RESEARCH REPORT

ENVIRONMENT

Title: Estimation of the mass balance of nutrients for specific production phases and the flow of nutrients through a swine farm - **NPB #05-130**

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Abstract

Three experiments were conducted. In Experiment 1, seventy-six crossbred pigs (28 kg body weight) were used to evaluate the effects of reducing dietary crude protein (CP), phosphorus (P), and trace minerals (TM) on dry matter (DM), nitrogen (N), P, and mineral excretion and on ammonia and hydrogen sulfide emissions during a 110-d finishing period. Pigs were blocked by body weight and randomly allotted to dietary treatments. Pigs were housed in an environmentally-controlled building with 4 identical rooms, each room having a shallow pit, pull plug system (19 pigs/room, 2 rooms/treatment). The control diet was a fortified corn-soybean meal diet with 0.1% inclusion of TM premix for Phases 1, 2 , 3 and 4. Diet 2, which was a low nutrient excretion (LNE) diet, was similar to the control with the exceptions that CP was reduced by 3% units, P by 0.1% units, phytase added (500 FYT/kg), and TM premix reduced by 50, 77, 83 and 100% for Phases 1 - 4, respectively. Diets were formulated on true digestible lysine basis, and methionine, threonine and tryptophan were added to LNE on an ideal basis as needed. Pig weight, feed intake, pit volume, and slurry pH were measured weekly. Feed and slurry samples were collected weekly for DM, N, P, and mineral analyses. Slurry pH and electroconductivity tended to be reduced for pigs fed the LNE diet. Slurry from pigs fed the LNE diet had lower concentrations of DM, N, P, carbon, ammonium nitrogen, calcium, potassium, sulfur, iron, zinc, copper, and manganese. Daily N and P excretion was reduced in each phase for pigs fed the LNE diet and this reduction led to a 30 and 34% reduction for the entire finishing phase. Macro-mineral excretion was reduced on average of 23% and for the micro-minerals, excretion was reduced by 46% for pigs fed the LNE diet. The cumulative excretion of DM, N, and P for the entire finishing period was reduced by 3.7, 1.1, and 0.23 kg/pig, respectively, for pigs fed the LNE diet. The concentration (mg/m^3) and emission rate (mg/min) of ammonia in the exhaust air was reduced by 52% for pigs fed the LNE diet. The decrease in emission rate for pigs fed the LNE diet resulted in a 59% decrease in ammonia emitted per pig per day. However, the concentration, emission rate, and emission per pig for hydrogen sulfide were not affected by dietary treatment. Diet did not affect growth performance, carcass traits, or whole body composition and accretion, or feed costs per pig. From these data, mass balance of nutrients for the finishing phase was calculated. Based on mass balance, it was calculated that for pigs fed the LNE diet that 58% of the nitrogen entering the room exited the room via the pigs versus 47% for pigs fed the control diet. Likewise, the amount of P exiting the room via the pigs as a percentage of that entering room increased from 37% for pigs fed the control diet to 48% for pigs fed the LNE diet. These results suggest a marked reduction in nutrient excretion and ammonia emission for pigs fed LNE during the finishing period.

In another series of experiments, nutrient excretion for pigs during the nursery phase was determined (Experiment 2) and the effect of waste treatment on the concentration of nutrients in the waste stream was determined (Experiment 3). Nutrient excretion increased with each progressive nursery phase with the greatest differences in excretion observed for zinc and copper. The cumulative excretion for DM, N, and P equaled 7.32 kg, 0.424 kg, and 41.9g per pig during the 43-d nursery phase. The waste treatment system used on this farm decreased the nutrients measured by greater than 77% with a 90, 93, and 91% reduction in total nitrogen, ammonium-nitrogen, and phosphorus concentration from the effluent leaving the barns to the 2nd stage aerobic lagoon.

Introduction

Estimation of nutrient excretion is an essential component in the development of a comprehensive nutrient management plan (CNMP). Current estimates of nutrient excretion by various classes of swine are outdated and do not allow for prediction of nutrient excretion based on dietary nutrient intake or retention. Recently, however, the ASABE initiated development of equations that could be used to estimate N and P excretion by swine (Carter et al., 2003). These equations, while an improvement over previous estimates, are still inadequate in many areas, such as excretion of nutrients other than N and P, slurry volume, feed wastage, and water usage. The basis for the development of these equations was the swine NRC (1998) and experimental data using individually-fed pigs. One could argue that the data used to develop these equations was not indicative of group-housed pigs under commercial conditions. Also, these equations were developed on an "as-excreted" basis, with no accounting of factors that may affect the ultimate release of nutrients from a facility (i.e., feed wastage, N volatilization, pit management, etc). In addition to these deficiencies, the excretion of many trace minerals (Fe, Zn, Cu) was not attempted due to lack of data. A total inclusive CNMP would account for all nutrients entering a facility via the feed, pigs, water, and air while also accounting for nutrients leaving a facility via the pigs, slurry (waste stream), and exhaust air. Thus, a mass balance approach is needed in order to account for all nutrients entering and exiting a facility. However, data are generally lacking with respect to one or more of these inputs or outputs for group-housed pigs in the nursery and finishing phases. For producers and regulatory officials to accurately account for nutrients in a production system, quantifying inputs and outputs is warranted.

Stated Objectives from original proposal:

The objectives of this proposal were to:

1) Quantify the mass balance (intake minus output) of nutrients, as affected by diet, for the finishing phase (50 to 250 lb) on a weekly basis, on a dietary phase basis, and for the entire growth period. Nutrients evaluated include nitrogen and its derivatives (NO_3+NO_2-N, NH_4-N, and TKN), total and water soluble P, and macro-and micro-minerals.
2) Quantify the mass balance (intake minus output) of nutrients for the nursery phase (12 to 50 lb) on a weekly basis, on a dietary phase basis, and for the entire growth period using the same parameters as the finisher phase experiment.
3) Develop prediction equations to estimate nutrient output for nursery and finishing pigs on a per pig per day or per pig per phase basis based on inputs of feed, body weight, body weight gain, and(or) age (time), and
4) Determine nutrient flow (TKN, NH_4-N, NO_3+NO_2-N, TP, K) for the whole farm (120 sow farrow-to-finish).

Materials and Methods:

Finishing experiment (Exp. 1): A total of seventy-six crossbred ([York x Landrace] x Duroc [Danbred 610]) pigs initially weighing 27.9 kg were stratified by sex and ancestry, blocked by body weight, and allotted two dietary treatments. Dietary treatments were randomly allotted to four rooms with 2 pens per room (19

pigs/room). Each room was housed within the same building with each room receiving the same incoming air. Each room was equipped with a shallow pit with a pull-plug. Thus, each room served as the experimental unit. All pigs within a room were fed one of two diets. The dietary treatments were fed in four phases: 27.9 to 53.8, 53.8 to 83.4, 83.4 to 104.4, and 104.4 to 118 kg. The two dietary treatments (Table 1) included a fortified corn-soybean meal diet or a low protein, low phosphorus, amino acid- and phytase-supplemented diet with trace mineral reduction. The low nutrient excretion (LNE) diet was formulated to approximately 3 percentage units lower in crude protein and 0.10% lower in total phosphorus as compared with the fortified corn-soybean meal diet. Crystalline amino acids were added to the LNE diet on a true ileal digestible basis and phytase was added to supply 500 phytase units/kg. Trace minerals (Fe, Zn, Cu, Mn) were reduced by 50, 66, 84, and 100% during the 4 dietary phases, respectively, compared with the control diet. Feed was weighed before filling the feeders, and each room was equipped with a water meter to determine water disappearance (water intake).

Each week the pigs were removed from each room and weighed. At this time, the feeders were weighed to calculate feed intake and a feed sample was collected from each feeder. Also, at this time, total pit volume was determined and sampling the pit commenced. To sample the pit, a submersible pump was placed in the pit and used to circulate the slurry contents. Also, the output from the pump was used to wash the remaining fecal material into the pit. After recirculating the pit, a sampling pump was placed at the pull-plug. The plug was pulled and as the slurry exited the pit, the sampling pump pulled a continuous sample from the exiting slurry. At this time, slurry pH, and EC were measured. Following these measurements, a mixing-sampling unit was placed in the bucket to mix the sample while 2 one liter bottles were filled for later analyses. One sample bottle of slurry was acidified to a pH of 2 to 3. The two sample bottles were frozen for later analyses.

The analyses of the feed and slurry samples were performed by the OSU Soil Testing Lab. The nutrients in the feed measured included: dry matter, total nitrogen, total phosphorus, carbon, calcium, potassium, magnesium, sodium, sulfur, iron, copper, zinc, and manganese. The slurry was measured for these nutrients plus NH_4-N, and NO_3-N. Total nitrogen and carbon of the samples were analyzed using a LECO Carbon/Nitrogen analyzer. Ammonium nitrogen and nitrate were analyzed by extracting nitrate and ammonium from the slurry samples with 1.0 M KCl. Ammonium and nitrate are simultaneously measured on a flow-injection analyzer. The ammonium is analyzed using the salicylate method, and the nitrate is measured using the cadmium reduction method. Mineral concentrations in the feed and slurry were analyzed by digestion at 120˚ C with concentrated nitric acid and hydrogen peroxide. The resulting solution was analyzed on an ICP. All analyses were performed according to Recommended Methods for Manure Analysis, 2003, University of Wisconsin-Extension A3769.

