# Diet Modification to Reduce Odors, Gas Emissions and Nutrient Excretions from Swine Operations

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**Species:** Swine
**Use Area:** Animal Housing
**Technology Category:** Diet Modification
**Air Mitigated Pollutants:** Ammonia, Hydrogen Sulfide, Volatile Fatty Acids, Volatile Organic Compounds, and Odor

## Description:

Compatibility of pork production with neighbors in rural America is a major concern. When a pork operation moves into a rural community or expands an existing operation, the public often raise concerns about the potential impacts of the operation on water, air quality and health. Odor and gas emissions from pork operations primarily come from the anaerobic degradation of manure. Manure generated at pig facilities consists primarily of feces, urine, and some spilled water and feed. Nutrients excreted by the pig are from undigested feed ingredients and losses from normal metabolism. Since the pig is the initial point source of nutrients excreted and resultant gas and odor emissions, diet modification has the potential to reduce nutrients excreted and thereby reduce gas and odor emissions.

Pig diets are often formulated with a safety factor to assure that all pigs receive adequate nutrients to meet growth requirements and maximize gain. In addition, pig diets are often formulated on a least-cost basis using lower cost ingredients (by-product ingredients for example) which may result in feeding nutrients greater than the pig's requirements. The principle of using diet modification techniques is to carefully match available nutrients via feed ingredient selection to the specific nutrient requirements of the pig and thereby reduce excess nutrients in the diet. If lower levels of nutrients are excreted, then the precursors for odor and gas production are also reduced. In this research, low nutrient excretion (LNE) diets were formulated and fed to pigs in group feeding trials to determine the impacts on nutrient excretion, and gas and odor emissions.

## Mitigation Mechanism:

Numerous compounds have been identified from anaerobic degradation of animal manures, and can be generally grouped as sulfurous compounds, indoles and phenols, volatile fatty acids (VFA), and ammonia ($NH_3$) and volatile amines (Lei, et al 2005). Many of these volatile compounds come from the degradation of amino acids and proteins. For example, indoles and phenols are derived primarily from the degradation of tyrosine, phenylalanine and tryptophan. Volatile sulfur containing compounds come from the amino acids methionine and cysteine plus mineral sulfates and other sulfides in the diet. Many of the VFA and methane are produced from the degradation of proteins and from the degradation of a multitude of fermentable carbohydrates in the feces by indigenous bacteria in the gastrointestinal tract. Since there is considerable variation in the chemical composition of feed ingredients and the availability of nutrients from those ingredients, the impact of diet composition can have a substantial impact on nutrient excretion, gas emissions and odor generation.

In a typical corn-soybean meal based diet, the ratio of amino acids provided in the diet does not match the ratio required by the pig for maintenance and growth (Sutton, et al 1999). Therefore, when the diets are formulated to meet the most limiting amino acid, lysine, there are excesses of other amino acids which the pig excretes. If the amount of soybean meal (primary protein source) concentration in the diet is reduced by using synthetic amino acids, there is significantly less nitrogen (N) excreted by the pig. This will reduce $NH_3$ emissions from pig manure. Similarly, reducing the concentration of dietary sulfur (S) containing amino acids and any excess S containing minerals (in the trace mineral mix) can reduce S excretion (Shurson, et al 1999). Altering the VFA and other volatile organic acids (VOC) with diet modification is more difficult. Use of low levels of fiber (soybean hulls, sugar beet pulp, wheat bran, and wheat middlings) can alter the form of excretion of N and the production of VFA (Cahn, et al 1997; Shriver, et al 2003).

## Applicability:

Pigs were group-fed in facilities that represent commercial settings to determine the effects of diet manipulation on nutrient excretion, gas emissions and odors from swine buildings. The intent of this research was to demonstrate that a producer can use low nutrient excretion (LNE) diets in production settings without sacrificing animal performance or product quality, and thereby reduce the potential impact of manure excretion on air quality. Following is a brief description of the research methods and results:

A total of 1,920 pigs (equal barrows and gilts) with an average initial body weight (BW) of 5.16 kg (11.4 lb) were used in a wean-finish experiment to evaluate the effects of diet (Control (CTL) vs. LNE) on growth performance, carcass characteristics, manure excretion, and gas and odor emissions. Pigs were housed in an environmentally-controlled building in 12 identical rooms with independent ventilation, feeding systems, water, and manure storage pits. Each room housed 10 pigs per pen with 60 pigs per room. Pigs were blocked by BW and sex (10 pigs/pen; 60 pigs/room) and randomly allotted to 1 of 2 treatments (standard commercial corn-SBM control, CTL; or LNE). Pigs were split-sex and phase-fed to meet or exceed nutrient requirements (NRC, 1998). This trial consisted of five nursery phase diets and four grow-finish phase diets. The nursery phases included: 1) Pellets, a common diet for all pigs, d 0-7; 2) Phase 1, d 7-14; 3) Phase 2, d 14-28; 4) Phase 3, d 28-42; and 5) Phase 4, d 42-56. The grow-finish phases included: 1) Grower 1, d 56-84; 2) Grower 2, d 84-112; 3) Finisher 1, d 112-140; and 4) Finisher 2, d 140-152. Individual/pen body weights and pen feed consumption data were collected weekly during phase 1, then every two weeks thereafter. Four pigs from each pen were scanned ultrasonically to determine loin eye area and 10$^{th}$ rib backfat thickness starting at two months of age and every four weeks thereafter. At the end of the experiment, carcass data were collected at harvest on all pigs by a commercial slaughter facility. An example of CTL and LNE formulations for one phase is shown in Table 1. The LNE diets had reduced crude protein compared to the CTL diets, and included synthetic amino acids, phytase (Natuphos, BASF, New Jersey, USA), added fat, and a non-sulfur trace mineral premix. Diets were formulated based on NRC (1998) requirements for available phosphorus and true ileal digestible amino acids, while maintaining similar lysine: calorie ratios.

**Table 1. Dietary Treatments for Finisher 1.**

| | Control | | LNE | |
|---|---|---|---|---|
| *Ingredients, %* | Barrows | Gilts | Barrows | Gilts |
| Corn | 81.05 | 79.27 | 81.66 | 79.68 |
| Soybean meal | 17.00 | 18.79 | 12.03 | 14.01 |
| Choice white grease | ------ | ------ | 4.00 | 4.00 |
| Calcium carbonate | 0.66 | *0.65* | *0.90* | *0.90* |
| Dicalcium phosphate | 0.70 | 0.69 | 0.34 | 0.33 |
| Vitamin premix | 0.10 | 0.10 | 0.10 | 0.10 |
| TM premix | 0.05 | 0.05 | ------ | ------ |
| Non-sulfur TM premix | ------ | ------ | 0.05 | 0.05 |
| Phytase | ------ | ------ | 0.083 | 0.083 |
| Salt | 0.25 | 0.25 | 0.25 | 0.25 |
| Lysine-HCl | 0.10 | 0.10 | 0.32 | 0.32 |
| DL-methionine | ------ | ------ | 0.05 | 0.06 |
| L-threonine | 0.01 | 0.02 | 0.12 | 0.12 |
| L-tryptophan | ------ | ------ | 0.02 | 0.02 |
| Tylan 40 | 0.025 | 0.025 | 0.025 | 0.025 |
| Se 600 | 0.05 | 0.05 | 0.05 | 0.05 |
| *Calculated Analysis* | | | | |
| ME, kcal/kg | 3347 | 3346 | 3517 | 3517 |
| Lysine:calorie ratio | 2.101 | 2.235 | 2.101 | 2.235 |
| Calcium, % | 0.50 | 0.50 | 0.50 | 0.50 |
| Avail. Phosphorus. % | 0.19 | 0.19 | 0.19 | 0.19 |

Real-time instruments monitored $NH_3$, hydrogen sulfide ($H_2S$), carbon dioxide ($CO_2$), and methane ($CH_4$) continuously throughout the trial. Thirty nine (39) odor samples were collected at months 1, 3, and 5 of each replicate with three samples obtained from each room exhaust and three from the fresh air plenum that is common to all rooms. The three odor samples obtained from each room were collected at each measurement location simultaneously. Air samples were collected into 10-L Tedlar bags. An olfactometer (AC'SCENT International, St. Croix Sensory, Inc., St. Paul, MN) was used to evaluate each bag sample of air. All evaluations were performed by trained human panelists. Sample evaluation occurred the same day as sampling to minimize bag losses.

All data were analyzed using the GLM procedure of SAS (2006; SAS Institute Inc., Cary, NC). Pen was the experimental unit for animal performance and carcass characteristics. Manure pit was the experimental unit for manure management strategy, and room was the experimental unit for gas emissions.

