

EFFECTS OF DIET MODIFICATION DURING THE
LACTATION AND FINISHING PERIODS
ON PERFORMANCE AND NUTRIENT
EXCRETION FOR SWINE HOUSED
IN COMMERCIAL CONDITIONS

By

JUSTIN WADE BUNDY

Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

2005

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
December, 2007

EFFECTS OF DIET MODIFICATION DURING THE
LACTATION AND FINISHING PERIODS
ON PERFORMANCE AND NUTRIENT
EXCRETION FOR SWINE HOUSED
IN COMMERCIAL CONDITIONS

Thesis Approved:

S. D. Carter

Thesis Adviser

R. G. Teeter

J. A. Hattey

A. Gordon Emslie

Dean of the Graduate College

ACKNOWLEDGEMENTS

I would like to acknowledge my appreciation towards all of the people that have helped me to achieve my goals over the last couple of years. First and foremost, I would like to thank God for giving me the opportunity to be who I am and blessing me with everything in my life. My family has continued to show their support for me since I first started graduate school and I am truly thankful for their prayers, thoughts and willingness to help whether it be talking with me during hard times or reminding me to make wise decisions and stick with the priorities that I have made. I would also like to thank Dr. Scott Carter for accepting me as a graduate student and constantly challenging me to do my best in everything that I do. I could not be the person I am today without the continuous support of friends that I have been blessed with, they have really made my college career an enjoyable experience. Furthermore, I would like to thank everyone who has had faith in my ability to achieve my goals as well as those who have doubted that I had the qualities required to pursue the goals that I have set forth in my life, which has continued to help increase the motivation and dedication that is necessary in order to continually strive towards achieving results.

TABLE OF CONTENTS

Chapter	Page
I. INTRODUCTION	1
II. REVIEW OF LITERATURE	
Methods to Reduce Nutrient Excretion:	
Nitrogen	3
Phosphorus	6
Nonstarch Polysaccharides	11
III. INFLUENCE OF DIETARY MANIPULATION ON DM, N, AND P EXCRETION OF LACTATING SOWS.	
Abstract	15
Introduction	16
Materials and Methods	16
Results	18
Discussion	20
Implications	21
IV. EFFECTS OF FIBER ADDITION TO A LOW EXCRETION DIET ON PERFORMANCE AND SLURRY CHARACTERISTICS DURING AN ENTIRE FINISHING PHASE.	
Abstract	26
Introduction	27
Materials and Methods	28
Results	29
Discussion	35
Implications	37
V. Conclusion	44
REFERENCES	46
APPENDIX	51

LIST OF TABLES

Table	Page
1. Diet composition of control and LNE treatments	22
2. Calculated and analyzed values for the dietary treatments.....	23
3. Effects of dietary treatment on sow and litter performance.....	23
4. Daily nutrient intake for sows fed either LNE or control	24
5. Nutrient concentrations in the slurry for the dietary treatments	24
6. Daily nutrient excretion values for sows fed either LNE or control.....	24
7. Excretion values for sows fed LNE and control diets expressed as a percentage of intake	25
8. Slurry characteristics for sows fed LNE and control diets	25
9. Composition of Phase I diets for all treatments	38
10. Calculated composition of CSB diets for Phase I-IV	39
11. Analyzed values for crude protein content of each dietary treatment	39
12. Analyzed P content of each dietary treatment.	39
13. Effects of dietary treatment on pig performance.	40
14. Daily DM, P, and N intake of pigs.....	40
15. Effects of dietary treatment on nutrient concentration of the slurry	40
16. Cumulative nutrient excretion averaged over the four phases.....	41
17. Daily nutrient excretion for pigs fed each dietary treatment	41
18. Nutrient excretion expressed as a percentage of intake	42

19. Effects of dietary treatment on slurry characteristics	42
20. NH ₃ emissions for each dietary treatment	43
21. Barn means for days, number of sows (Sows), sow weight at day 110 of gestation (110W), and sow weight change during lactation (WCHG) – Experiment 1.....	52
22. Analysis of variance for days, number of sows (Sows), sow weight at day 110 of gestation (110W), and sow weight change during lactation (WCHG) – Experiment 1.....	52
23. Barn means for number of piglets born alive (NBA), number of piglets weaned (NW), number of piglets weaned per sow (NW/S), and average litter weight at birth (LW) – Experiment 1.....	53
24. Analysis of variance for number of piglets born alive (NBA), number of piglets weaned (NW), number of piglets weaned per sow (NW/S), and average litter weight at birth (LW) – Experiment 1.....	53
25. Barn means for average daily feed intake (ADFI), daily dry matter intake (DMI), daily nitrogen intake (NI), and daily phosphorus intake (PI) – Experiment 1.....	54
26. Analysis of variance for average daily feed intake (ADFI), daily dry matter intake (DMI), daily nitrogen intake (NI), and daily phosphorus intake (PI) – Experiment 1.....	54
27. Barn means for pH, slurry temperature (Temp), electroconductivity (EC), and slurry volume (VOL) – Experiment 1.....	55
28. Analysis of variance for pH, slurry temperature (Temp), electroconductivity (EC), and slurry volume (VOL) – Experiment 1.	55
29. Barn means for dry matter (DM), nitrogen (N), ammonium-N(NH ₄ -N), and phosphorus (P) concentration in the slurry – Experiment 1.	56
30. Analysis of variance for dry matter (DM), nitrogen (N), ammonium-N(NH ₄ - N), and phosphorus (P) concentration in the slurry – Experiment 1.	56

31. Barn means for nitrogen (N), ammonium-N(NH ₄ -N), and phosphorus (P) concentration in the slurry on a dry matter basis – Experiment 1.	57
32. Analysis of variance for nitrogen (N), ammonium-N(NH ₄ -N), and phosphorus (P) concentration in the slurry on a dry matter basis – Experiment 1.....	57
33. Barn means for daily dry matter (DM), nitrogen (N), and phosphorus (P) excretion per pig – Experiment 1.....	58
34. Analysis of variance for daily dry matter (DM), nitrogen (N), ammonium-N(NH ₄ -N), and phosphorus (P) excretion per pig – Experiment 1.	58
35. Barn means for dry matter (DMEPI), nitrogen (NEPI), and phosphorus (PEPI) excretion as a percentage of intake – Experiment 1	59
36. Analysis of variance for dry matter (DMEPI), nitrogen (NEPI), and phosphorus (PEPI) excretion as a percentage of intake – Experiment 1	59
37. Room means for average daily gain (ADG), average daily feed intake (ADFI), and feed conversion (F:G) – Experiment 2.....	60
38. Analysis of variance for average daily gain (ADG), average daily feed intake (ADFI), and feed conversion (F:G) – Experiment 2.....	60
39. Room means for dry matter (DM), phosphorus (P), nitrogen (N), and ammonium-N (NH ₄ -N) concentration in the slurry and slurry volume (VOL) – Experiment 2	61
40. Analysis of variance for dry matter (DM), phosphorus (P), nitrogen (N), and ammonium-N (NH ₄ -N) concentration in the slurry and total volume (VOL) – Experiment 2.....	61
41. Room means for phosphorus (P), nitrogen (N), and ammonium-nitrogen (NH ₄ -N) concentration of slurry on a dry matter basis – Experiment 2	62
42. Analysis of variance for phosphorus (P), nitrogen (N), and ammonium-nitrogen (NH ₄ -N) concentration of slurry on a dry matter basis – Experiment 2.....	62

43. Room means for dry matter (DM), phosphorus (P), nitrogen (N), and ammonium-N ($\text{NH}_4\text{-N}$) cumulative excretion per pig per phase (21 days), and the ratio of ammonium-N to total N ($\text{NH}_4\text{-N:N}$) – Experiment 2	63
44. Analysis of variance for dry matter (DM), phosphorus (P), nitrogen (N), and ammonium-N ($\text{NH}_4\text{-N}$) cumulative excretion per pig per phase (21 days), and the ratio of ammonium-N to total N ($\text{NH}_4\text{-N:N}$) – Experiment 2	63
45. Room means for pH, electroconductivity (EC), and temperature (Temp) – Experiment 2	64
46. Analysis of variance for pH, electroconductivity (EC), and temperature (Temp) – Experiment 2	64
47. Room means for dry matter intake (DMI), dry matter excretion (DMEX), and dry matter excretion as a percentage of intake (DMEXPI) – Experiment 2	65
48. Analysis of variance for dry matter intake (DMI), dry matter excretion (DMEX), and dry matter excretion as a percentage of intake (DMEXPI) – Experiment 2	65
49. Room means for nitrogen intake (NI), nitrogen excretion (NEX), and nitrogen excretion as a percentage of intake (NEPI) – Experiment 2	66
50. Analysis of variance for nitrogen intake (NI), nitrogen excretion (NEX), and nitrogen excretion as a percentage of intake (NEPI) – Experiment 2	66
51. Room means for phosphorus intake (PI), phosphorus excretion (PEX), and phosphorus excretion as a percentage of intake (PEPI) – Experiment 2.	67
52. Analysis of variance for phosphorus intake (PI), phosphorus excretion (PEX), and phosphorus excretion as a percentage of intake (PEPI) – Experiment 2	67
53. Room means for ammonia emitted on a mg/pig/d basis, ammonia concentration leaving the room per minute, ammonia emitted on a mg/kg/d basis, and ammonia emitted on a g/d/500 kg (AU) – Experiment 2	68
54. Analysis of variance for ammonia emitted on a mg/pig/d basis, ammonia concentration leaving the room per minute, ammonia emitted on a mg/kg/d basis, and ammonia emitted on a g/d/500kg (AU) – Experiment 2	68

