfect fit. The second component (C_b) is the bias correction factor that indicates how far the regression line deviates from the line of unity. This value also ranges from 0 to 1 and 1 indicates that no deviation from the line of unity has occurred. Finally the estimate μ measures location shift relative to the scale (difference of the means relative to the square root of the product of 2 standard deviations). This value ranges takes negative and positive numbers, with the latter indicating under-prediction and the former over-prediction.

An assessment of prediction bias has been presented in the form of residual plots in which the residuals (observed – predicted) were plotted against predicted values (Figures 2 and 3).

RESULTS

Mineral/Nutrient Excretion

There was no significant difference observed in feed intake and N intake (*P* =0.685 and 0.460, respectively) in sows fed both treatment diets. However, a significant difference in P intake was observed (*P* =0.013). Phytase amendment to a P reduced diet did not show a significant reduction in P excreted in the feces (*P* =0.363) and urine (*P* =0.866). Total P output was 66.7% and 69.1% of the total P intake in the No-phytase and Phytase diets, respectively and showed no significant difference between the two dietary treatments (*P* =0.566). These values were 71.6% and 61.3% for the excretion of N. Furthermore, there was no significant reduction in N excretion as result of phytase amendment to a P reduced diet (P =0.420) (Table 2).

In all the performance trials with starter to finisher pigs and sows, phytase supplementation did not result in a significant reduction/increase in the excretion of N in the feces and urine, even though in all the fecal excretions numerical reduction was observed with Phytase diet.

Table 2. Excretion of P and N from sows fed diets with (+) or without (-) phytase

	Intake			Retention			Excretion					
Treatment	Feed	P	N	FCR[1]	P	N	P			N		
	kg/d	--- (g/d) ---			--- (g/d) ---		----- (g/d) -----			----- (g/d) -----		
							feces	urine	total	feces	urine	total
- Phytase	2.79	16.4	87.1	3.33	1.98	9.33	8.76	2.17	10.9	9.46	52.9	60.8
+ Phytase	2.88	14.8	92.9	6.04	2.19	10.3	7.86	2.36	10.2	9.36	47.6	55.5
SED[2]	0.084	0.182	6.40	0.262	0.153	0.153	1.163	0.197	0.849	1.287	6.891	4.519
P (NP vs. Phytase)	0.685	0.013	0.460	0.188	0.183	0.186	0.522	0.444	0.566	0.944	0.526	0.420

[1] FCR = Feed conversion ratio

[2] SED = Standard error of the difference of the two means

In all the performance trials with starter to finisher and sows, phytase supplementation did not result in a significant reduction/increase in the excretion of N in the feces and urine, even though in all the fecal excretions numerical reduction was observed with Phytase diet.

Model Evaluation

Regression analysis of observed vs. predicted showed a weak relationship between the two for the P excretion in the manure of sows in both the No-phytase (r^2 =0.25) and Phytase (r^2 =0.18) diets. Visual assessment of residuals also showed similar observations as more scatter in data points was observed for both No-phytase and Phytase diets (Figures 2 and 3). However, the intercept was not significantly different from zero in both the No-phytase (*P* >0.869) and Phytase (*P* >0.421) diets (Table 1). Similarly, the slopes of the regression were not significantly different from one for both the No-phytase (*P* = 0.114) and Phytase diets (*P* = 0.282).