Nutrient concentration of the slurry was multiplied by total pit volume to achieve total nutrient output per week, by dietary phase, and for the entire finishing period. There were 16 measurements per room for the entire period

In addition to the slurry data, the rooms were monitored for ammonia and hydrogen sulfide concentrations. Each room was equipped with two variable speed fans (PH 4E40Q, Multifan, Bloomington, IL) controlled with one unit (Varifan ECS-3M). Air samples were collected from ducts attached to each exhaust fan. Sampling ports were inserted into the ducts, and air samples were drawn from each duct to a stationary control instrumentation trailer. Air samples from each duct were automatically switched sequentially between eight sampling manifolds and one background sample. Gases were measured for a twenty minute period for each fan. The first 19 minutes of the cycle was used to purge the sample line and equilibrate the analyzer. During the last minute of each cycle, gas measurements were averaged and recorded with data software. A total of eight samples were analyzed per fan per day (16 measures per room per day) for a total of 56 measures per fan per week.

Ammonia concentration in the exhaust air was be measured by first oxidizing NH_3 to NO with an NH_3 converter and then detecting the NO with a chemiluminescence detector (Model 17C, Thermo Environmental Instruments, Franklin, MA). Hydrogen sulfide was measured using a pulsed fluorescence analyzer by conversion of the H_2S in the sample to SO_2 and its subsequent detection by the SO_2 analyzer (Model 450C-TL, Thermo Electron Corporation). Each analyzer was calibrated weekly using a Multigas Calibration System (Model 146C, Thermo Environmental Instruments, Franklin, MA). Sample lines (Teflon, Dupont, Wilmington, DE) were inspected regularly.

Airflow from each fan was continuously measured using current transducers (Hawkeye 822, Portland, OR) attached to each fan control unit. Voltage readings were regressed against actual flow from each fan to generate prediction equations for each fan. Airflow was determined for each fan using a flowhood (8400 Flowhood kit, Shortridge Instruments, Scottsdale, AZ) that measured the total volume of air exhausted by each fan. Voltage was regressed against airflow across the range for the minimum speed fan (40 to 100%) and for the 2nd stage fan (40 to 100%). The minimum speed fan was set to run at all temperatures with a minimum speed of 40% of maximum fan speed. The 2nd stage fan turned on at minimum speed (40%) when the ambient temperature in each room exceeded 5 degrees from the set point. Fans were calibrated each week when the pigs were removed from the room for weighing. The flow rates were recorded using a data logger (Omega Engineering, Inc) for each sampling cycle. Data for air flow rates and gas concentration were downloaded daily to a personal computer.

The generation and emission rates of each gas were calculated according to Heber et al. (2001). The emission rates for Rooms 1 to 4 were based on the mean gas concentration in the exhaust air of each room and the total airflow rate for each sampling cycle.

When a room of pigs reached approximately 118 kg, six pigs were selected for whole body composition analysis and six pigs were used to collect carcass data. The pigs were transported to the university meat lab and humanely slaughtered. Following this, the six pigs identified per room for whole body analysis were ground with a whole body grinder and a sample was taken to determine nutrient content of the pig. In addition, six pigs were slaughtered at the beginning of the test period to determine initial nutrient content. For the six pigs used for carcass data, following scalding, scraping, and evisceration, hot carcass weight was recorded and carcasses were allowed to chill overnight. Standard carcass measures were collected the following morning. Nutrient retention was calculated by subtracting initial nutrient content from final content. Following determination of this data, mass balance was calculated for N and P by quantifying the total nutrients entering the room and the total nutrients exiting the room via the slurry, exhaust air, and pigs. The calculations for intake minus output (slurry, exhaust air) were calculated on a weekly basis, by dietary phase, and for the total growth period.

Data were analyzed as a randomized complete block design. The model included the effects of treatment, block, and block x treatment (error). A simple contrast was used to compare the control diet with the LNE diet. Room served as the experimental unit. Data were analyzed in this manner by phase and for the entire finishing period.

Nursery experiment (Exp. 2). A total of 189 crossbred ([York x Landrace] x Duroc [Danbred 610]) pigs initially weighing 6.3 kg were stratified by sex, ancestry, and weight and housed in two identical nursery rooms. Each room was housed within the same building with each room receiving the same incoming air. Each room was equipped with a shallow pit with a pull-plug. All pigs were fed the same diet across both rooms in order to establish baseline excretion estimates. Diets were fed in a three phase program; d 0 to 14, d 14 to 28, and d 28 to 42, respectively. The Phase 1 diet contained 23.8% CP, 1.60% Lys, 0.90% Ca, 0.70% P, 2,210 ppm Zn, and 25 ppm Cu; the Phase 2 diet contained 22.9% CP, 1.40% Lys, 0.80% Ca, 0.70% P, 2,213 ppm Zn, and 25 ppm CU; the Phase 3 diet contained 20.2% CP, 1.20% Lys, 0.70% Ca, 0.65% P, 194 ppm Zn, and 228 ppm Cu. Feed was weighed before filling the feeders.

Each week the pigs were weighed. At this time, the feeders were weighed to calculate feed intake and a feed sample was collected from each feeder. Also, at this time, total pit volume was determined and slurry samples collected as described for the finishing experiment. Pits were recharged with fresh water after sampling. Analysis of the concentration of nutrients and calculation of excretion were similar to that described for the finishing experiment. Results were averaged for the two nursery rooms. Due to technical difficulties with the gas analyzers, ammonia and hydrogen sulfide emissions were not collected.

Nutrient Concentration of the Waste Stream: The concentrations of total solids, N, NH_4-N, NO_3-N, P, and K in the effluent were determined at three points in the waste treatment system. The first sampling site was a "manhole" that captured effluent leaving the buildings. At this site, an autosampler unit was stationed. The autosampler collected a 100 mL sample at 7 minute intervals each time a pit was dumped throughout the course of one week. The sample was stored in a refrigeration unit (35 ^{o}F) attached to the autosampler. Each week the

sample from the autosampler was collected and frozen for later analysis. The second point sampled in the waste stream was from the 1st stage anaerobic, covered lagoon. This sample was obtained by walking out on the cover to a sampling port. A sampling probe was placed through the port and a sample of the contents was collected from three feet below the surface. The third sample was collected from the 2nd stage aerobic lagoon and the collection area for the pit recharge pump. This sample was collected by placing the sampling probe three feet below the surface to obtain the sample. Once the samples were collected, pH and electroconductivity were immediately measured and the sample was then frozen for later analysis.

Results

Finishing Experiment (Exp. 1):

All procedures were approved by the OSU Institutional Animal Care and Use Committee. The experiment began in July, 2007 and ended in November, 2007.

Growth Performance and Carcass data: There were no effects ($P > 0.10$) of dietary treatment on ADG, ADFI, and F:G (Table 2). However, daily intake of N and P was reduced ($P < 0.05$) for pigs fed the LNE diet. There were no effects of treatment on carcass traits (Table 3). These results are important in that pig performance and carcass data were not affected by consuming the LNE diet.

Whole Body Composition and Nutrient Accretion: Chemical composition of the whole body is shown in Table 4. The percentages of water, CP, fat, N, and P were not affected ($P > 0.01$) by dietary treatment. However, the percentage of ash in the whole body tended to be reduced ($P = 0.06$) for pigs fed the LNE diet. Accretion rates were not affected ($P > 0.10$) by dietary treatment; however, ash accretion was numerically decreased for pigs fed the LNE diet. On the other hand, P accretion was numerically increased of pigs fed LNE. These results suggest that accretion (retention) was not affected for pigs consuming the LNE diet with the exception of possibly ash accretion. This slight decrease in ash percentage and accretion was not accompanied by a decrease in P accretion suggesting that the removal of trace minerals from the diet may have impacted the accretion of these nutrients in the whole body. Further analyses of the whole body and a core sample of the longissimus should be able to quantify any affects on trace mineral retention.

Slurry Characteristics: Slurry volume was numerically ($P > 0.10$) higher for pigs fed the LNE diet; this increase was due to a water line break in one room of pigs fed the LNE diet. Otherwise, slurry volume was similar for both treatments. Temperature of the slurry was similar ($P > 0.10$) across all four rooms (Table 5). However, slurry EC and pH tended to be reduced ($P < 0.08$) for pigs fed the LNE diet. Nutrient concentration of the slurry is shown in Table 6. Slurry from pigs fed the LNE diet had lower ($P < 0.10$) concentrations of DM, C, N, NH_4-N, P, Ca, K, S, Fe, Zn, Cu, and Mn. Also, the ratio of C:N and N:P tended ($P < 0.10$) increase for pigs fed the LNE diet. Furthermore, the water soluble P:total P ratio was not affected by dietary treatment which is important because inclusion of phytase in the diet has been shown, in some instance to increase this ratio. Furthermore, total water soluble P concentration of the slurry reduced ($P < 0.05$) for pigs fed the LNE diet.