LIST OF FIGURES

Figure	Page
1. N excretion of sows fed the control and LPP diets during the lactation period....	19
2. P excretion of sows fed the control and LPP diets during the lactation period	19
3. Average daily DM excretion for each dietary treatment.	31
4. Average daily P excretion for each dietary treatment.....	32
5. Average daily N excretion for each dietary treatment.	32
6. Average ammonium-N (NH ₄ -N) to total N (TN) excretion ratio (NH ₄ -N:TN) for each dietary treatment.....	33
7. Average slurry pH during all four phases by dietary treatment.....	34
8. Average daily NH ₃ emission for each dietary treatment.....	35

CHAPTER I

INTRODUCTION

Recently, one of the most important factors for concentrated animal feeding operations (CAFOs) is the excretion of nutrients that can potentially harm the environment. For many years, the main nutrients of concern have been nitrogen (N) and phosphorus (P). The concern with N in animal effluent is due to the ability of nitrates to leach throughout the soil profile and reach groundwater supplies. Reducing the amount of nitrogen that is released in animal production requires whole-farm management (Rotz, 2004). While P is adsorbed onto soil particles and does not readily leach into ground water, it can erode into streams, lakes and rivers (NRC, 1998). These two elements pose the greatest concerns related to water contamination as well as ammonia emission into the air. The NRC (1998) stated almost 10 years ago that future diet formulation will be integrated into all aspects and stages of production with nutrient as well as manure management being its major components of concern. There are several strategies that can be used for reducing the amount of nutrients excreted. These strategies include: phase feeding; utilizing available synthetic amino acids (AA) for supplementation of limiting AA; inclusion of microbial phytase to reduce the amount of additional P supplementation; improved diet formulation in regards to the animal requirements; and reducing feed wasted by the animal (Kornegay and Harper, 1997; Aarnink and Verstegen,

2007). There is a great potential to reduce environmental loads within pig dense regions of the country by utilizing improved nutritional means (Aarnink and Verstegen, 1997). Only recently has the positive influence of dietary composition on excretion products been studied intensely (Sutton et al., 1999).

CHAPTER II

REVIEW OF LITERATURE

Nitrogen

Nitrogen is an important element in many aspects of agriculture; it is commonly the most limiting nutrient for plant growth behind the basic needs of water, air, and sunlight. The natural nitrogen cycle is necessary to maintain all living organisms (O'Leary et al., 1994). However, when concentrated sources of nitrogen are present, the potential for contamination of both ground and surface water is greatly increased.

Nitrogen in the form of nitrate is of concern because of its negative charge which is the same charge of soil colloids, thus can cause leaching of nitrates deep into the soil profile allowing them to contaminate not only surface water, but ground water as well (Gangbazo et al., 1995). Nitrogen excreted from swine production comes from dietary protein sources as well as protein turnover and microbial sources in the hindgut of the animals. Pigs normally excrete 45 to 60% of the N consumed when fed diets consisting of common feedstuffs (Kornegay and Harper, 1997). The excretion of N by swine can be decreased by improving the balance of amino acids that are required, as well as improving production efficiency. Improving efficiency can reduce excess excretion by reducing the maintenance protein required per unit of production (Rotz, 2004). One of the most efficient methods of reducing the amount of N excreted is to decrease the level of dietary protein with the inclusion of crystalline amino acids (Tuitoeck et al., 1997;

Johnston et al., 1999). There has been an abundance of research conducted to determine the efficacy of lowering the crude protein (CP) content and adding amino acids to grow-finish pigs with promising results (Kerr and Easter, 1995; Carter et al., 1996; Kornegay and Verstegen, 2001).

Effects of feeding reduced CP diets on N excretion

Values have been published estimating that a 9% reduction of ammonium nitrogen in the slurry can be achieved with a 1% unit reduction in crude protein (Aarnink et al., 1993). Another similar study observed a 28% reduction in total N excretion with a 3% unit reduction in CP with supplemented crystalline AA (Sutton et al., 1999). As nonruminant animals consume diets that are more precisely formulated for meeting amino acid needs, their efficiency will improve, further reducing N excreted and the excretion of other nutrients (Kornegay and Harper, 1997). A 3% unit reduction in dietary crude protein with crystalline amino acid supplementation can be fed to pigs with no adverse affect on N retention (Otto et al., 2003). While investigating N excretion of pigs fed a diet with a 4% unit reduction in CP compared to a typical corn-soybean meal diet, Shriver et al. (2003) observed a 40% reduction in total N excreted. Lachmann et al. (2006; 2007) reported a series of experiments conducted with different reductions in dietary protein from 2 to 4%. In these experiments, on average there was an 8-10% reduction in N excretion for every 1% reduction in CP with adequate AA supplementation (Lachmann et al., 2006; Lachmann et al., 2007).

Effects of feeding reduced CP diets on performance

Cromwell et al. (1983) found that reducing CP by more than 2% units with lysine added can negatively affect pig performance. This was probably due to a lack of availability of synthetic amino acids for supplementation. Kerr et al. (1995) concluded that while reducing CP by 4 percentage units (3 during the last phase) can negatively affect pig growth and carcass characteristics, these effects can be corrected with the supplementation of crystalline AA. The supplementation of AA can completely alleviate the negative effects of reducing crude protein (Kerr et al., 1995). Figueroa et al. (2003) observed that supplementation of AA to a diet formulated to contain 5% units less CP than a traditional diet maintained daily gain for finishing gilts.

Effects of feeding reduced CP diets on carcass characteristics

Kerr et al. (1995) reported that pigs fed a reduced CP diet without AA supplementation produced carcasses with significantly higher average backfat measurements and reduced loin eye area leading to a lower percentage of muscle. However, with supplementation of lysine, tryptophan, and threonine, pigs consuming a reduced CP diet produced carcasses with a loin eye area that was similar to pigs fed an adequate CP diet. Also, the carcasses from the AA supplemented pigs had lower average backfat depths compared to the unsupplemented, but the average backfat depths were still significantly higher than that of pigs fed a traditional CP diet (Kerr et al., 1995). Several years later, Kerr et al. (2003) conducted a series of experiments further investigating the influence of AA supplementation to reduced CP diets. The data obtained from these experiments indicate that pigs fed low CP diets that have been supplemented with

synthetic AA have carcass characteristics similar to pigs fed higher levels of CP without AA supplementation. Kerr et al. (2003) concluded that a 3% units reduction in CP with AA inclusion in the diet can be fed with no serious adverse effects on growth, gain:feed, or carcass traits.

Effects of reducing CP during lactation phase

Touchette et al. (1998) conducted an experiment investigating the effect on sow performance with decreasing protein levels utilizing crystalline amino acids in an attempt to meet the production requirements of the sows. They concluded that lowering protein and supplementing available amino acids decreased the number of pigs weaned and increased the preweaning mortality (Touchette et al. 1998). This could be due to additional limiting AA that were not available for supplementation. The impact of AA nutrition during lactation should not be under-estimated. Jones and Stahly (1999) investigated amino acid restriction during the entire lactation phase concluding that restriction increases mobilization of proteinaceous tissue and reduces milk nutrient output. Additional studies will be needed in order to more accurately determine if lowering protein with the addition of crystalline amino acids is an acceptable method for reducing excess N excretion in the lactation phase of swine production.

Phosphorus

In recent years, phosphorus has also been a major nutrient of concern for waste management. Several studies have documented that 50-80% of total phosphorus in feedstuffs is present in the form of phytic acid or phytate (Nelson et al., 1968; Kornegay

and Harper, 1997; Veum et al., 2006). The low bioavailability of phytate-phosphorus leads to the addition of inorganic phosphorus in order to achieve optimal animal performance. The fact that P can be adsorbed to soil particles and be transported to surface water from runoff or soil erosion can lead to environmental concerns. In aquatic environments, P is often times the first limiting nutrient for plant growth (Sharpley et al., 1994). When P is introduced into the aquatic environment, microflora growth can peak very fast. Eventually, eutrophication can cause negative effects to the surrounding environment. Eutrophication is a process by which a body becomes rich in dissolved nutrients and often, seasonably deficient in oxygen (Sharpley et al., 1994). This can lead to death of other aquatic species as well as accumulation of dead algae (Smil, 2000).