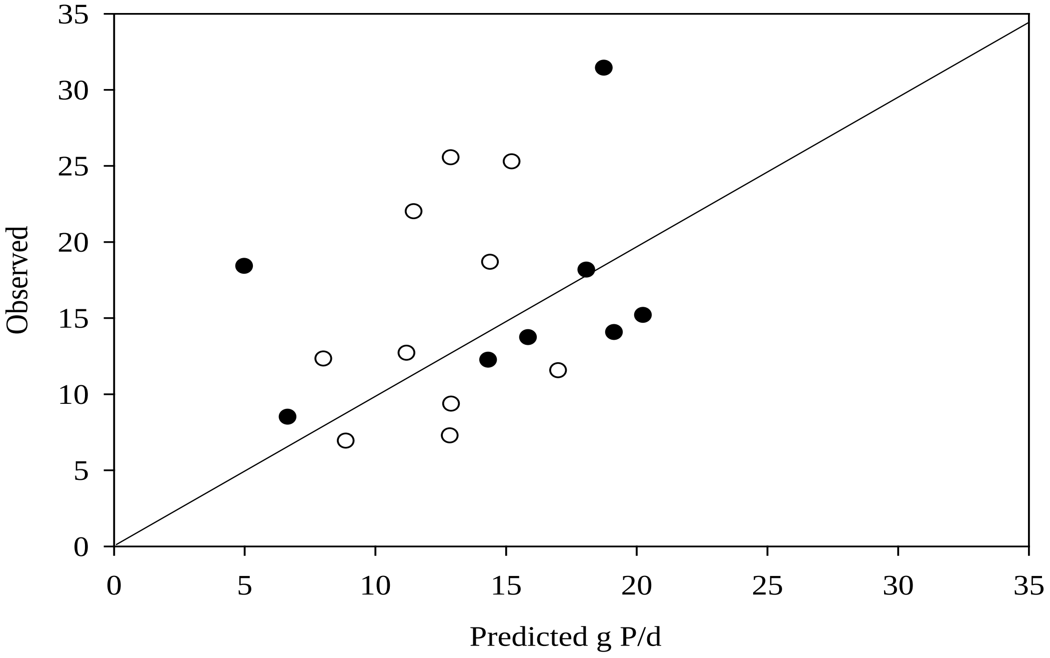

Figure 2. Plot of observed vs. predicted of manure P in sows. Solid symbols represent No-phytase diet and open symbols, the Phytase diet.

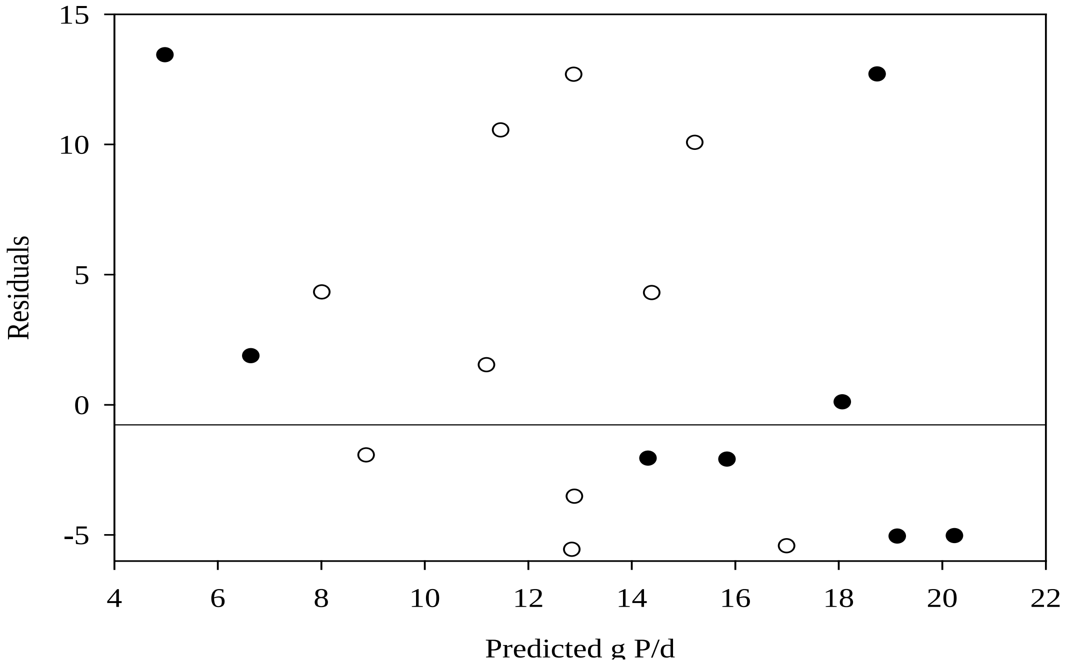

Figure 3. Plot of residuals vs. predicted P output in manure of sows. Solid symbols represent No-phytase diet and open symbols, the Phytase diet.