Nutrient concentration of the slurry was multiplied by total volume of the slurry and divided by the number of pigs and days on test to calculate excretion on a g/pig/d basis. Excretion of carbon was not affected ($P > 0.10$) by dietary treatment (Table 7). However, DM, N, P, Ca, K, Mg, S, Fe, Zn, Cu, and Mn excretion were reduced ($P < 0.05$) for pigs fed the LNE diet. The cumulative excretion of DM, N, and P for the entire finishing period was reduced by 3.7, 1.1, and 0.23 kg/pig, respectively, for pigs fed the LNE diet. The excretion of N and P for pigs fed both diets during the four dietary phases is shown in Figures 1 and 2. Daily N and P excretion was reduced in each phase for pigs fed the LNE diet and this reduction led to a 30 and 34% reduction for the entire finishing phase. It is also important to note that excretion increased as days (phases) progressed in the finisher. The percentage reduction in nutrient excretion for pigs fed the LNE diet compared to pigs fed the control diet for the finishing period is shown in Figure 3. Note that with the exception of Na,

nutrient excretion was reduced for pigs fed the LNE diet. Macro-mineral excretion was reduced on average of 23% and for the micro-minerals, excretion was reduced by 46% for pigs fed the LNE diet.

Airflow, NH_3 and H_2S Emissions: Airflow was similar ($P > 0.10$) for all rooms (Table 8). However, the concentration (mg/m^3) of NH_3 in the exhaust air was reduced ($P < 0.04$) by 52% for pigs fed the LNE diet. The emission rate (mg/min) of ammonia also was reduced ($P < 0.03$) by a similar amount for pigs fed the LNE diet. The decrease in emission rate for pigs fed the LNE diet resulted in a 56% decrease in ammonia emitted per pig per day. However, the concentration, emission rate, and emission per pig for H_2S were not affected ($P > 0.10$) by dietary treatment. Emission of NH_3 and H_2S on per body weight basis and on a g/d/AU basis is shown in Figure 4. Emissions of NH_3, expressed on a mg/kg body weight or mg/d per AU basis, was reduced by 59% for pigs fed the LNE diet. However, H_2S emissions expressed on a mg/kg body weight or mg/d per AU basis, were not affected by dietary treatment. The reduction in ammonia emission of 56% for pigs fed the LNE diet is greater than the decrease in total N excreted which averaged 31%. However, NH_4-N concentration in the slurry was reduced by approximately 40% and this coupled with the decrease in pH of the slurry resulted in the 56% reduction in ammonia emission. However, H_2S emission was not affected by dietary treatment most likely due to the short length of time (7 d) the manure remained in the pit for this shallow pit, pull-plug system.

Calculation of Mass Balance of Nitrogen and Phosphorus: Table 9 shows the calculations for mass balance of nitrogen and phosphorus during the 110-d finishing period. Nutrients entering the facility were assumed to enter via the feed and the pigs. Analysis of water entering the building suggested negligible amounts of these two nutrients entering via the water. Nutrients exiting the facility were assumed to be via the slurry, pigs, and exhaust air. Based on initial pig composition and chemical composition of the feed, the amount of N and P entering were reduced ($P < 0.03$) for pigs fed the LNE diet. Based on reductions in the excretion of N and P, a reduction in NH_3-N emission, with no change in N and P content of the carcass, the amount of N and P exiting the facility was reduced ($P < 0.04$) for pigs fed the LNE diet. Surprisingly, the calculation of mass balance for N and P was close to zero, or in other words, the amount of N and P exiting the facility was similar to that entering. For N, the difference in N exiting the facility and that entering was approximately -0.2 kg/pig or .0.2 kg more N exited the facility compared with that calculated entering the facility. For P, approximately 67 g was unaccounted for in the pigs or slurry leaving each room.

Figures 5 and 6 show the proportion of total N and P entering and exiting the room via the pigs, feed, slurry, and air. In the case of N, due to the decrease in N intake for pigs fed the LNE diet, the proportion of N entering the facility via the pigs increased with the amount entering via the feed decreasing as compared with pigs fed the control diet (Figure 5). For N exiting the facility, the proportion exiting via the pigs increased from 46% for pigs fed the control diet to 56% for pigs fed the LNE diet. This increase was due to the reduction in N exiting via slurry for pigs fed the LNE diet (50 vs. 42%). Also, the amount of N exiting via the exhaust air decreased for pigs fed LNE; however, the proportion of total N exiting the facility via exhaust air was small compared to that exiting via the pigs or slurry.

A similar trend was found for the proportion of P entering and exiting the facility via the pigs, feed, and slurry (Figure 6). The proportion of P entering the facility via the feed decreased (87 vs. 84%) for pigs fed the LNE diet due to the decrease in feed intake. For total P exiting the facility, exited the facility via the pigs with a marked reduction exiting via the slurry for pigs fed the LNE diet. In fact the proportion of P exiting the facility in the slurry or pigs decreased from 60:40 to 50:50 (slurry P:pig P) for pigs fed the LNE diet.

From these values it can be calculated that for pigs fed the LNE diet that 58% of the nitrogen entering the room exited the room via the pigs versus 47% for pigs fed the control diet. Likewise, the amount of P exiting the room via the pigs as a percentage of that entering room increased from 37% for pigs fed the control diet to 48% for pigs fed the LNE diet. These results suggest that a greater proportion of the N and P entering each room was retained by pigs fed the LNE diet vs. those fed the control diet.

Prediction of Excretion: The ASABE model (2005) for estimating nutrient excretion was used to compare results of this experiment to those predicted by the model. The BASAE model allows for the input of data specific to a particular production phase. Input data such as pig weight, lean gain per day, carcass yield, average daily feed intake, average daily gain, and dietary characteristics such as crude protein and phosphorus

percentage can be use to predict N and P excretion. These data were included in the model to estimate N and P excretion for pigs fed the control diet in the current experiment. Estimate of excretion for N and P produced by the model were 32.6 and 5.77g/pig/d, respectively. The estimate of N excretion produced by the model is very similar to the actual excretion obtained in the current study (32.6 vs. 33.4) for pigs fed the control diet. However, as we have observed in two previous studies, the model tends to differ from actual data collected in regards to P excretion. The model estimated P excretion as 5.77 g/pig/d whereas the actual result obtained in the current study was an excretion of P of 6.20 g/pig/d. In all of our studies completed to date, the estimate of P excretion from the model has been lower that that obtained in the actual experiment. Further work with this data set will allow for refinement of the prediction model for P and also for the basis for prediction of other nutrients.

In addition to comparing these results with that predicted by the ASABE (2005) model, these data can also be used to generate prediction equations for nutrient excretion over the entire finishing period. For example, Figure 7 shows nitrogen excretion plotted against body weight during the finishing period. Note that greater than 80% of the variation associated with N excretion was accounted for by body weight alone. The same is true for phosphorus (Figure 8) with the exception that body weight accounted for 69 to 75% of the variation in P excretion. Due to limited space, prediction equations for other nutrients are not presented. Also, the actual equations are not presented due to the fact that for a differing set of circumstances (i.e., lean growth rate, feed intake, etc) these equations based on body weight may not be accurate. Further work with this data set will allow for the generation of prediction equations that take into account other factors besides body weight in order to predict excretion.

Cost analysis: The cost of each diet within each phase was calculated based on ingredient prices at the OSU Feed Mill during July through November 2007. Diet costs were multiplied by the amount of feed consumed within each phase for both dietary treatments and a total cost per pig was calculated. Average diet costs were very similar for both diets ($0.085 vs. $0.087/lb) and the total feed cost per pig was $44.74 and $44.54 for the control and LNE diet, respectively. These results suggest that the decrease in excretion and ammonia emissions can be obtained with no effect on growth performance and carcass traits without increasing feed costs per pig.

Nursery experiment (Exp. 2):

For the nursery experiment, no dietary treatments were employed and the 2 rooms were averaged to determine baseline excretion values during a 3 phase feeding program. Nutrient concentration of the slurry and excretion (g/pig/d) were similar for both nursery rooms. Table 10 shows the average nutrient concentration of the slurry during the 3-phase feeding program. Nutrient concentration of the slurry was similar in all three phases from most variables measured with the exception of Zn and Cu. Zinc concentrations were greater in Phases 1 and 2 compared with Phase 3, and Cu concentrations were greater in Phase 3 compared with Phases 1 and 2. These changes in concentration were due to the zinc and copper levels in the diets for Phase 1, 2, and 3. The C:N and N:P ratios were higher in the slurry of nursery pigs compared with that found for the finishing pigs.

Nutrient excretion for nursery pigs on a g/pig/d basis is shown in Table 11. Note that for most nutrients, excretion increased with each progressive phase. The greatest differences in excretion across the three dietary phases were for Zn and Cu. Zinc excretion increase from Phase 1 to 2, but then decreased for Phase 3 whereas, Cu excretion increased slightly from Phase 1 to 2, but a dramatic increase in Phase 3 was observed. Again, these changes in excretion were indicative of the Zn and Cu concentrations in each dietary phase. The excretion of N and P for the nursery phase averaged 9.9 and 0.97 g/pig/d. The cumulative excretion for DM, N, and P equaled 7.32 kg, 0.424 kg, and 41.9g per pig during the 43-d nursery phase.