It has been estimated that pigs fed a traditionally formulated diet normally excrete up to 80% of the P consumed (Kornegay and Harper, 1997). Decreasing phosphorus levels with the addition of phytase can effectively reduce the amount of P excreted. Phytase is an exogenous enzyme that can be supplemented to the diet of swine in order to liberate the P bound in the form of phytate. Cromwell et al. (1993) observed that the growth rate and bone strength can increase linearly with increasing levels of supplemental phytase. At a high level of inclusion (1,000 FTU/kg), phytase can liberate approximately one-third of unavailable P to an available form therefore increasing the bioavailability of phytate-P (Cromwell et al., 1993). Inclusion of phytase to improve retention has been documented more so in both nursery and grow-finish pigs compared to lactating sows (Kies et al., 2005; Braña et al., 2006).

It is important to realize that P is also becoming a resource increasing in scarcity. It has been estimated that P resources will only last for an estimated 80 years at the

current rate of extraction (Smil, 2000). Phytase supplementation reduces the need for inorganic P inclusion in the diet which can often be the third-most expensive ingredient in nonruminant diets behind energy and protein (Augsperger et al., 2007).

Effects of the inclusion of phytase on P excretion

Supplemental microbial phytase is an effective means of improving P utilization (Traylor et al., 2001). Braña et al. (2006) reported that phytase inclusion can improve P digestibility up to 44% and it can be included at levels as high as 10,000 FTU/kg without negative effects. Positive effects of inclusion have been found from supplementation rates as low as 500 FTU/kg. Harper et al. (1997) observed a reduction in P excretion of 21.5% for finishing pigs fed 500 FTU/kg with a reduction of 0.1% unit in P content compared to a control with no added phytase. In a subsequent experiment also published by Harper et al. (1997), a linear increase in apparent P digestibility was observed for pigs fed 0, 250, 500 FTU/kg when added to a low-P diet with no effect on Ca and dry matter (DM) digestibility (Harper et al., 1997). Another study that reported a reduction in P excretion studied a 0.15% unit deficiency of available P with different levels of phytase inclusion compared to an adequate P diet. In this study P excretion was reduced by 35, 42, and 61% for inclusion rates of 500, 2,500, and 12,500 FTU/kg, respectively (Veum et al. 2006). A maximum effective concentration of phytase in the diet was not stated in this experiment because no plateau was observed in the response criteria with inclusion rates as high as 12,500 FTU/kg which is considered a very high rate for nonruminant diets (Veum et al., 2006).

Effects of reducing P with the inclusion of phytase on growth and pig performance

A 0.1% unit reduction below the requirement in P content can reduce average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency by 18, 15, and 3% respectively. However, adding between 250 and 500 FTU/kg of microbial phytase to the diet can restore pig performance to levels within 96% of that for pigs fed a diet adequate in P content (Harper et al. 1997). Veum et al. (2006) observed linear and quadratic increases in ADG and G:F with increasing supplementation of phytase to a decreased P diet. During the first half of the finishing phase, ADG and G:F was improved beyond that of pigs an adequate level of P with no phytase for pigs fed 12,500 FTU/ kg (Veum et al., 2006). One of the most recent phytase studies involved supplementation of high amounts of phytase with the exclusion of all inorganic P in grow-finish pigs (Augspurger et al., 2007) Based on the results from this study, high inclusion rates can completely replace the need for addition of inorganic P without affecting animal growth performance (Augspurger et al., 2007).

Effects of reducing P with the inclusion of phytase on carcass quality/bone strength

Harper et al. (1997) observed no effect on carcass quality with phytase inclusion and a linear increase in tenth rib shear force and ash. In an experiment conducted by Louisiana State University, the addition of phytase at 880 FTU/kg reversed the negative carcass effects of reduced Ca and P levels in a negative control diet (Shelton et al., 2004). Cromwell et al. (1993) conducted a series of experiments investigating the efficacy of phytase in improving the bioavailability of P in pig diets. During these experiments a decrease in metacarpal-metatarsal bone strength was observed for pigs receiving a diet

deficient in available P. Phytase supplementation to the deficient diet restored metacarpal-metatarsal bone strength to values that were partially equal to that of adequate diets (Cromwell et al., 1993). Veum et al. (2006) observed linear and quadratic increases in bone breaking strength and ash with increasing inclusion rates of phytase to diets that were inadequate in available P. Furthermore, pigs fed the low-P diets containing high inclusion rates (2,500 or 12,500 FTU/kg) of *E. coli* phytase had greater values for bone breaking strength and ash than that of pigs fed a positive control formulated to what was considered adequate in available P content (Veum et al., 2006).

Effects of reducing P with the inclusion of phytase on lactating sows

Inclusion of phytase to improve retention has been documented more so in both nursery and grow-finish pigs than in lactating sows (Kies et al., 2005; Braña et al., 2006). However, some studies have been published in relation to phytase addition in lactating sow diets. The addition of microbial phytase at the rate of 400 FTU/kg can improve the apparent total tract digestibility by an average of 6.7% for lactating sows (Kempe et al. 1997). Another study states that a higher inclusion rate of 500 FTU/kg can reduce P excretion by 27.2% (Baidoo et al., 2002). Jongbloed et al. (2004) conducted a subsequent study using varying levels of phytase addition in order to measure performance and excretion values. This study estimated significant reductions with up to 10,000 FTU/kg added, it is also important to note that even at this high inclusion level there were no differences in sow performance during the experimental period. However, subsequent litter performance was not evaluated in this study (Jongbloed et al., 2004).

Non-starch Polysaccharides

The main strategies that have been proposed to lower ammonia emission include: lowering crude protein in the diet with supplemental limiting amino acids; shifting N excretion away from urine with more excreted in the feces through the inclusion of fermentable carbohydrates to the diet; lowering the pH of urine by adding acidifiers to the diet; and lowering the pH of the feces with the inclusion of fermentable carbohydrates in the diet (Aarnink et al., 1993). Aarnink et al. (1993) reported that the use of these aforementioned strategies can be additive and, that when used collectively, can reduce ammonia emission by up to 70% in grow-finish pigs. Canh et al. (1998a) also concluded that adding non-starch polysaccharides to the diet can influence the pH and ammonia emission in slurry collected from grow-finish pigs. Although, Canh et al. (1998a) were investigating diets that are not corn-soybean meal based, and more similar to diets fed in the Dutch industry, it is important to note that a diet that consisted of 30% sugar beet pulp when fed to pigs produced a slurry that was 0.8 pH units lower and emitted approximately 50% less ammonia and a higher concentration of VFA when compared to the control diets (Canh et al. 1998a).

There are four main groups of odor causing compounds: sulfurous compounds, indolic and phenolic compounds, volatile fatty acids (VFA), and ammonia or amines. Most of these compounds are either intermediate or end products of the metabolism of amino acids (Le et al., 2007). Therefore, the AA excreted should be taken in to account in order to consider methods of reducing odor emission. The theory for including non-starch polysaccharides to the diet is that they will provide an energy substrate for the microorganisms in the hindgut to utilize in order to help contain the amino acids that are

either going to be excreted, or more likely deaminated in the hindgut and utilized by microbes. The excess N being reabsorbed in the hindgut will later be excreted as urea from the urinary tract. The excess amino acids can rather be incorporated into microbial protein, rather than metabolized and later emitted as sources of odorants. Thus, inclusion of non-starch polysaccharides can be useful by reducing the amount of N that is excreted in the urine which is more likely to be later involved in ammonia volatilization as opposed to intact microbial protein.

While investigating different sources of non-starch polysaccharides and their influence on slurry characteristics, Canh et al. (1998b) observed the greatest effect on reducing pH and ammonia emission with the use of soybean hulls as a source of non-starch polysaccharides compared to coconut expeller and dried sugar beet pulp. The effects on slurry characteristics was approximately the same for pigs fed either coconut expeller or dried sugar beet pulp as a source of non-starch polysaccharides (Canh et al. 1998b). Kornegay (1981) reported that soybean hulls can be used as a feedstuff at inclusion rates as high as 15% without adversely affecting pig performance. Lowering crude protein and supplementing synthetic amino acids along with the addition of 15% or lower non-starch polysaccharides can be helpful in lowering the amount of odorous compounds released from swine production systems (Sutton et al., 1999). The fermentation of fiber in the large intestine of pigs is more similar to ruminants than that of humans because of the amount and type of microflora present (Varel and Yen, 1997).

The inclusion of soybean hulls to reduced protein diets can significantly affect manure composition and concentrations of VFA and other odorous compounds as well as N_2O . These effects may influence the environmental impact of production on air and

water quality (Kerr et al., 2006). Canh et al. (1997) concluded that nonstarch polysaccharides influence N excretion towards fecal as opposed to urinary excretion, thereby influencing slurry pH. The effects of reducing CP and fermentable fiber inclusion are additive for lowering ammoniacal N and ammonia volatilization (Zervas and Zijlstra, 2002). The inclusion of either soybean hulls or beet pulp to swine finishing diets reduces the ratio of urinary N:fecal N, and therefore lowers ammonia emission (Mroz et al., 2000; Shriver 2003). Shriver et al. (2003) conducted an experiment investigating different fiber source supplementation to reduced crude protein diets in order to determine the effects on N excretion, performance, and carcass characteristics. In this study they observed a decrease in slurry pH as well as ammonium N and urea N excretion. It was concluded that inclusion of fiber to a low nutrient excretion diet can have beneficial effects in regards to N excretion without affecting performance or carcass characteristics (Shriver et al., 2003). Although much is known about the relationship between non-starch polysaccharides and VFA production in the large intestine, little research had been conducted to understand the relationship between non-starch polysaccharides, fecal composition and the resulting ammonia emitted from the slurry of growing swine (Canh et al., 1998b; Shriver et al., 2003). The inclusion of soybean hulls may be a very practical way to decrease ammonia emissions from the slurry of growing pigs (Canh et al. 1998b).