## Results

In the nursery phase, pigs fed the LNE diets had improved feed efficiencies (Gain: Feed) as a result of reduced average daily feed intakes (ADFI) and increased average daily gains (ADG) compared to CTL-fed pigs. By the end of the nursery period, LNE-fed pigs tended ($P = 0.09$) to be 0.98 kg (2.16 lb) heavier than CTL-fed pigs. During the nursery period, performance was similar for pigs fed LNE diets compared to the CTL diet.

Throughout the grow-finish phases, ADFI were lower ($P < 0.001$) and feed efficiencies were improved ($P < 0.001$) for LNE-fed pigs compared to CTL-fed pigs. Overall, pigs fed the LNE diet grew faster (0.998 vs. 0.965 kg/d (2.20 vs 2.13 lb/d)) ($P < 0.002$) while consuming less feed (2.55 vs. 2.77 kg/d (5.62 vs. 6.10 lb/d)) ($P < 0.001$) than CTL-fed pigs. This resulted in a better overall feed efficiency (0.39 vs. 0.35) ($P < 0.001$) for LNE-fed pigs compared to CTL-fed pigs.

Similar to live weight, carcass weights were 3.8 kg (8.4 lb) heavier ($P < 0.001$) for LNE-fed pigs (96.6 kg; 213.0 lb) compared to CTL-fed pigs (92.8 kg; 204.6 lb). Along with higher carcass weights, LNE-fed pigs had 2.2 cm (5.6 in) of extra backfat depth ($P < 0.001$) compared to CTL-fed pigs. However, there were no differences ($P > 0.10$) in carcass loin depth.

Daily excretion of dry matter (DM), N, ammonium N, phosphorus (P), potassium (K), ash, and VFA were greater for CTL-fed pigs compared to LNE-fed pigs and linearly increased over time. DM excretion increased from 0.209 kg/pig/d (0.46 lb/pig/d) during wk 8 to 0.362 kg/pig/d (0.80 lb/pig/d) during wk 22 for CTL-fed pigs and from 0.153 kg/pig/d (0.34 lb/pig/d) during wk 8 to 0.315 kg/pig/d (0.69 lb/pig/d) during wk 22 for LNE-fed pigs. The LNE-fed pigs consistently excreted ~48 g (0.11 lb) less DM per day than CTL-fed pigs. Similar to DM excretion, N excretion increased over time and was lower ($P < 0.001$) for LNE-fed pigs than CTL-fed pigs (Figure 1). Regression curves were fit to CTL ($R^2 = 0.94$) and LNE pigs ($R^2 = 0.99$) for N excretion (g/pig/d) and indicated a linear increase in N excretion with week of production. The slope of this line was greater for CTL-fed pigs (1.69) than LNE-fed pigs (1.10) indicating that the difference in N excretion between CTL and LNE fed pigs increased as the pigs grew older. Ammonium N, which can be readily lost as $NH_3$ followed a similar pattern to total N. Based on regression equations, pigs fed LNE diets consistently excreted 26-28% less ammonium N than CTL-fed pigs. In another study, by using crystalline amino acids to reduce dietary crude protein concentration in corn-soybean meal diets, N excretion was reduced 20 to 30% without influencing growth performance, carcass value or cost of production. Total mineral excretion as estimated by ash content of the manure increased with week of production ($P < 0.001$) and was lower ($P < 0.001$) for LNE-fed pigs than CTL-fed pigs. Specifically, P excretion (Figure 2) was 40% lower ($P < 0.001$) at all time points for LNE-fed pigs compared to CTL-fed pigs, while K excretion was 17-18% lower ($P < 0.001$) for LNE-fed pigs compared to CTL-fed pigs. Volatile fatty acids which have been attributed to various odorous compounds originating in swine manure increased ($P < 0.001$) in amount/pig/d as the pigs got older and heavier, and were greater ($P < 0.001$) for CTL-fed pigs compared to LNE-fed pigs (Figure 3). Excretion of acetate, propionate valerate, and isovalerate were approximately 26, 26, 36, and 47% lower ($P < 0.001$), respectively, for LNE-fed pigs compared to CTL-fed pigs, and did not change with time. However, since excretion of these compounds linearly increased over time, the actual reduction in excretion of LNE-fed pigs compared to CTL-fed pigs increased from 5.9-16.4, 2.0-4.2, 0.57-1.38, and 0.88-1.12 mmole/pig/d for acetate, propionate, valerate, and isovalerate, respectively from wk 8 to 22. For butyrate and isobutyrate , the slope of the regression line was smaller for CTL-fed pigs over time than for LNE-fed pigs. Therefore, while excretion of butyrate and isobutyrate was lower for LNE-fed pigs at all time points, the difference in excretion decreased from 29-15% for butyrate and 30-21% for isobutyrate from wk 8 to 22.