In addition, the same *set* of pigs was used in both the nursery experiment and the finishing experiment; however, the same individual pig used in the nursery may have not been used in the finishing experiment. There was only a one week period between ending the nursery experiment and starting the finishing experiment. If the cumulative excretion of N and P in the nursery and finishing (control pigs) experiments are summed, the

total N and P excretion from 6.3 kg to 118 kg was 4.09 and 1.10 kg/pig, respectively. Also, plotting N and P excretion versus body weight generates prediction excretions with an $R^2 > 0.88$ for this period (data not shown).

Nutrient Concentration of the Waste Stream (Exp. 3):

Nutrient concentration of the effluent was determined at three points in the waste treatment system. Table 12 shows the average effluent characteristics and concentration of nutrients of weekly samples collected from September 2006 through February 2007. Note that pH of the effluent increased from leaving the barns to storage in the 1st stage covered lagoon, but then decreased in the 2nd stage aerated lagoon. Electroconductivity of the effluent decreased with each successive treatment stage. The concentrations of nutrients, with the exception of NO_3-N, decreased with each treatment stage. The concentration of NO_3-N increased dramatically in the open 2nd stage aerobic lagoon indicative of the aerobic nature of this treatment step. Figure 9 shows that the waste treatment system used on this farm decreased the nutrients measured by greater than 77% with a 90, 93, and 91% reduction in N, NH_4-N, and P concentration from the effluent leaving the barns to the 2nd stage aerobic lagoon.

Discussion:

These results suggest that dietary manipulation can have profound effects on the input and output of nutrients during the finishing phase. Pigs fed the LNE diet had a 30% reduction in N excretion for the entire finishing period. Previous reports from our station demonstrated a 20 and 40% reduction in N excretion for pigs fed diets with crude protein reduced by 2 and 4 percentage units during the finishing phase (Lachmann et al., 2006; 2007). Many studies have shown that reducing crude protein concentration of the diet with crystalline amino acid additions can reduce nitrogen excretion by 30 to 50% (Cromwell and Coffey, 1993; Sutton et al., 1999; Kornegay and Verstegen, 2001; Shriver et al., 2003). Kerr and Easter (1995) reported that for every one percentage unit reduction in dietary crude protein, nitrogen excretion could be reduced by eight percentage points. Our results agree with these previous reports in that we observed a 30% reduction in N excretion with a 3 percentage unit reduction in crude protein.

Phosphorus excretion was reduced by 35% in this study for pigs fed the LNE diet during the finishing phase. In previous studies at our station, we reported a 20% reduction in P excretion during the finishing phase for pigs fed a diet with phosphorus reduced by 0.10 percentage units. In this experiment, P was reduced by 0.10 percentage units, but phytase was added which resulted in the greater reduction in P excretion. Other reports have shown that feeding low P diets with phytase addition can reduce P excretion by 30 to 50% (Cromwell and Coffey, 1993; Sutton et al., 1999; Kornegay and Verstegen, 2001). Additionally, water soluble P was reduced for pigs fed the LNE diet and the ratio of water soluble P to total P was unchanged.

The effect of diet on the excretion of other macro-minerals and the trace minerals was profound. The excretion of Ca, K, Mg, and S was reduced from 10 to 30% for pigs fed the LNE diet. These decreases were primarily due to the reductions in soybean meal and dicalcium phosphate in the diet. The effect of the LNE diet on the excretion of Fe, Zn, Cu, and Mn was even more pronounced. Decreases in excretion for these trace minerals ranged from 30 to 60%. The removal of the trace minerals in this study was a step-wise reduction as pig weight increased. Total removal of trace minerals from the diet was achieved during the last three weeks of the finishing period. Mavromichalis et al. (1999) reported that total removal of trace minerals during the last 30 days of the finishing period did not affect growth performance or carcass traits of pigs. These reductions in mineral excretion are important due to the growing concern of Zn and Cu excretion to the environment.

Although the excretion of nutrients was reduced dramatically for pigs fed the LNE diet, possible effects on growth performance and carcass traits cannot be overlooked. In this study, neither growth performance, carcass traits, nor whole body composition were affected in pigs fed the LNE diet. Numerous other reports have shown that a reduction of 2 to 4 percentage units in crude protein of the diet with amino

acid supplementation does not affect growth performance or carcass traits. Similarly, reducing P with phytase supplementation has not affected swine growth performance or carcass traits. The main concern in removing trace minerals from the diet is the possible effect on tissue concentrations of these minerals. In this study, although not significant, was the numerical reduction in ash accretion for pigs fed the LNE diet. This slight reduction in ash accretion was not accompanied by a reduction in P accretion suggesting that the accretion of other minerals may have been affected. We are currently analyzing the whole body and a core sample of the longissimus dorsi for trace minerals to determine the effect on tissue trace mineral levels. Other studies have found no effect of trace mineral withdrawal on tissue levels of these minerals in pork (Shaw et al., 2002).

In addition to the effects on nutrient excretion, ammonia concentration and emission rates for pigs fed the LNE diet were dramatically reduced. Average ammonia emission for pigs fed the control diet was 15.5 g/d/AU. These results are slightly higher than that reported by Lim et al (2002) of 5.7 to 6.8 g/d per AU for pigs housed in barns with pull-plug, pit recharge systems flushed weekly or biweekly. However, ammonia emission was reduced by 59% to 6.4 g/d/AU for pigs fed the LNE diet. This reduction in ammonia emission is similar to that reported by Panetta et al. (2006) of a 57% decrease for pigs fed a low crude protein, amino acid supplemented diet. Our results suggest a 20% reduction ammonia emission for every 1% reduction in crude protein concentration of the diet. The effects of diet on hydrogen sulfide emissions were minimal. Hydrogen sulfide emissions in this study average 0.14 g/d/AU which is similar to that summarized by Lim et al (2002). These results suggest that diet may have minimal impact on hydrogen sulfide emissions for pigs housed in facilities with shallow pit, pull-plug, recharge systems.

For total inclusive comprehensive nutrient management plans, accurate accounting of nutrient inputs and outputs from a facility are needed. In this study, we were able to account for both inputs and outputs for the finishing phase. Surprisingly, our calculations of mass balance for pigs fed either diet were close to zero. Or in other words, for both N and P, inputs of these nutrients equaled outputs. Calculations from mass balance demonstrated that diet can have a pronounced effect on both inputs and outputs of these two nutrients for the finishing phase. Based on these data, a greater proportion of N and P entering the facility was retained in the pigs fed the LNE diet. As such, the amount of N and P exiting the facility in the slurry or exhaust air as a percentage of these nutrients entering was greatly reduced for pigs fed the LNE diet. Also, this data suggest that approximately 1.5 to 3% of the nitrogen exiting the facility was due to NH_3 emissions. Many reports have shown that dietary manipulation can decrease N and P excretion dramatically, but in this experiment we were able to partition nutrients leaving the facility to pigs, slurry, and exhaust air. Very few studies have been performed to determine actual mass balance on nutrients for the finishing phase. Our results suggest that using the techniques employed, we were able to account for nutrients entering and exiting the facility.

Modeling mass balance of nutrients for the finishing phase requires accurate determination of nutrient input and output. The ASABE (2005) model for predicting nutrient excretion of swine is, in concept, based on mass balance with the exception of not accounting for N exiting via the exhaust air. This model utilizes nutrient intake and retention to calculate excretion. When the data from this experiment is used in the model, predicted N excretion is similar to that obtained in this experiment. Thus, for this to be the case, N intake and N retention were similar to that obtained with this set of pigs. Thus, it appears that the ASABE (2005) model, based on this experiment and two previous reports from our station (Lachmann et al. (2006,2007), accurately predicts input and output of N for finishing pigs with the exception of that emitted via the exhaust air. The model also uses a similar procedure to estimate P excretion. However, based on this experiment and our two previous reports, measured P excretion has been greater than that predicted by the model. Additionally, the data collected in this experiment can be used to develop prediction equations for nutrient excretion for pigs during the finishing phase as shown for N and P excretion versus body weight. Further work with this data set should allow for the development of more robust equations for prediction of excretion for not only N and P but for other nutrients as well.

Data related to nutrient excretion for pigs throughout the nursery phase is limited. The results obtained during the nursery stage in Exp. 2 provide a baseline for which future work regarding dietary manipulation can be compared. Nutrient excretion increased with each successive nursery phase and was dramatically influenced by dietary nutrient concentrations, especially the trace minerals. Results suggest that pigs excrete 424 g of N and 42 g of P during the nursery phase. Additionally, when comparing the results obtained in this experiment with that predicted by the ASABE (2005) model, N excretion tends to be similar, but as was observed in the finishing pig, P excretion was greater for results obtained in the current experiment compared with that predicted by the model. More work is warranted with differing nutrient concentrations in nursery diets to provide additional data with which prediction models can be developed for the nursery phase.