The majority of research in the area of nutrient and waste management with swine has been conducted using pigs that have been individually fed. There is very little data available pertaining to environmental issues using pigs fed in commercial-like conditions. This could be due to the facilities, equipment, and labor needed to complete such tedious

research. However, as environmental concerns continue to increase, the need and ability to conduct research that is more commercially applicable is becoming more and more necessary. The need for more commercially-useful research is needed in order to determine the ability to minimize the impact on production while also minimizing the impact on the environment.

CHAPTER III

INFLUENCE OF DIETARY MANIPULATION ON DM, N, AND P EXCRETION OF LACTATING SOWS

ABSTRACT

A total of 86 sows was used during four different lactation periods to determine the effects of reducing dietary CP and P on sow performance and DM, N, and P excretion. Prior to farrowing, sows were placed into one of two identical barns with shallow pit, pull-plug drainage systems. Each barn was randomly allotted to one of two dietary treatments. The control diet consisted of a fortified corn and soybean meal based diet formulated to 18.5% CP and 0.60% P. The experimental diet (LNE) was similar to the control diet with the exceptions of a 0.50% unit reduction in CP with 0.05% lysine HCL added, and a 0.1% unit reduction in P with the inclusion of 500 phytase units. Diets were formulated on a true digestible lysine basis. Sows were weighed upon entry into the farrowing house and at weaning. Also, litter weights and weaning weights were recorded. All feed and water intake were recorded weekly and samples were collected from the pit weekly prior to draining. Pits were refilled with fresh water after draining. Feed and pit samples were collected for DM, N, and P analysis. No differences in sow and litter performance or ADFI were noted between treatments. Daily DM excreted was similar between treatments, but daily N excretion was reduced for sows fed the LNE diet. Likewise, daily P excretion was reduced with the LNE diet. Based on these results, the

LNE diet did not affect sow performance, intake, or daily DM excretion. However, the results of this study suggest that feeding an LNE diet to lactating sows can reduce daily N and P excretion.

Introduction

The impact of livestock production on environmental quality is becoming more important as swine production continues to intensify. For many years, the main nutrients of concern have been nitrogen and phosphorus. These two elements possess the greatest potential for pollution, especially water contamination. Several methods can be utilized to reduce excess nutrient excretion. For instance, diets can be formulated to meet the animal requirements with less overfeeding of nutrients. Also, CP levels can be reduced with the inclusion of crystalline amino acids (Touchette et al., 1998). Additionally, P levels can be reduced with the addition of phytase (Baidoo et al., 2002). Recently, several studies have been conducted quantifying these strategies for reducing excess nutrient excretion during the finishing phase with individually-fed pigs (Otto et al., 2003; Braña et al., 2006; Veum et al., 2006). However, there is very little data available in which these strategies were used during the lactation phase of production. Therefore, the objectives of this research were to determine the influence of reducing dietary CP and P on DM, N, and P excretion during the entire lactation period in commercial conditions.

Materials and Methods

A total of 86 Yorkshire and Yorkshire x Landrace sows (211 kg body wt, parity 1.2) was used during four lactation periods. Sows were stratified by parity, BW, and breed and placed into one of two identical farrowing barns. The barns consisted of two identical environmentally-controlled barns equipped with shallow pit, pull-plug drainage

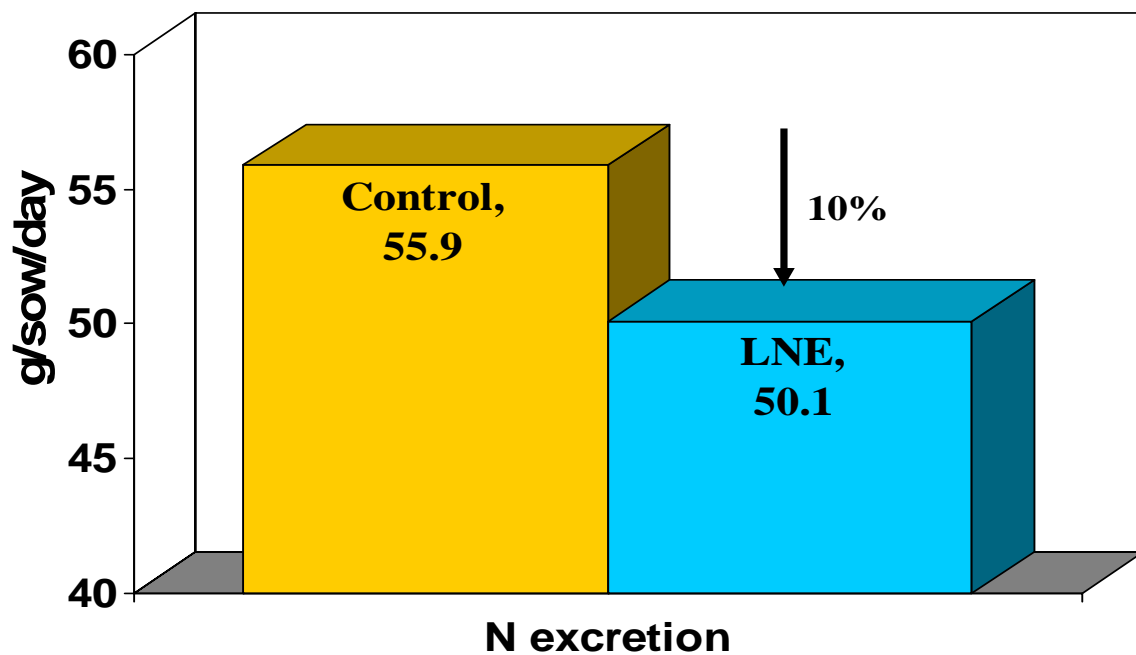
systems. Each barn was randomly allotted to one of two dietary treatments. Diet 1 (control) was a fortified corn and soybean meal based diet formulated to 18.5% CP and 0.60% P. Diet 2 (LNE) was formulated to contain lower protein (18%) with the inclusion of lysine HCL (0.05%) as well as lower P (0.50%) with 500 FTU/kg phytase included (Table 1). Both diets were formulated on a true digestible lysine basis (0.88%).

Performance measurements collected included: sow weight upon entry to the farrowing house, number of pigs born alive, litter birth weight, number of pigs weaned, litter weaning weight, and sow wt. at weaning. Feed and water intake were recorded and feed samples were collected weekly. Pit volume was recorded prior to draining the pit, the slurry was mixed with a submersible pump placed in the pit and mechanical scrapers in an attempt to achieve a homogeneous mixture of the pit contents. As the pit was draining, a sample was collected. At this time, slurry pH, electroconductivity, and temperature were recorded. Sub samples were taken to be taken to the lab for storage and the pit was refilled with fresh water after draining. Weekly feed and pit samples were analyzed for DM, N, and P according to AOAC (1998) approved methods. In order to compare excretion values, slurry nutrient concentrations (Table 3) were multiplied by pit volume then, divided by the number of sows in the room to achieve values on a g/sow/day basis. Data were analyzed as a completely randomized design. The barn served as the experimental unit and contrasts were made between dietary treatments (Control vs LNE).