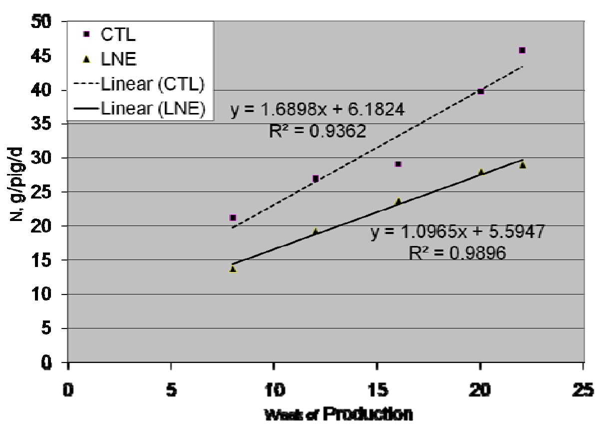


**Figure 1. Effect of LNE diet on total N excretion (Diet effect, P < 0.001; Week effect, P < 0.001; Diet*Week, P > 0.10).**

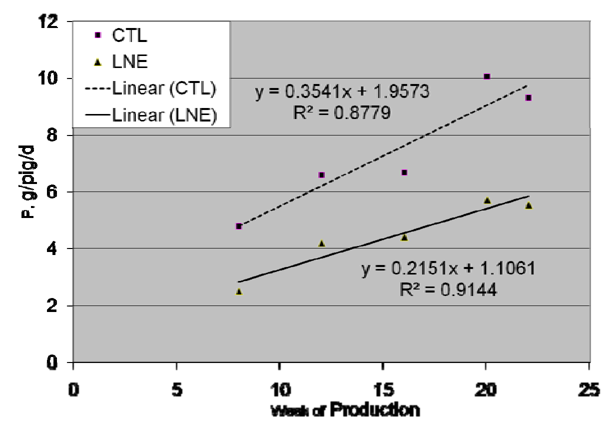


**Figure 2. Effect of LNE diet on P excretion (Diet effect, P < 0.001; Week effect, P < 0.001; Diet*Week, P > 0.10).**

Pigs fed LNE diets reduced aerial $NH_3$ emissions over the wean-finish period by 13.6% (P<0.001) compared to pigs fed CTL diets (Figure 4). Aerial $H_2S$ and $SO_2$ concentration were not different (P>0.10) among dietary treatments even though LNE diets were formulated with a non-sulfur trace mineral premix. Air concentration data was also affected by wk of production, except for aerial $SO_2$ concentration. Aerial $NH_3$, $H_2S$, and $CH_4$ concentrations were increased by 43.4, 68.3, and 29.0%, respectively, from wk 4 to wk 16 (P<0.001). Conversely, the concentration of $CO_2$ was reduced by 13.6% during wk 20 compared to wk 4 (P<0.001). There was no significant effect of dietary treatment on odor emissions.