Once slurry exits the building, dramatic changes in nutrient concentrations will occur. For the treatment system employed on this farm, dramatic reductions in nutrient concentrations of the effluent were observed. The concentrations of the nutrients measured were reduced by greater than 77%. A marked reduction in total solids, N, P, and K were observed between that leaving the barns and that measured in the 1st stage anaerobic lagoon. Further reductions in these nutrients were observed from the 1st stage lagoon and the 2nd stage aerobic lagoon. The greatest effect was observed for NH_4-N between the 1st and 2nd stage lagoon with a dramatic increase in NO_3-N. These results suggest that the treatment system employed on a particular farm will markedly impact the nutrients available for irrigation purposes and ultimately affect the mass balance for the whole production system.

Lay Interpretation

Results from these experiments suggest that dietary manipulation can have dramatic effects on the mass balance of nutrients during the finishing phase. Altering the dietary crude protein and phosphorus concentration in the diet reduced nitrogen and phosphorus excretion by 30 and 35%, respectively. Lowering the trace minerals in the diet reduced the excretion of iron, zinc, copper, and manganese by 40 to 60%. Additionally, the reduction in dietary crude protein resulted in a 59% reduction in ammonia emissions during the finishing phase for pigs housed in a facility with a shallow pit, pull-plug, recharge system. However, dietary treatment did not effect hydrogen sulfide emissions. When the inputs and outputs of nitrogen and phosphorus for the finishing phase were evaluated, dietary manipulation can markedly increase the percentage of nitrogen and phosphorus leaving the finishing phase via the pigs compared to the slurry. These reductions were observed without any effects on growth performance, carcass traits, or whole body composition of finishing pigs. Furthermore, feed costs per pig were not affected by the dietary manipulations employed in this experiment. Current models for predicting excretion appear to accurately estimate nitrogen excretion, but may underestimate P excretion for finishing pigs. Results from the nursery phase suggest that excretion increases with age and feed intake, and that trace mineral supplementation can have profound effects on excretion. The waste treatment system employed at a particular site can markedly affect nutrient concentration of the effluent and affect the mass balance of nutrients for the whole production system.

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Table 1. Dietary composition for the four dietary phases (as-fed basis) (Exp. 1).

	Phase 1		Phase 2		Phase 3		Phase 4	
Ingredient, %	Control	LNE	Control	LNE	Control	LNE	Control	LNE
Corn	65.72	74.24	71.30	79.90	76.71	85.37	80.54	89.16
SBM, 48% CP	29.11	20.58	23.66	15.07	18.30	9.73	14.58	6.12
L-lysine		0.27		0.28		0.27		0.27
DL-methionine		0.01						
L-threonine		0.08		0.09		0.07		0.04
L-tryptophan		0.01		0.02		0.02		0.004
Soybean oil	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Dicalcium phos.	0.61	0.26	0.54	0.20	0.47	0.12	0.39	0.04
Limestone	0.97	0.98	0.94	0.90	0.93	0.88	0.90	0.85
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin mix	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
TM mix	0.10	0.05	0.10	0.03	0.10	0.02	0.10	
Antibiotic	0.10	0.1	0.10	0.10	0.10	0.10	0.10	0.10
Phytase		0.02		0.02		0.02		0.02
Calculated composition								
ME, kcal/kg	3483	3487	3490	3494	3494	3501	3499	3508
CP, %	19.3	16.3	17.2	14.2	15.1	12.1	13.6	10.6
Lysine, %	1.05	1.03	0.90	0.88	0.75	0.73	0.65	0.63
Ca, %	0.60	0.50	0.56	.044	0.52	0.40	0.48	0.36
P, %	0.50	0.40	0.46	0.36	0.43	0.33	0.40	0.30
Fe, mg/kg	225	132	213	101	199	69	188	39
Zn, mg/kg	137	79	136	59	134	39	132	19
Cu, mg/kg	18.8	11.9	17.9	9.1	16.9	6.3	16.3	3.9
Mn, mg/kg	51.9	31.4	49.4	24.3	46.8	17.3	44.5	10.6

Table 2. Growth performance and nutrient intake of pigs (Exp. 1)[a].

	Dietary Treatment			
	Control	LNE	SE	P <:[b]
Initial wt, kg	27.94	27.89	0.02	NS
Final wt, kg	117.9	116.7	1.24	NS
Days on test	109.7	109.7		NS
ADG, g	821.1	810.0	2.17	NS
ADFI, g	2,252	2,203	7.65	NS
F:G	2.74	2.72	0.02	NS
Dry matter intake, g/d	1925	1879	9.4	NS
N intake, g/d	53.4	45.0	0.03	0.01
P intake, g/d	9.78	7.38	0.09	0.04

[a]Least square means for 2 rooms (19 pigs/room) per dietary treatment.
[b]NS = not significant, P > 0.10.

Table 3. Carcass data of pigs (Exp. 1)[a].

	Dietary Treatment			
	Control	**LNE**	**CV**	**P <:** [b]
Live weight, kg	115.4	113.3	0.02	NS
Hot carcass wt, kg	88.3	87.2	0.35	NS
10^{th} rib fat depth, in	2.10	1.98	0.03	NS
LMA, sq in	46.9	44.8	1.23	NS
Carcass yield, %	76.6	77.3	0.51	NS
Fat-free lean, %	52.9	52.9	0.22	NS

[a]Least square means for 2 rooms (6 pigs/room) per dietary treatment.
[b]NS = not significant, P > 0.10.

Table 4. Whole body composition and nutrient accretion of pigs (Exp. 1)[a].

	Dietary Treatment			
	Control	**LNE**	**SE**	**P <:** [b]
Live weight, kg	116.6	116.0	0.40	NS
H_2O, %	49.96	50.18	0.47	NS
CP, %	16.96	16.67	0.25	NS
Ash, %	2.47	2.36	0.01	0.06
Fat, %	25.49	25.88	0.53	NS
N, %	2.86	2.80	0.06	NS
P, %	0.37	0.39	0.01	NS
H_2O, kg	58.57	58.45	0.09	NS
CP, kg	20.01	19.54	0.57	NS
Ash, kg	2.93	2.77	0.05	NS
Fat, kg	30.15	30.67	0.16	NS
N, kg	3.37	3.29	0.12	NS
P, g	436.7	457.0	10.7	NS
H_2O, g/d	367.8	366.8	4.11	NS
CP, g/d	134.6	130.5	4.16	NS
Ash, g/d	18.99	17.55	0.308	NS
Fat, g/d	225.4	230.6	2.79	NS
N, g/d	23.08	22.36	0.91	NS
P, g/d	2.60	2.79	0.07	NS

[a]Least square means for 2 rooms (6 pigs/room) per dietary treatment.
[b]NS = not significant, P > 0.10.

Table 5. Volume, temperature, EC, and pH measures of the pit contents (Exp. 1)[a].

	Dietary Treatment			
	Control	**LNE**	**SE**	**P <:** [b]
Volume, L/pig/d[c]	7.46	9.18	0.615	NS
Temperature, ^{o}C	19.9	19.9	0.03	NS
EC, mS	8.70	6.48	0.49	0.08
pH	7.07	6.59	0.07	0.05

[a]Least square means for 2 rooms (19 pigs/room) per dietary treatment.
[b]NS = not significant, P > 0.10.
[c]Increase for LNE due to a water line break in one room of pigs fed LNE.

Table 6. Nutrient concentration (DM basis) of the slurry averaged for the 110-d period (Exp. 1)[a].

	Dietary Treatment			
	Control	**LNE**	**SE**	**P <:** [b]
DM, %	1.21	1.04	0.01	0.06
C, %	43.0	44.6	0.04	0.03
N, %	11.40	8.99	0.21	0.02
NH_4-N, %	6.99	5.01	0.02	0.02
P, %	2.11	1.56	0.06	0.03
Water-soluble P, %	1.88	1.44	0.06	0.04
Ca, %	2.71	2.33	0.05	0.03
K, %	5.37	4.73	0.04	0.06
Mg, %	1.05	1.06	0.02	NS
Na, %	1.50	1.72	0.02	0.08
S, %	0.99	0.89	0.01	0.01
Fe, ppm	1,552	943	41.2	0.01
Zn, ppm	929	477	31.6	0.01
Cu, ppm	134	96	4.5	0.03
Mn, ppm	330	213	8.2	0.01
C:N	3.76	4.96	0.01	0.02
N:P	5.40	5.71	0.07	0.09
WSP:P	0.89	0.91	0.04	NS

[a]Least square means for 2 rooms (19 pigs/room) per dietary treatment.
[b]NS = not significant, P > 0.10.

Table 7. Nutrient excretion for pigs averaged for the 110-d period (Exp. 1)[a].