Results

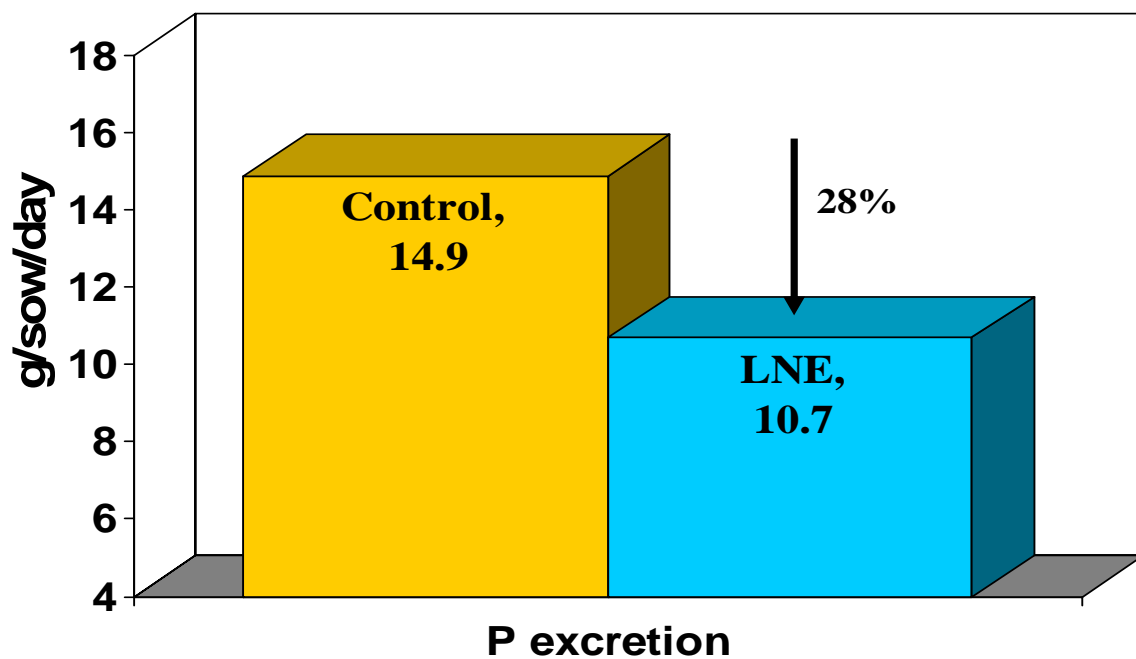
The average parity for both treatments was 1.22. Days and the number of sows used were similar for both dietary treatments. Additionally, ADFI was similar ($P > 0.10$) for both treatments with an average of 3.5 kg. Average sow body weight upon entry to the farrowing house as well as sow weight at weaning was similar ($P > 0.10$) for both treatments. Furthermore, the criteria used to evaluate litter performance, indicated no difference ($P > 0.10$) between treatments (Table 3).

After diets were analyzed, the actual reductions in CP were 0.82% units which was a higher reduction than was anticipated with the calculated values in the diet formulation (Table 2). However, the anticipated 0.10% unit reduction in P content was equal to the values anticipated with formulation (Table 2). Daily DM and nitrogen intake values were not significantly different for sows fed the LNE diet compared to the control. However, P intake was significantly reduced for sows receiving the LNE compared to the control diet. The nutrient concentrations (Table 5) in the pit were multiplied by pit volume and divided by the number of sows in order to compare values on a g/sow/day basis. There were numerical reductions in N and P concentrations in the LNE pits when compared to concentrations in the control pits, but no significant differences. Daily DM excreted was similar ($P > 0.10$) between treatments (Table 6). Daily N excretion was not significantly reduced ($P > 0.10$) for sows fed the LNE diet (Table 6). However, there was a numerical reduction of 10% for sows fed the LNE diet compared to the control (Figure 1). Furthermore, daily P excretion was reduced ($P < .05$) with the LNE diet (Table 6). On a daily basis, P excretion was reduced 28% for sows fed the LNE diet compared to the control (Figure 2).



($P > 0.1$, $SE = 3.7$)

Figure 1. N excretion (g/sow/day) of sows fed the control and LNE diets during the lactation period.



($P < 0.01$, $SE=0.46$)

Figure 2. P excretion (g/sow/day) of sows fed the control and LNE diets during the lactation period.

The daily nutrient excretion values (Table 6) were divided by the daily nutrient intake values (Table 4) to obtain excretion values as a percentage of intake (Table 7). The excretion values when expressed as a percentage of intake indicate no differences ($P > 0.10$) in DM or N excretion. However, P excretion tended to be reduced ($P < 0.08$) for sows fed the LNE diet when compared to the control diet. Also, slurry pH, electroconductivity, temperature were similar for sows fed the LNE diet compared to those fed the control diet. (Table 8).

Discussion

Touchette et al. (1998) found that a reduction of 1, 2, and 3% units in CP did not affect sow performance, but there was a linear increase in pig mortality as well as a tendency for a decrease in number of pigs weaned. However, data collected during this experiment suggest that a 0.5% unit reduction in CP with supplemented lysine did not affect sow or litter performance. Furthermore, the 0.5% unit reduction in CP numerically decreased N excretion on a g/sow/day basis by 10% when compared to the control diet (Figure 1). The 10% numerical reduction of N excretion with a 0.82% unit reduction in CP is comparable to data obtained from grow-finish research which states a 8-10% reduction in N excretion for every 1% unit reduction in dietary CP (Sutton et al 1999; Lachmann et al., 2006; Lachmann et al., 2007). Additionally, Baidoo et al. (2003) conducted a study using various levels of phytase in order to measure performance and excretion values. Baidoo et al. (2003) concluded that levels of phytase up to 10,000 FTU/kg significantly reduced P excretion with no negative effects on sow performance. Our results agree with Baidoo et al. (2003), indicating that a 0.1% unit reduction in

dietary P with the inclusion of 500 phytase units reduced excretion by 28% (Figure 2) with no negative impact on sow and litter performance during the lactation period. The results obtained during this experiment also agree with results from grow-finish research which indicates a 30-60% reduction in P excreted with reductions in dietary P content and supplemental microbial phytase. Based on these results, the LNE diet did not affect sow performance, intake, or daily DM excretion. However, the results of this study suggest that feeding an LNE diet to lactating sows can reduce daily N and P excretion.

Implications

Feeding a lactation diet with a 0.5% unit reduction in CP with supplemented lysine and a 0.1% unit reduction in P with phytase supplemented at 500 FTU/kg will not affect sow and litter performance during the lactation phase for sows housed in commercial conditions. Furthermore, feeding a LNE diet can reduce N excretion by 10%. In addition, feeding an LNE diet during the lactation phase can decrease P excretion by 28% compared to a more traditional diet with no phytase added.

Table 1. Diet composition of control and LNE treatments

Ingredient, %	Diet ^a	
	Control	LNE
Corn	65.8	67.6
Soybean Meal	27.5	26.0
Soybean oil	3.0	3.0
L-lysine	--	0.05
Dicalcium phosphate	1.20	0.70
Limestone	1.02	1.08
NaCl	0.50	0.50
Trace mineral premix ^b	0.15	0.15
Vitamin premix ^c	0.25	0.25
Sow add-pak ^d	0.25	0.25
Dynamate		
Ethoxyquin	0.03	0.03
Chloratetracycline	0.10	0.10
Dynamate	0.20	0.20
Phytase ^e	--	0.03

^aControl = fortified corn-soybean meal diet; LNE = low nutrient excretion diet, low protein and phosphorus diet with supplemented lysine and phytase.

^bProvided 165.2 mg/kg zinc oxide or sulfate, 165.2 mg/kg ferrous sulfate, 39.7 mg/kg manganese oxide or sulfate, 16.5 mg/kg copper sulfate, 0.3 mg/kg calcium iodate, and 0.3 mg/kg sodium selenite.

^cProvided 11013.2 mg/kg vitamin A or equivalent, 1652.0 mg/kg vitamin D₃, 44.1 mg/kg vitamin E 50%, 4.4 mg/kg of MPB, 0.04 mg/kg B₁₂ 600, 9.9 mg/kg riboflavin 95%, 33.0 mg/kg d-Cal pantothenic acid, and 55.1mg/kg niacin.

^dProvided 550.7 mg/kg choline, 0.2 mg/kg biotin, 1.7 mg/kg folic acid, 15.1 pyridoxine.

^eProvided 500 FTU/kg phytase.

Table 2. Calculated and analyzed values for the dietary treatments.

Calculated	Diet^a	
	Control	LNE
CP, %	18.50	17.99
P, %	0.60	0.50
Analyzed		
CP, %	18.57	17.75
P, %	0.60	0.50

^aControl = fortified corn-soybean meal diet; LNE = low nutrient excretion diet, low protein and phosphorus diet with supplemented lysine and phytase.

Table 3. Effects of dietary treatment on sow and litter performance.^a

	Diet^b		SE
	Control	LNE	
Days ^c	26	26	
Sows ^c	43	43	
Parity ^c	1.22	1.22	
ADFI, kg ^c	3.34	3.59	0.10
Sow wt d110, kg ^c	209.6	214.1	3.20
Sow wt. at weaning, kg ^c	185.5	182.1	3.20
Pigs born alive ^c	9.12	9.76	0.29
Litter birth wt., kg ^c	15.6	15.6	2.30
Pigs weaned, per sow ^c	8.31	8.73	0.41
Litter weaning wt., kg ^c	48.1	50.4	2.80

^aLeast square means for 4 lactation periods per treatment

^bControl = fortified corn-soybean meal diet; LNE = low nutrient excretion diet, low protein and phosphorus diet with supplemented lysine and phytase.

^cLNE vs. Control, (P > 0.10)

Table 4 Daily nutrient intake for sows fed either control or LNE.^a

	Diet ^b		SE	P value
	Control	LNE		
DM, g/sow	2900.45	3065.83	64.02	0.16
N, g/sow	98.71	100.00	2.03	0.68
P, g/sow	19.79	17.52	0.53	0.05

^aLeast square means for 4 lactation periods per treatment

^bControl = fortified corn-soybean meal diet; LNE = low nutrient excretion diet, low protein and phosphorus diet with supplemented lysine and phytase.