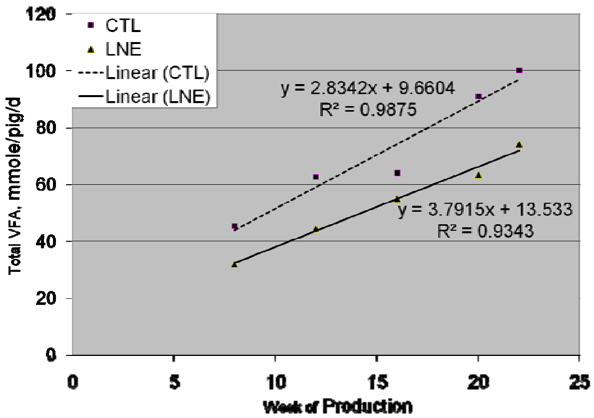


**Figure 3. Effect of LNE diet on VFA excretion (Diet effect, P < 0.001; Week effect, P < 0.001; Diet*Week, P > 0.10).**

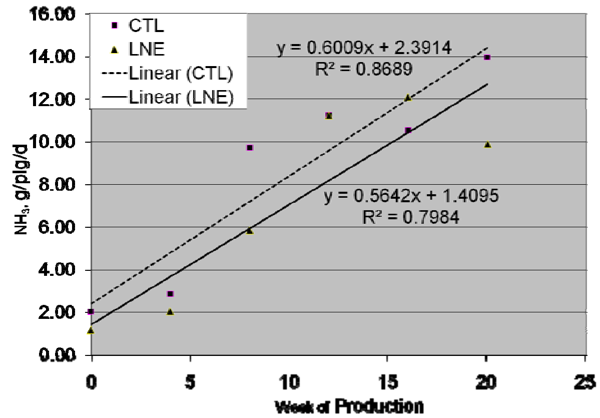


**Figure 4. Effect of LNE diet on $NH_3$ emission (Diet effect, P > 0.10; Week effect, P < 0.001; Diet*Week, P > 0.10).**

# Limitations:

The major limitation of diet modification techniques is the potential impact of utilizing specific feed ingredients, synthetic amino acids or feed additives on the cost of the diet. Since feed is 60-70% of the out-of-pocket cost of pork production, producers want to minimize feed costs without sacrificing pig performance. Therefore, nutritionists and pork producers may be resistant to decreasing safety margins and using alternative feed ingredients. In addition, the availability of these feed ingredients to produce consistent diets is important for implementation. Lysine, threonine and methionine are readily available and economical; the cost and availability of tryptophan is currently cost prohibitive. Similarly, the lack of availability and potential higher cost of non-sulfate mineral sources for pig diets may not be practical. If fiber is included in the finishing pig's diet from 7 to 10%, fat may need to be added to the diet to supply energy to support pig performance when feeding fiber sources.

From a practical standpoint, diet modification can significantly reduce $NH_3$, $H_2S$, VFA, and VOC emissions, but will not reduce them to zero. Feeding highly digestible ingredients to pigs is theoretically possible; however, the availability and costs of these diets are prohibitive. However, with the potential for genetically altering feed ingredients, formulating more nutrient digestible and efficient diets may be possible in the future. Inclusion of byproduct feeds such as distillers dry grains with solubles may create a greater emission of $NH_3$ and $H_2S$ because of the high concentrations of protein and sulfur compounds in this ingredient. Care is needed in selecting other byproduct feeds for pig diets and their potential impacts on nutrient excretion and air emissions.

# Cost:

Economic analysis of CTL and LNE formulations proceeded in three fashions. The cost per kg of feed was computed using average corn, soybean meal, and hog prices for the last two years and current prices for other ingredients. Carcass value was based on the Indiana Packers Carcass Buying Program (http://www.inpac.com/proc/carcass.html) as of March 2008. The cost of feed per kg was essentially constant for all formulations and phases. While the cost of feed is important it does not encompass all of the economic decisions associated with diet manipulation. The implications of animal performance in terms of feed efficiency and carcass quality must also be considered. In the context of a production contract, a contractor who owns the pigs makes feeding decisions that are independent from a grower's manure management constraints or opportunities. Thus, the net return over feed costs is the determining factor in diet choice. Using data from this trial, the higher gain to feed ratio for the LNE-fed pigs regardless of sex favors the use of LNE diets from a net return over feed cost standpoint. The estimated economic benefits range from $8.92 per head for barrows to $10.82 per head for gilts. A portion of this difference is the result of a common slaughter age (153 days) used in all treatments. In all likelihood, the economically optimal slaughter age for CTL animals would be greater than that for the faster growing LNE animals. Allowing the CTL animals more time to reach a heavier carcass would result in more net return over grow-finish feed costs and narrow the economic gap delineated above. However, with higher feed ingredient costs, larger facilities investments, and rigidly fixed farrowing schedules, it is likely that LNE diets would still be preferred to the CTL.