	Dietary Treatment			
	Control	**LNE**	**SE**	**P <:** [b]
Daily excretion				
DM, g	293.3	259.6	4.28	0.04
C, g	126.1	113.3	8.22	NS
N, g	33.4	23.1	0.62	0.01
P, g	6.20	4.05	0.13	0.01
NH_4-N, g	20.5	12.99	0.28	0.01
Ca, g	7.95	5.94	0.11	0.02
K, g	15.75	12.24	0.47	0.01
Mg, g	3.08	2.74	0.03	0.04
Na, g	4.40	4.46	0.17	0.81
S, g	2.90	2.29	0.08	0.04
Fe, mg	455	240	16.9	0.02
Zn, mg	272	122	12.8	0.02
Cu, mg	39.3	24.5	1.9	0.04
Mn, mg	97.0.	54.4	3.6	0.02
Cumulative excretion[c]				
DM, kg/pig	32.2	28.5	0.46	0.03
N, kg/pig	3.67	2.56	0.07	0.01
P, kg/pig	0.68	0.45	0.02	0.01

[a]Least square means for 2 rooms (19 pigs/room) per dietary treatment.
[b]NS = not significant, P > 0.10.
[c]Total excretion per pig for the 110-d period.

Table 8. Airflow, NH_3 and H_2S emissions for pigs during a 110-d finishing period (Exp. 1)[a].

	Dietary Treatment			
	Control	**LNE**	**SE**	**P <:** [b]
Air flow, m^3/min	46.06	45.74	1.22	NS
NH_3, mg/m^3	0.863	0.418	0.017	0.04
NH_3, mg/min	29.78	12.80	0.51	0.03
NH_3, g/pig/d	2.32	1.02	0.02	0.02
H_2S, ug/m^3	7.36	8.65	0.66	NS
H_2S, ug/min	240.1	262.7	9.24	NS
H_2S, mg/pig/d	18.98	20.51	0.97	NS

[a]Least square means for 2 rooms (19 pigs/room) per dietary treatment.
[b]NS = not significant, P > 0.10.

Table 9. Calculation of mass balance of N and P for the finishing period (Exp. 1)[a].

	Dietary Treatment			
	Control	**LNE**	**SE**	**P <:** [b]
Total N entering, kg/pig	7.01	5.73	0.03	0.03
Pig Initial N, kg/pig	(0.837)	(0.835)	0.01	NS
Feed N entering, kg/pig	(6.17)	(4.89)	0.03	0.01
Total N exiting, kg/pig	7.22	5.93	0.02	0.02
Slurry N, kg/pig	(3.67)	(2.53)	0.06	0.05
Pig Final N, kg/pig	(3.34)	(3.30)	0.04	NS
NH_3-N, kg/pig	(0.208)	(0.089)	0.004	0.03
Difference, kg/pig	-0.214	-0.201	0.01	NS
Total P entering, g/pig	1,207	945	7.6	0.03
Pig Initial P, g/pig	(151)	(151)	0.07	NS
Feed P entering, g/pig	(1,056)	(793)	7.6	0.03
Total P exiting, g/pig	1,125	894	9.3	0.04
Slurry P, g/pig	(680)	(444)	6.8	0.03
Pig Final P, g/pig	(445)	(450)	2.5	NS
Difference, g/pig	83	51	1.7	0.05

[a]Least square means for 2 rooms (19 pigs/room) per dietary treatment.
[b]NS = not significant, P > 0.10.

Table 10. Nutrient concentration of the slurry for the nursery phase (Exp. 2)[a].

	Nursery Phase[b]			
	Phase 1	**Phase 2**	**Phase 3**	**Total**
DM, %	2.73	1.94	2.92	2.56
C, %	7.27	6.56	6.97	6.91
N, ppm	1,481	1,523	1,438	1,476
NH_4-N, ppm	436	634	663	599
P, ppm	133	127	167	146
Ca, %	220	193	250	224
K, %	286	344	334	326
Mg, %	51.0	55.7	67.6	59.8
Na, %	108	133	107	116
S, %	54.6	76.3	68.0	67.4
Fe, ppm	14.4	13.3	17.7	15.5
Zn, ppm	32.9	65.8	19.9	37.7
Cu, ppm	3.18	2.51	7.66	4.93
Mn, ppm	2.23	2.33	3.07	2.63
C:N	4.91	4.31	4.84	4.67
N:P	11.10	11.99	8.61	10.10

[a]Average of two barns for each phase.
[b]Phase 1, 2, and 3 = weaning to d 14, d 14 to 28, and d 28 to 43, respectively.

Table 11. Nutrient excretion of pigs during the nursery phase (Exp. 2)[a].

	Nursery Phase[b]			
	Phase 1	**Phase 2**	**Phase 3**	**Total**
Weight, kg	6.3 – 9.5	9.4 -14.2	14.2 – 22.6	6.3 – 22.6
Daily excretion				
DM, g	131	132	260	170
C, g	34.9	44.6	61.9	46.1
N, g	7.1	10.4	12.8	9.9
P, g	0.64	0.86	1.49	0.97
Ca, g	1.06	1.31	2.22	1.49
K, g	1.37	2.34	2.97	2.18
Mg, g	0.25	0.38	0.60	0.40
Na, g	0.52	0.91	0.95	0.78
S, g	0.26	0.52	0.61	0.45
Fe, mg	69.3	90.4	157.9	103.4
Zn, mg	158.3	447.9	177.0	255.0
Cu, mg	15.3	17.0	68.2	32.7
Mn, mg	10.7	15.9	27.4	17.8
Cumulative excretion[c]				
DM, kg				7.32
N, kg				0.424
P, g				41.9

[a]Average of two barns for each phase.
[b]Phase 1, 2, and 3 = weaning to d 14, d 14 to 28, and d 28 to 43, respectively.
[c]Total excretion per pig for the 43-d period.

Table 12. Average nutrient concentration of the waste treatment system[a].

	Waste Treatment System		
	AS	**CL**	**OAL**
pH	7.64	7.93	7.64
EC	8.75	6.04	1.62
TS, ppm	92.6	21.8	9.2
N, ppm	1,189	536	142
NH_4-N, ppm	648	517	43.6
NO_3-N, ppm	0.92	0.13	87.9
P, ppm	323.4	88.9	29.3
K, ppm	580.5	345.4	132.5

[a]Average of weekly samples collected from September, 2006 to February, 2007.
[b]Waste treatment system; AS= autosampler of effluent leaving barns; CL = 1st stage covered anaerobic lagoon; and OAL = 2nd stage aerobic lagoon.

Figure 1. Nitrogen excretion for pigs fed the control diet or the LNE diet during each dietary phase or for the total finishing period (Exp. 1).

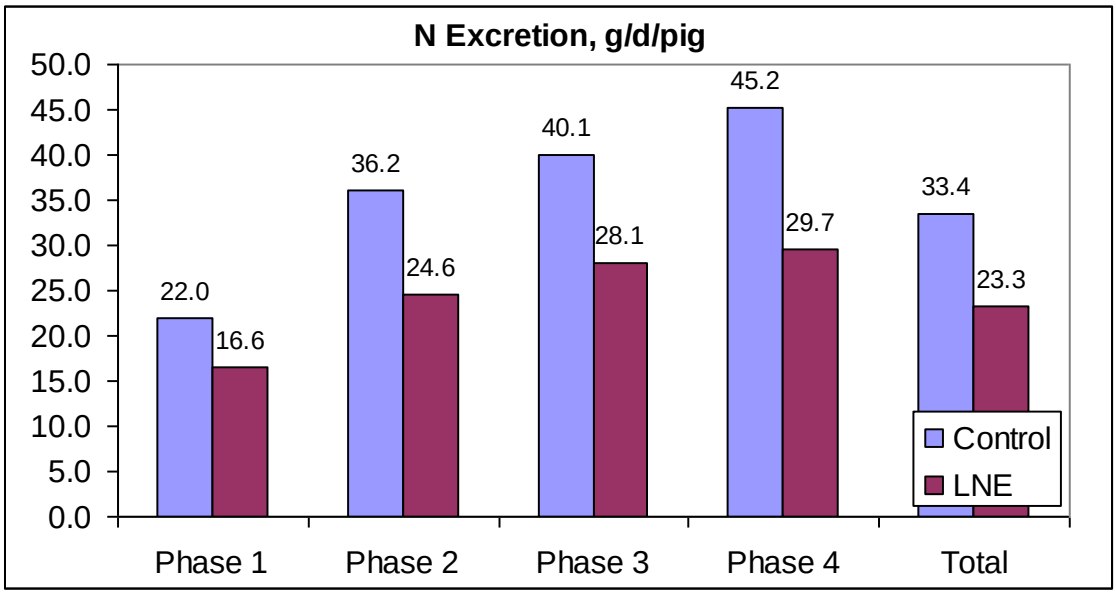

Figure 2. Phosphorus excretion for pigs fed the control diet or the LNE diet during each dietary phase or for the total finishing period (Exp. 1).