Table 5 Nutrient concentrations in the slurry for the dietary treatments^a

	Diet ^b		SE	P value
	Control	LNE		
DM, %	0.73	0.89	0.06	0.15
N, % DM	14.62	13.44	1.27	0.56
P, % DM	7.48	4.88	0.84	0.11

^aLeast square means for 4 lactation periods per treatment

^bControl = fortified corn-soybean meal diet; LNE = low nutrient excretion diet, low protein and phosphorus diet with supplemented lysine and phytase.

Table 6 Daily nutrient excretion values for sows fed either control or LNE.^a

	Diet ^b		SE	P value
	Control	LNE		
DM, g/sow	408.63	418.75	16.89	0.700
N, g/sow	55.93	50.06	3.66	0.339
P, g/sow	14.94	10.67	0.46	0.007

^aLeast square means for 4 lactation periods per treatment

^bControl = fortified corn-soybean meal diet; LNE = low nutrient excretion diet, low protein and phosphorus diet with supplemented lysine and phytase.

Table 7. Excretion values for sows fed control and LNE diets expressed as a percentage of intake.^a

	Diet ^b		SE	P value
	Control	LNE		
DM, %	14.26	13.74	0.78	0.67
N, %	57.74	50.25	4.78	0.35
P, %	75.72	61.46	3.89	0.08

^aLeast square means for 4 lactation periods per treatment

^bControl = fortified corn-soybean meal diet; LNE = low nutrient excretion diet, low protein and phosphorus diet with supplemented lysine and phytase.

Table 8. Slurry characteristics for sows fed control and LNE diets.^a

	Diet ^b		SE	P value
	Control	LNE		
pH	7.58	7.57	0.02	0.71
Electroconductivity, mS	7.36	7.43	0.35	0.90
Temperature, °C	20.54	20.39	0.13	0.47

^aLeast square means for 4 lactation periods per treatment

^bControl = fortified corn-soybean meal diet; LNE = low nutrient excretion diet, low protein and phosphorus diet with supplemented lysine and phytase.

CHAPTER IV

EXPERIMENT 2

EFFECTS OF SOYBEAN HULL ADDITION TO A LOW NUTRIENT EXCRETION DIET ON PIG PERFORMANCE AND NUTRIENT EXCRETION DURING THE FINISHING PHASE.

ABSTRACT

A total of 88 crossbred pigs was used to determine the effects of soybean hull addition to a low excretion diet on pig performance and nutrient excretion during an entire finishing period (32 to 124 kg). Pigs were housed in an environmentally-controlled building with four identical rooms (22 pigs/room), each with a shallow pit, pull-plug system. Pigs were stratified by sex, BW, and ancestry then randomly assigned to one of four rooms. Rooms were randomly allotted to a 4 x 4 Latin square design with four rooms and four phases. The four dietary treatments included: 1) a fortified corn-soybean meal based diet (CSB); 2) a low nutrient excretion diet (LNE) similar to CSB with a reduction in CP by 3% units with crystalline AA addition, and P reduced by 0.1% with the addition of phytase (500 FYT/kg); 3 and 4) were similar to LNE with inclusion of 7.5 (LNE+1SH) and 15% (LNE+2SH) soybean hulls (SH), respectively. All diets were formulated on a true dig. Lys and ME basis. Each phase consisted of a 4-wk period which included a 1-wk adjustment period followed by a 3-wk slurry collection period. Dietary treatment did not affect ($P > 0.10$) pig performance. Also, daily DM intake was similar ($P > 0.10$) among all treatments. However, slurry concentration and daily

excretion of DM increased ($P < 0.01$) quadratically with SH inclusion. Daily P and N intake was lower ($P < 0.01$) for pigs fed LNE. Additionally, slurry concentration and daily excretion of P and N was reduced ($P < 0.02$) for pigs fed LNE compared with CSB. The addition of SH to LNE did not affect ($P > 0.10$) P and N intake or excretion. Slurry pH and ammonium-N ($\text{NH}_4\text{-N}$) concentration were decreased ($P < 0.02$) for pigs fed LNE compared with CSB, and linearly reduced ($P < 0.05$) with increasing SH addition to LNE. In addition, ammonia (NH_3) emissions were reduced ($P < 0.05$) for pigs fed LNE vs. CSB. These results suggest that feeding the LNE diet reduced daily P and N excretion by 29 and 28%, respectively. Furthermore, the addition of SH to the LNE diet further reduced slurry pH and $\text{NH}_4\text{-N}$ concentrations without affecting pig performance.

Introduction

As environmental concerns continue to arise from swine production, the need for quality research continues to be in demand. Several methods have been proven successful in reducing nutrient excretion including multiple phase feeding and formulating diets more closely to the animal requirements, in order to reduce the excess nutrients fed to pigs that are not utilized (Lachmann et al., 2006). The future of diet formulation in all phases of production will include manure nutrient management as a major priority of concern (NRC, 1998). The addition of fiber sources to swine diets has also been shown to have the ability to influence the characteristics of excreta (Shriver et al., 2003). The concept of utilizing dietary manipulation with non-starch polysaccharides to reduce pH and ammonia emission have not been thoroughly explored (Canh et al., 1998). Therefore, the objectives of this research were to determine the influence of the addition of soybean hulls as a source of non-starch polysaccharides to a low excretion

diet on pig performance and slurry characteristics during an entire 16-week finishing period in commercial like conditions.

Materials and Methods

A total of 88 [Duroc x (Yorkshire x Landrace)] pigs (32 kg, initial wt) were used during an entire 16-week finishing period (125 kg, final wt). Pigs were stratified by body weight and placed into one of four identical rooms. The rooms consisted of four identical environmentally-controlled rooms located within one barn. Each room was equipped with a shallow pit, pull-plug drainage system. Each room was allotted to the treatments in a 4 x 4 Latin square design with four rooms and four, 4-week, phases. Each room received one of the treatments during one phase only. Each sampling period lasted three weeks with the first week of the phase considered as a cleanout period. Diet 1 (CSB) was a fortified corn and soybean meal based diet. Diet 2 (LNE) was formulated to contain lower crude protein, as well as lower P with amino acids and phytase included. Diet 3 (LNE+1SH) was formulated as Diet 2 with 7.5% soybean hulls. Diet 4 (LNE+2SH) was formulated as Diet 2 with an inclusion of 15% soybean hulls (Table 9).

All dietary treatments were fed in four phases with 0.92, 0.79, 0.65, and 0.56% true digestible lysine in Phase I-IV, respectively. The control diet was formulated with P levels of 0.50, 0.46, 0.43 and 0.40% for Phase I-IV, respectively. All LNE diets were formulated to contain a 3% unit reduction in CP and a 0.1% unit reduction in P while maintaining isocaloric ME values with the use of soybean oil (Table 10). Crystalline amino acids were added to LNE diets to maintain ideal AA ratios within treatments.

Pigs were weighed weekly with feed and water intake recorded. Slurry samples were collected weekly after measuring pit volume. In an attempt to homogenize the

slurry in the pit, the slurry was mixed with a submersible pump and pit scrapers. Once the slurry was mixed, the plug to the pit was removed to drain the slurry. As the slurry was leaving the room, a continuous sample was taken using the aforementioned submersible pump. After sampling, temperature, electroconductivity, and pH of the slurry were measured and recorded. Sub-samples were taken and frozen for later analysis of the slurry. The pit was refilled with fresh water after draining. Weekly feed and pit samples were analyzed for DM, N, and P content according to AOAC (1998) approved methods.

Exhaust airflow and ammonia emissions were analyzed from each room. Ammonia concentration was measured utilizing a TEI model 17C chemiluminescence ammonia analyzer (Thermo Eletron Corporation, Waltham, MA). Each room was sampled and analyzed in 20 minute cycles every 80 minutes. In order to quantify the values obtained from ammonia analysis, air flow leaving the room was measured using fan operation voltage. An equation was developed to determine the air flowing from the fan based on fan operation voltage.

Data were analyzed as a 4 x 4 Latin square design. The room served as the experimental unit. Treatment means were separated with contrasts of CSB vs LNE. The three LNEs were contrasted for linear and quadratic effects of 0, 7.5, and 15% inclusion of soybean hulls.

Results

The diet analysis results indicated an average reduction on 2.86% units of CP with an anticipated reduction of 3% units of CP in the LNE diets compared to the control (Table 11). Also, the analyzed P values indicated an average reduction of 0.093% units

in the LNE diets compared to the control with an anticipated reduction of 0.1% unit reduction of P content (Table 12). These results are indicative that the anticipated reduction of nutrient content in the LNE diets were achieved.