The manure management and diet choice decisions are not decoupled on all farms. Independent producers make decisions about cropping patterns, manure management, and crop fertilization in conjunction with their choice of feed rations for livestock. The model developed by Yap et al. (2004) and recently updated by Hollas (2008) for a representative independent Indiana farm combines these decisions to choose the mix of farm activities that maximizes the whole farm net return over variable costs. This model requires input on a finite set of formulation alternatives and clearly the CTL and LNE formulations in this study are not inclusive of all potentially optimal formulations. However, applying the Yap et al. model (limiting land application of manure to the P requirement of the crops) to the two formulation choices for both gilts and barrows further reinforces the potential economic benefits of the LNE diets. While the optimal cropping pattern does not change when the model is forced to use the CTL formulations, the cost of manure disposal and feed increases, leading to economic gains from LNE formulations for a fixed schedule grow-finish system that is optimized for the faster growing LNE-fed animals. The economic benefits for LNE diets range from $7.21 per pig space for gilts to $8.79 per pig space for barrows.

## Implementation:

Dietary modifications using the techniques described are very effective in reducing environmental impacts of pork production. As a result, operations producing a majority of the pigs are using these techniques on their commercial operations. The implementation of LNE diets has become more commonplace recently because of the greater availability and lower cost of synthetic amino acids (lysine, threonine methionine), phytase, and various fiber sources. On-farm studies at commercial operations (1,000 head grow-finishers) have proven that these mitigating technologies work well. Ammonia emissions have been reduced consistently from 30 to 50% on commercial farms and H2S has been reduced by 20 to 30%. The degree of mitigating response depends upon the status of the initial commercial diet that was modified on the farm. There is still a need to educate and encourage producers to implement current diet modification technologies along with other feed management and production management practices.

## Technology Summary:

Odor and gas emissions from pork operations primarily come from the anaerobic degradation of nutrients in manure. Nutrients excreted by the pig are from undigested feed ingredients and losses from normal metabolism. Since the pig is the initial point source of nutrients excreted and resultant gas and odor emissions, diet modification has the potential to reduce nutrients excreted and thereby reduce gas and odor emissions. A wean-finish pig study was conducted to determine the effect of feeding a low nutrient excretion diet on nutrient excretion, gas and odor emissions. Overall, pigs fed the LNE diet grew faster while consuming less feed than CTL-fed pigs. This resulted in a better overall feed efficiency for LNE-fed pigs compared to CTL-fed pigs. Similar to live weight, carcass weights were heavier for LNE-fed pigs compared to CTL-fed pigs. Daily excretion of dry matter (DM), N, ammonium N, phosphorus (P), potassium (K), ash, and VFA were greater for CTL-fed pigs compared to LNE-fed pigs and linearly increased over time. Pigs fed LNE diets consistently excreted 26-28% less ammonium N than CTL-fed pigs. Phosphorus excretion was 40% lower for LNE-fed pigs compared to CTL-fed pigs, while K excretion was 17-18% lower for LNE-fed pigs compared to CTL-fed pigs. Pigs fed LNE diets reduced aerial $NH_3$ emissions over the wean-finish period by 13.6% compared to pigs fed CTL diets. Aerial $H_2S$ and $SO_2$ concentration were not different among dietary treatments even though LNE diets were formulated with a non-sulfur trace mineral premix. There was no significant effect of dietary treatment on odor emissions.

The major limitation of diet modification techniques is the potential impact of utilizing specific feed ingredients, synthetic amino acids or feed additives on the cost of the diet. Since feed is 60-70% of the out-of-pocket cost of pork production, producers want to minimize feed costs without sacrificing pig performance. Therefore, nutritionists and pork producers may be resistant to decreasing safety margins and using alternative feed ingredients. In addition, the availability of these feed ingredients to produce consistent diets is important for implementation. An economic analysis was conducted with this study and the cost per kg of feed was computed using average corn, soybean meal, and hog prices for the last two years and current prices for other ingredients. Carcass value was based on the Indiana Packers Carcass Buying Program (http://www.inpac.com/proc/carcass.html) as of March 2008. The cost of feed per kg was essentially constant for all formulations and phases. The higher gain to feed ratio for the LNE-fed pigs regardless of sex favors the use of LNE diets from a net return over feed cost standpoint. The estimated economic benefits range from $8.92 per head for barrows to $10.82 per head for gilts. A model used to include the decisions about cropping patterns, manure management, and crop fertilization in conjunction with their choice of feed rations for livestock further reinforces the potential economic benefits of the LNE diets. The economic benefits for the LNE diets range from $7.21 per pig space for gilts to $8.79 per pig space for barrows.

## Additional Resources:

Purdue Swine Research Reports accessed at http://www.ansc.purdue.edu

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