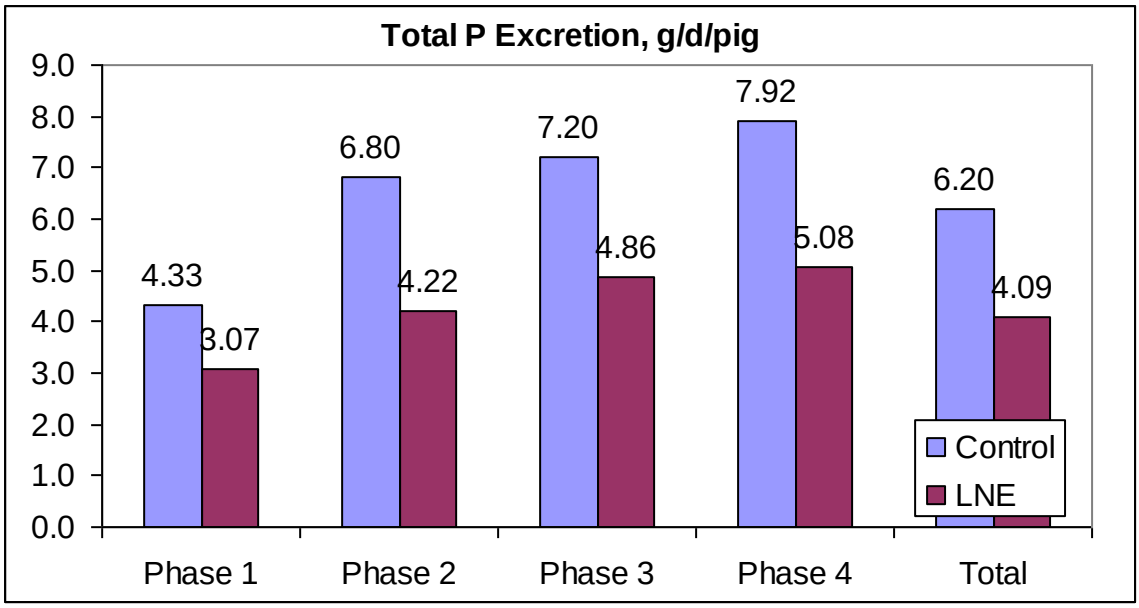

Figure 3. Percentage reduction in daily nutrient excretion for pigs fed the LNE diet versus pigs fed the control diet (Exp. 1).

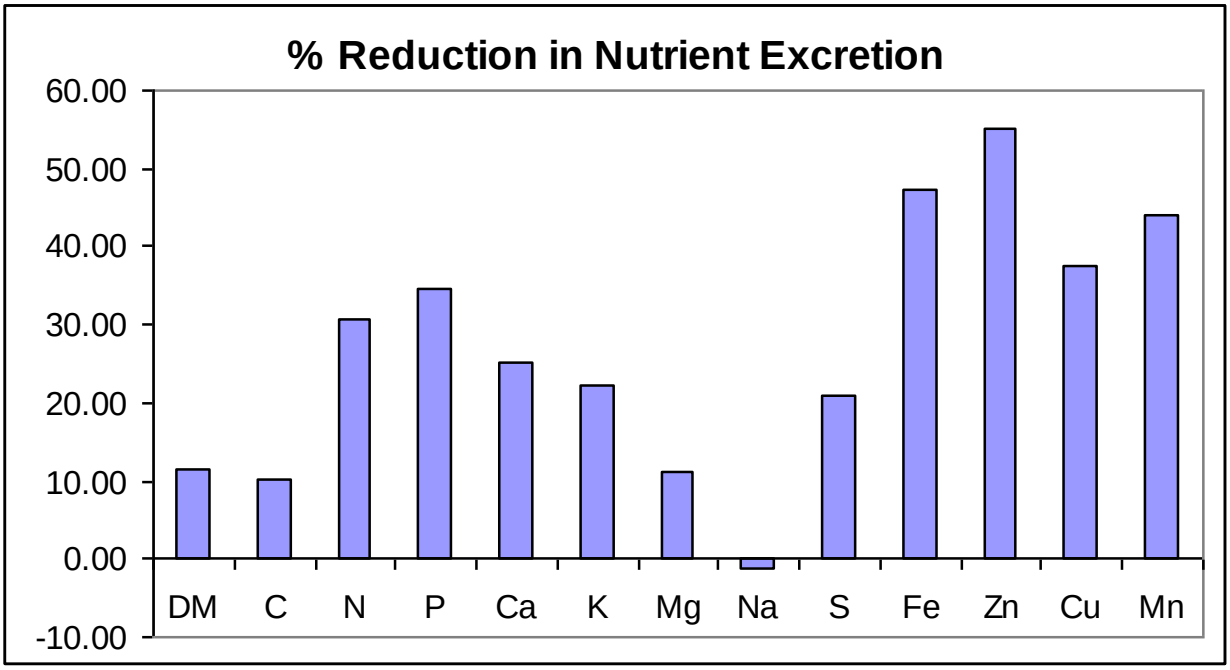

Figure 4. Ammonia and hydrogen sulfide emissions for pigs fed the control or LNE diet expressed on a mg/kg body weight or mg/d per AU (500 kg) basis (Exp. 1).

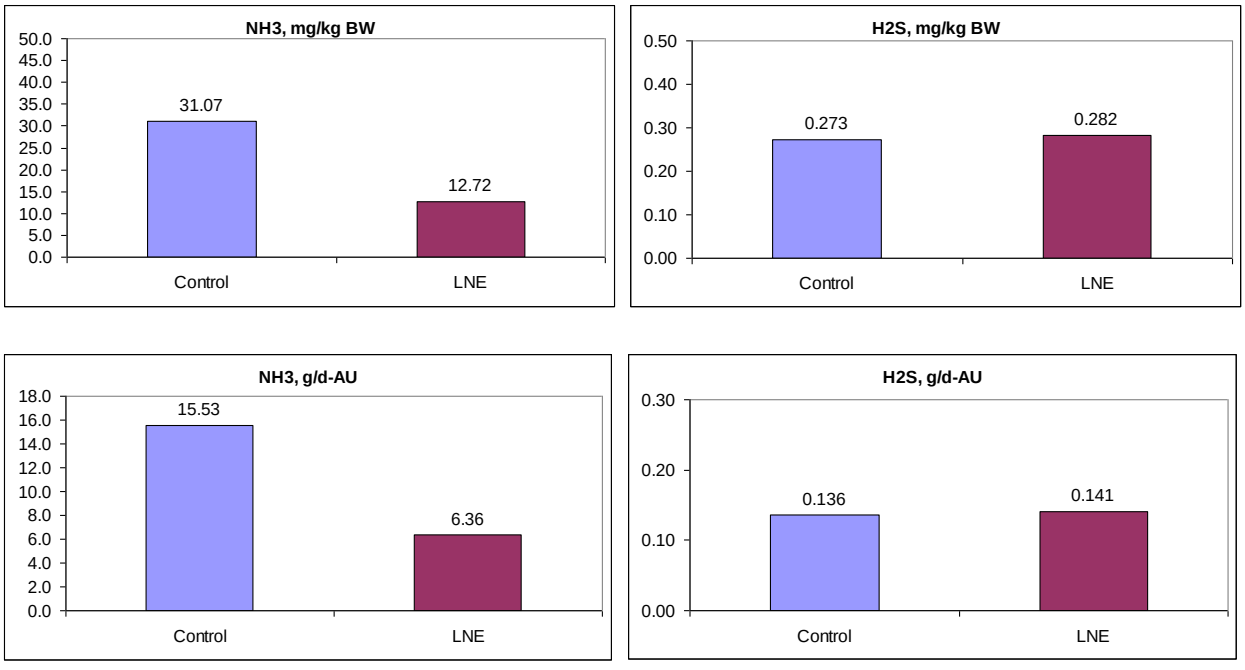

Figure 5. Proportion of total N entering and exiting the facility for pigs fed the control or LNE diet.

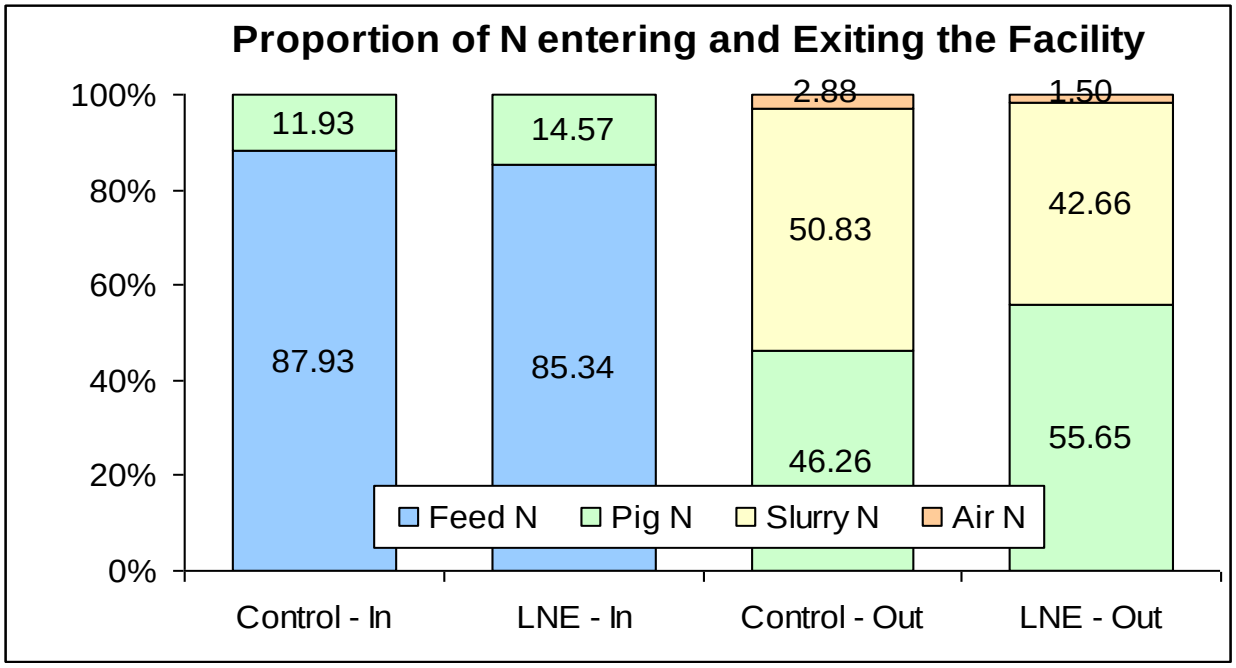

Figure 6. Proportion of total P entering and exiting the facility for pigs fed the control or LNE diet.