Table 3. Statistical summary of results from regression of predicted on observed P and N excretion from sows

Descriptive statistics	P		N	
Diet	No-phytase	Phytase	No-phytase	Phytase
Intake (g/d)	16.4	14.8	87.0	92.9
Excreted (g/d)				
Observed mean	10.9	10.2	62.3	57.0
Predicted mean	14.4	12.6	55.4	58.8
Observed SD	3.03	3.82	13.9	15.4
Predicted SD	5.57	2.88	19.5	10.1
Linear regression				
Intercept	*P* >0.869	*P* >0.421	*P* >0.651	*P* >0.531
Intercept	1.27 (±7.43)	5.05 (± 5.91)	15.0 (± 31.2)	19.7 (± 29.9)
Slope	1.04 (±0.57)	0.54(±0.46)	0.65 (± 0.50)	0.61 (± 0.50)

Further assessment of model predictions using partitioning of MSPE revealed that most (60%) of the total error of prediction was associated with ER in the No-phytase diet and ED (50%) in the Phytase diet. Prediction assessment using CCC showed that model predictions were precise for the No-phytase (r =0.61, P <0.05) than the Phytase diet (r =0.60, P <0.05).

However, predictions were more accurate for the later (C_b =0.76) than the former (C_b =0.45). There was a 32 and 24% overprediction of P excretion in the No-phytase (μ =-0.42) and Phytase diets (μ =-0.24) respectively.

Nitrogen is another nutrient of concern in swine operations with respect to environmental pressure. Hence adequate understanding of N flow in sow operations is crucial for development of economically and environmentally sustainable swine operations. Therefore, the model was also assessed for N prediction in sows. Regression analysis of observed on predicted values showed that the intercept was not significantly different from zero in both treatment diets (P >0.651 for the No-phytase and P >0.531 for the Phytase diets) and the slope was not significantly different from one in both diets (P =0.238 for the No-phytase diet and P =0.265 for the Phytase diet). Partitioning of the MSPE showed that model predictions for N performed well for the Phytase than the No-phytase diet. The ECT contributed less than 5% towards the total MSPE in both treatment diets. The ER was however different in both diets contributing the most towards the total error in the No-phytase (60.1%) than in the Phytase diet (9.76%). Random error contribution towards the total error was higher in the Phytase diet (85.3%) than in the No-phytase diet (39.8%). Furthermore, CCC assessment showed that model predictions were more accurate for No-phytase compared to Phytase diets (C_b =0.92 and 0.74 respectively). Model predictions were also more precise in the No-phytase (r =0.71, P <0.05) than the Phytase diet (r =0.59, P >0.05). The model underpredicted N excretion in the manure of sows by 11% in the No-phytase diet (μ =0.04) and over-predicted N excretion in the manure of sows by 3.2% when phytase was supplemented to the diet (μ =-0.8).

Supplementation of phytase to sow diet resulted in 6.67% (P >0.05) and 12.8% (P >0.05) reduction of land base requirement for the optimal manure application for the experimentally observed and model predicted values respectively (Table 3). The model prediction for land base requirement was not satisfactorily predicted where an overprediction of 30 and 21% was observed in the No-phytase and Phytase treatment diets respectively, even though this overprediction was not significantly different (P >0.139).

DISCUSSION

Phytase supplementation did not show any effect on the reduction of P excreted in feces and urine of sows. Other studies, however, reported the opposite where total P content in the feces of sows fed the phytase diet decreased by 27.2% compared to those fed a standard diet

(Baidoo *et al.* 2003) suggesting an improved digestibility of P, even though the study was conducted on lactating sows. Kemme *et al.* (1997) observed that the efficacy of phytase in improving digestibility of P decreased in the order of lactating sows, growing-finishing pigs, sows at the end of pregnancy, piglets, and sows at mid pregnancy. As the sows used in this study were neither pregnant nor lactating, observations of Kemme et *al.* (1997) might explain the absence of any effect of phytase in reducing excretion of P in the manure of sows in this trial.