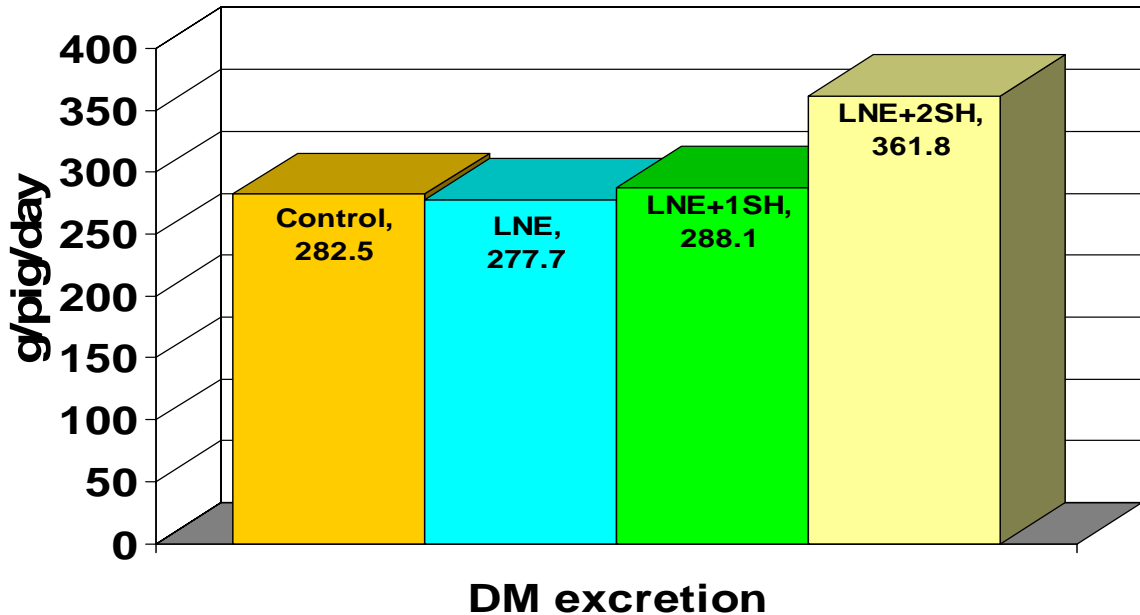
No differences ($P > 0.1$) in ADG, ADFI, and F:G were noted between treatments (Table 13). Also, the initial and final weight for each collection period were similar ($P > 0.10$) for all dietary treatments. The average BW at the beginning of the experiment was 32 kg. The average BW following the 16 wk finishing phase was 125 kg. The carcass characteristics were estimated using 4 pig from each room. Average dressing percentage was 77.1%. The average percentage of fat free lean was calculated to be 54.8%.

There was no effect ($P > 0.10$) of dietary treatment on DM intake. However, there was a reduction ($P < 0.05$) in N and P intake for pigs receiving the LNE diets compared to the control (Table 14). Furthermore, there was no difference in the DM concentration in the slurry collected. However, there was a quadratic increase ($P < 0.01$) in DM concentration of slurry with the increasing inclusion of SH to the LNE diets (Table 15). N and P concentration of the slurry were reduced ($P < 0.02$) for pigs fed the LNE diets compared to the control with no effect of increasing SH content in the LNE diet (Table 15).

The slurry nutrient concentrations were multiplied by pit volume and multiplied by the number of pigs in the room in order to express excretion on a per pig basis. These values could then be used to compare average cumulative excretion by phase (Table 16). Also, if the per pig excretion was divided by the number of days in the phase, excretion values could be compared on a g/pig/day basis (Table 17). Excretion values for DM indicate that there was no difference ($P > 0.10$) in DM excretion for pigs fed CSB

compared to LNE. However, there was a quadratic increase ($P < 0.05$) in DM excretion on both a cumulative and g/pig/day basis with increasing SH inclusion in the diets

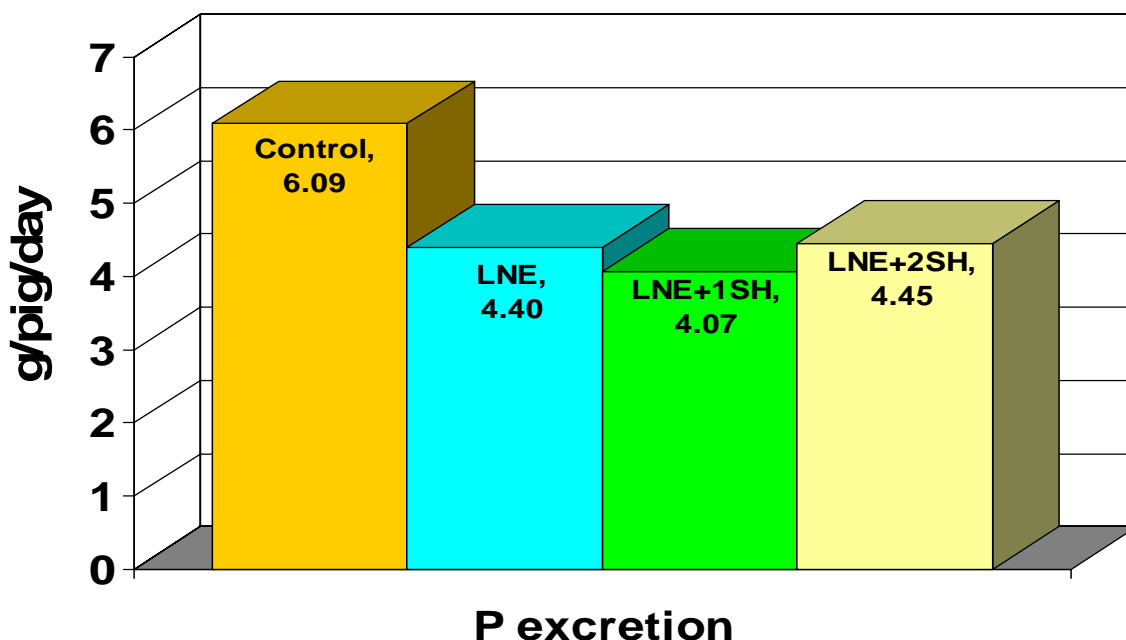
(Figure 3).



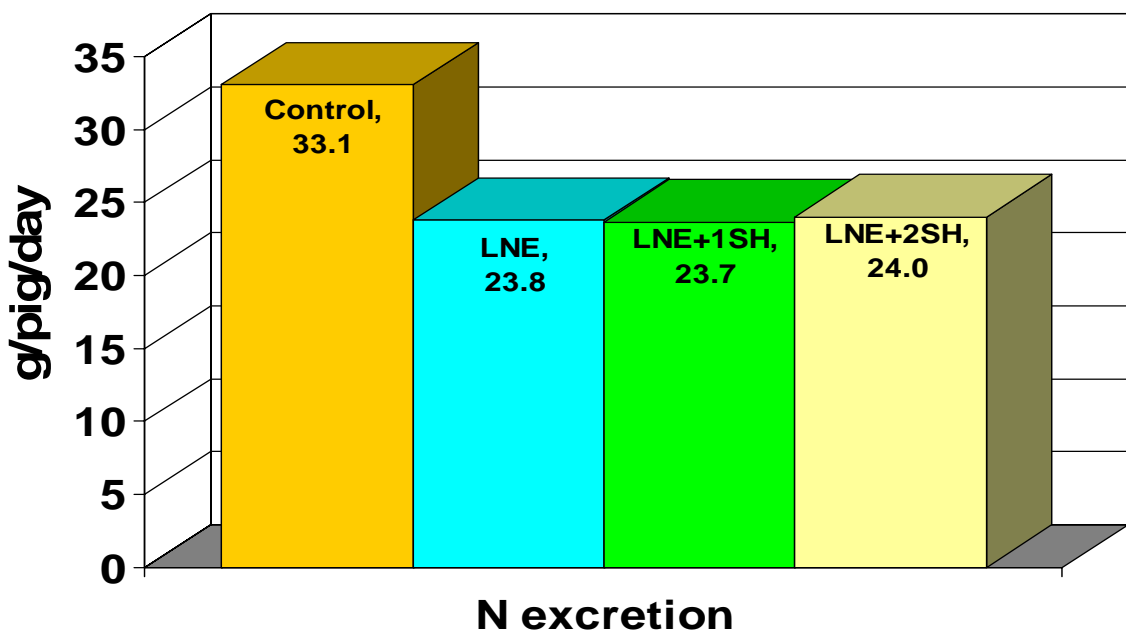
CSB vs. LNE ($P > 0.10$); LNE quad ($P < 0.05$); SE = 8.04

Figure 3. Average daily DM excretion for each dietary treatment.

The values for P and N excretion indicate that the excretion was reduced ($P < 0.05$) for pigs fed the LNE diets compared to the CSB on both a cumulative and a daily basis (Table 16 & 17; Figure 4 & 5). P and N excretion were reduced by 29 and 28%, respectively, with the use of LNE diets compared to CSB. Furthermore, there was no effect ($P > 0.10$) on P or N excretion with increasing addition of SH to an LNE diet. In addition, $\text{NH}_4\text{-N}$ excretion was reduced ($P < 0.05$) for pigs fed the LNE treatment compared to CSB. Also, there was a linear reduction ($P < 0.05$) in $\text{NH}_4\text{-N}$ excretion with increasing SH inclusion rates (Table 16 & 17).