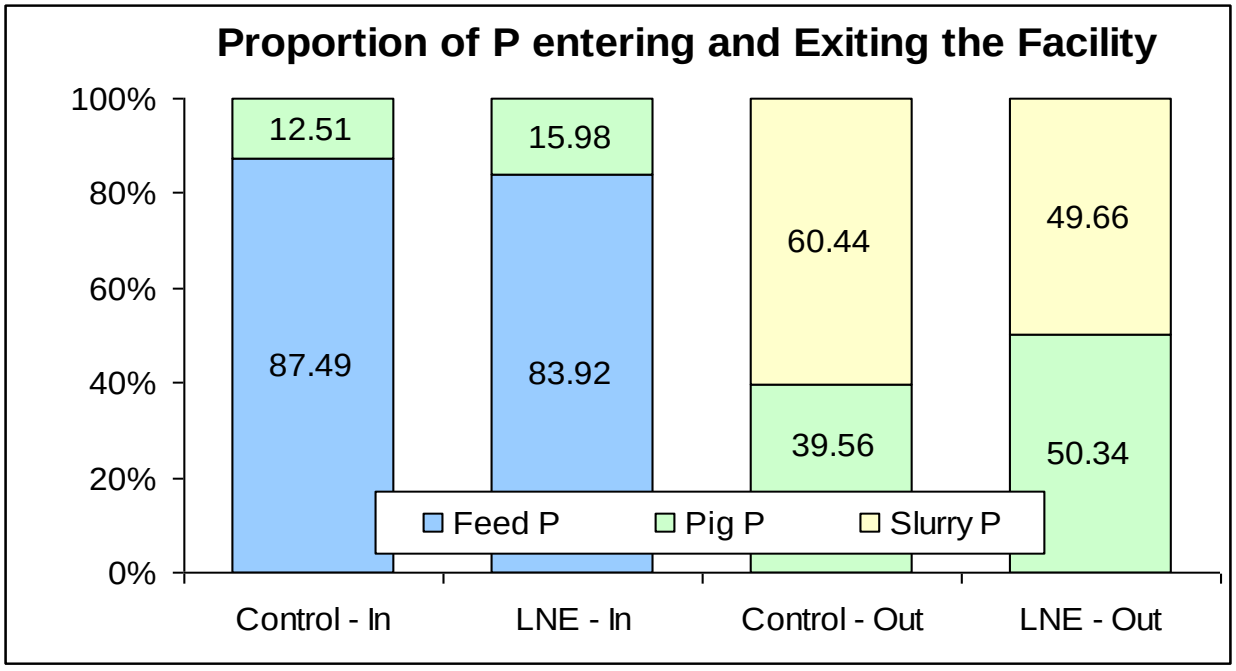

Figure 7. Nitrogen excretion plotted versus body weight for pigs fed the control or LNE diet. (Exp. 1)

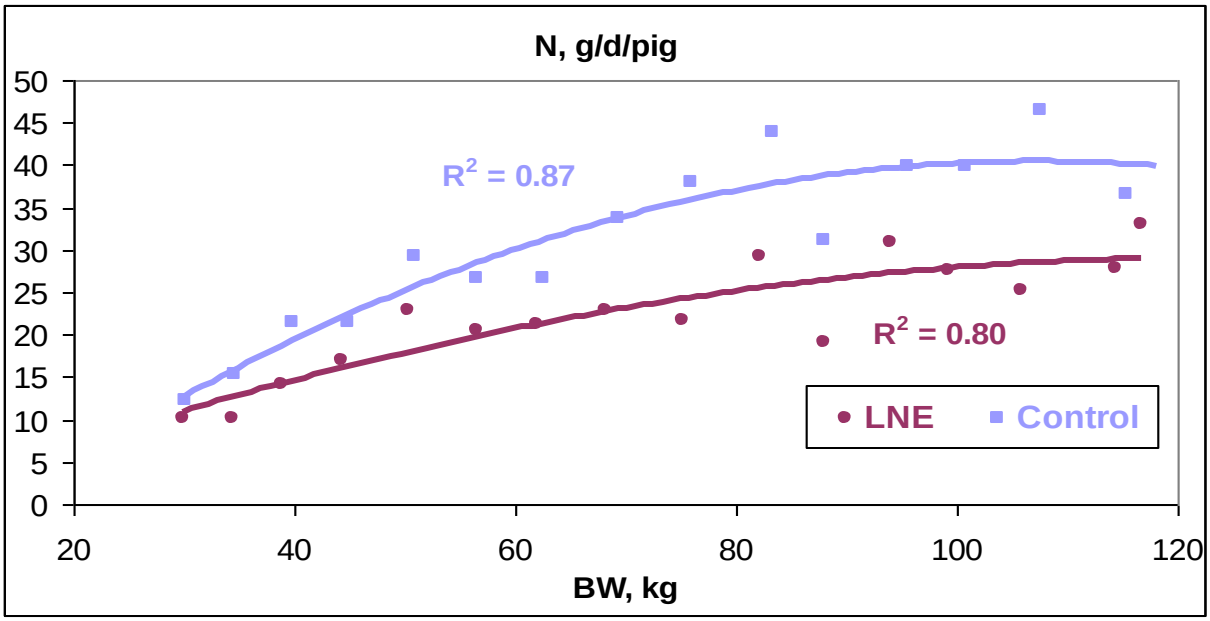

Figure 8. Phosphorus excretion plotted versus body weight for pigs fed the control or LNE diet (Exp. 2).

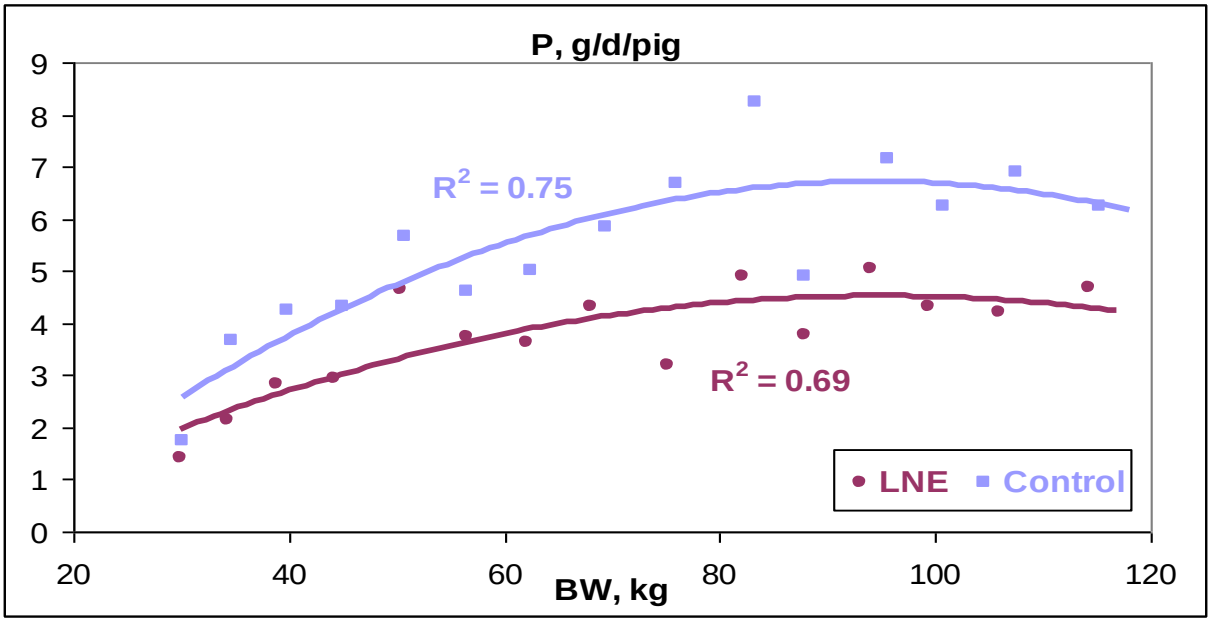

Figure 9. Percentage reduction in nutrient concentration of the effluent for that leaving the 2nd stage aerated lagoon versus that entering the treatment system from the barns.