The observations of the current study are in agreement with the study of Carter *et al.* (2003) on the excretion of P but not N. Carter *et al.* (2003) developed a more descriptive model for prediction of nutrient excretion based on differing nutritional scheme for gestation and lactation sows. The amount of P excretion predicted by the current model is also in agreement with the recommendation of the National Resource Conservation Service (NRCS) of the United States Department of Agriculture (USDA) where an excretion of P for gestation sows was estimated to be 10.0 g/d/sow (NRCS, 1992). However the prediction for N excretion was not in agreement with that of NRCS. Model prediction of the excretion of P was not in agreement with the estimates by Fernández *et al.* (1999b) where P excretion was estimated at 16.2 g/d/sow for the standard diet. However, the N excretion prediction was close to that of Fernández *et al.* (1999b) where excretions were estimated at 61.6 g/d/sow for the standard diet. The land base requirement observed in this study were similar to that reported by May & Rozeboom (2008) where the annual P_2O_5 output was reported to be 29,750 kg for a 2,400 sow breeding herd. The total land base required for the optimal spread of this manure was 524 ha.

Table 4. Evaluation of model predicted P and N excretion in the manure of sows

Statistic	P		N	
Diet	No-phytase	Phytase	No-phytase	Phytase
MSE	2.02	19.2	387	238
RMSE	1.42	4.38	19.7	15.4
r^2	0.25	0.18	0.14	0.17
MSPE	1.99	14.9	300	185
RMSPE	1.41	3.87	17.3	13.6
Partitioning of MSPE (%)				
ECT	11.4	32.9	0.11	4.97

ER	62.4	16.7	60.1	9.76
ED	26.2	50.4	39.8	85.3
Concordance correlation coefficient				
C_b	0.78	0.94	0.92	0.74
r	0.61*	0.60*	0.71*	0.59
μ	-0.42	-0.24	0.04	-0.80

Table 5. Land base requirement for manure spreading based on the P content of manure from sows fed standard and phytase diets

Diet	Observed	Predicted
	-------------- acre/sow/year -------------	
No-phytase	0.24^a	0.32^a
Phytase	0.23^a	0.28^a

^{a,b,c} Means followed by the same letter in a diet are not significantly different (P<0.05).

To the author’s knowledge, this is the only study that evaluated the model adopted by Manitoba Conservation using local data. However, it is recommended that a further assessment of this model be carried out to build the required confidence in the model for its intended purposes. This is important because the data used in this study showed variability in the observations for the outputs of total P and N in sows. Mitchell (1997) suggested that with more scatter in data point for evaluation of predictive models, the computed value of the test statistic would be smaller making the null hypothesis hard to reject, either due to the fact that the slope of the regression line being not significantly different from unity or due to the higher scatter around the line. Therefore, the observation of the current study for the prediction of nutrient excretions in sow operations needs further assessment.

CONCLUSION

In this study dietary phytase supplementation did not result in a reduced fecal and urine P excretion, however, P intake was reduced by almost 2 g/day. Phytase did not have any effect on the excretion of N in the manure of all classes of pigs. Model evaluation showed that the model adopted by Manitoba Conservation to predict the excretion of P and N in sows was not satisfactory when standard diet was used. The observed data showed large variation in P output in manure when phytase was supplemented to P deficient diet. Due to the scatter of the data, conclusions based on the current study were not sufficient enough to report the model as useful for both treatment diets. It is recommended that phystase to be used by producers as it will reduce the use of P and possibly P in manure (which then requires less land to spread). Because there is enough evidence that the model overpredicts land requirements, it is recommended that further research be conducted, preferabbly, under commercial setting to determine/confirm that the amount of P and N in manure measured in this study is representative in sow facilities in Manitoba. Further investigation should also be carried out for lactating sows as their diets and intake will be different from non-pregnant dry sows.

COMMUNICATION OF PROJECT RESULTS

The results of the final report make up a part of a M.Sc. thesis titled ‘Evaluation of an extant model for the excretion of phosphorus and nitrogen from swine fed diets with and without microbial phytase’. Some parts of the project have been communicated through presentations at national and international conferences.

ACKNOWLEDGEMENTS

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