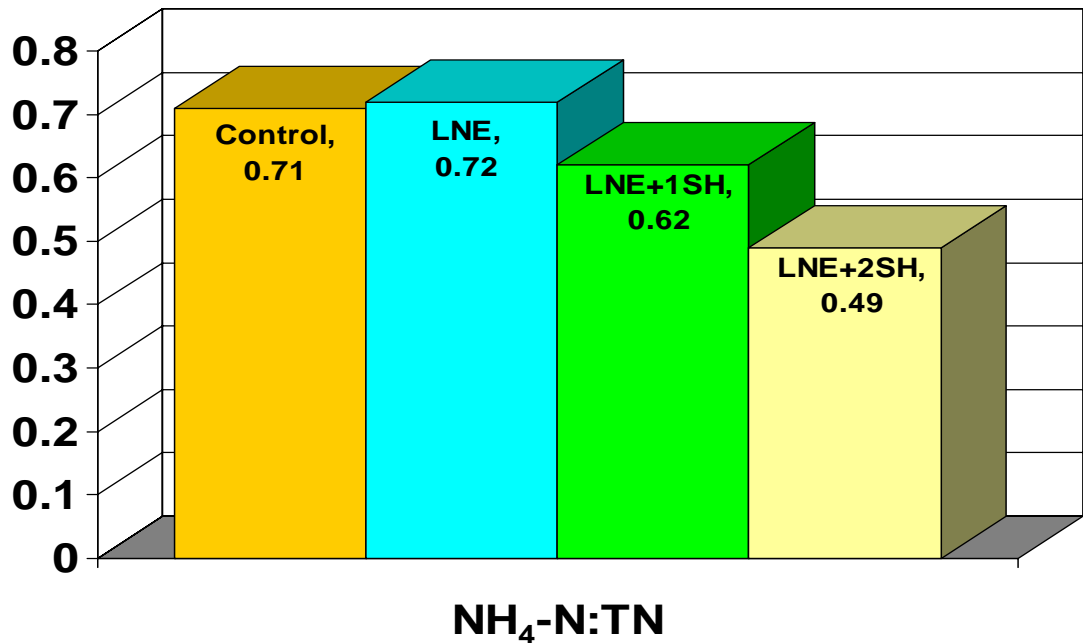


CSB vs. LNE ($P < 0.05$); SE = 0.25; 29% reduction
Figure 4. Average daily P excretion for each dietary treatment.



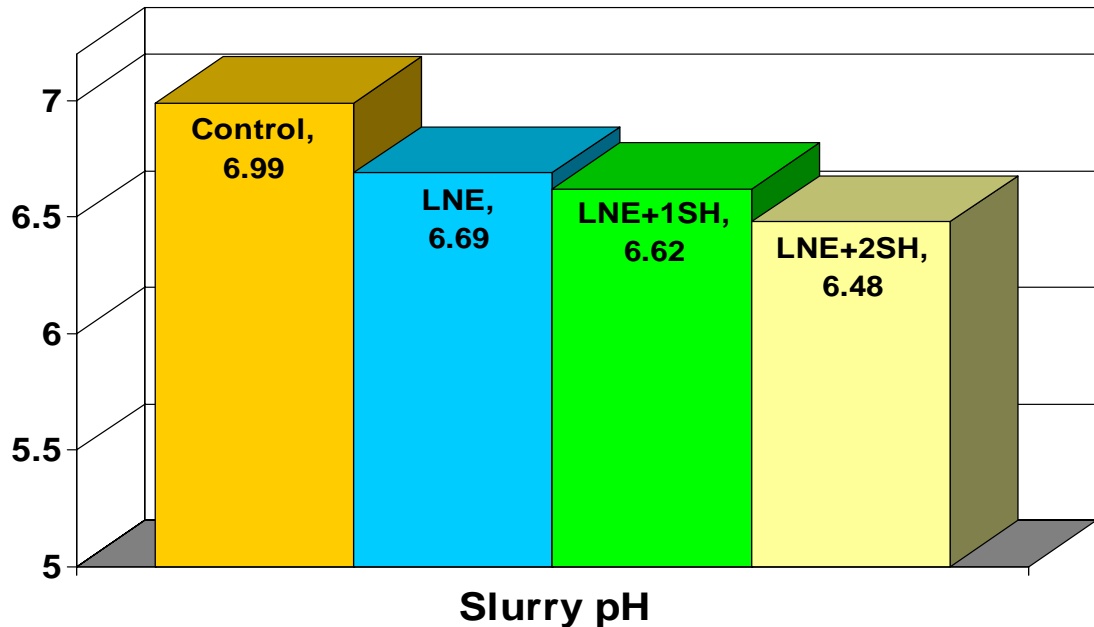
CSB vs. LNE ($P < 0.05$); SE = 0.70; 28% reduction
Figure 5. Average daily N excretion for each dietary treatment.

When excretion values were expressed as a percentage of intake, there was no difference ($P > 0.10$) in DM excretion for pigs fed the CSB diet and the LNE control. However, there was a quadratic increase ($P < 0.05$) in DM excretion with increasing SH inclusion (Table. 18). P excretion as a percentage of intake was not different ($P > 0.10$) for pigs fed LNE or CSB and there was no effect with increasing SH inclusion (Table 18). Nitrogen excretion as a percentage of intake was reduced ($P < 0.05$) for pigs fed the LNE diet compared to CSB, but there were no linear effect ($P > 0.10$) with increasing SH inclusions (Table 18). When the ratio of $\text{NH}_4\text{-N}$ to total N (TN) was compared between treatments, there was a reduction in $\text{NH}_4\text{-N}:\text{TN}$ for pigs fed LNE compared to CSB. Also, the ratio was linearly reduced with the increasing inclusion of SH to a LNE diet (Table 18; Figure 6).



CSB vs. LNE ($P > 0.10$); LNE linear ($P < 0.05$); SE = 0.03
Figure 6. Average ammonium-N ($\text{NH}_4\text{-N}$) to total N (TN) excretion ratio ($\text{NH}_4\text{-N}:\text{TN}$) for each dietary treatment.

Slurry pH was reduced ($P < 0.01$) in the rooms receiving the LNE diet when compared to the control (Figure 7). Furthermore, slurry pH also decreased ($P < 0.01$) linearly with increasing soybean hull inclusion among the LNE treatments (Figure 7). Electroconductivity of the slurry was also reduced ($P < 0.05$) for pigs receiving the LNE treatment when compared to the control. However, there was no linear or quadratic response ($P > 0.1$) with increasing fiber content (Table 19). Also, there was no effect of dietary treatment on slurry temperature (Table 19).

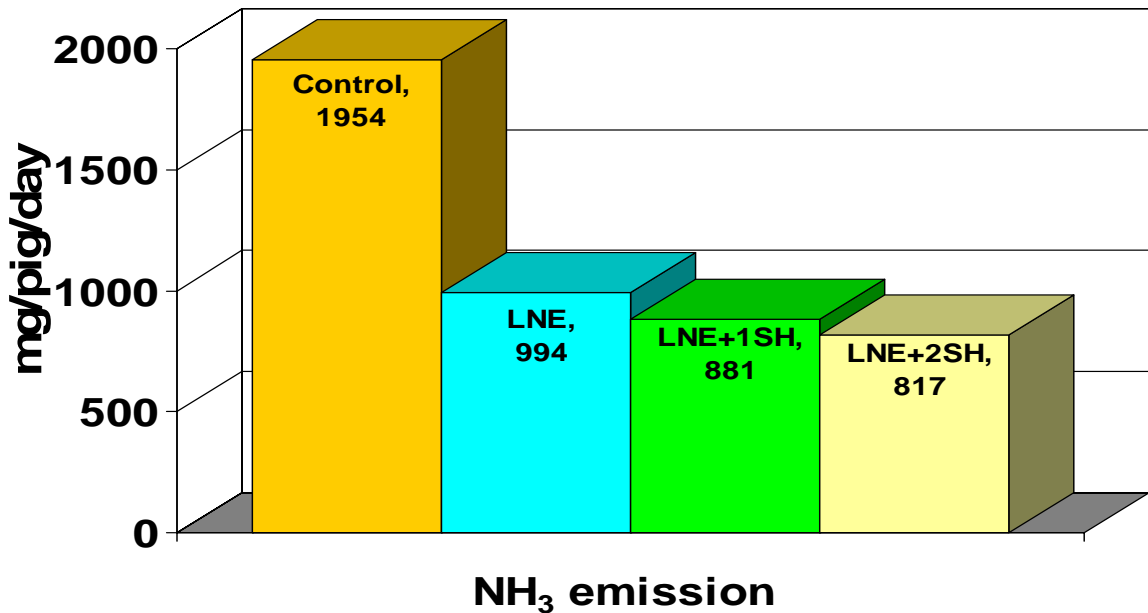


Con vs LNE ($P < 0.01$) ; LNE linear ($P < 0.01$) ; SE=0.03

Figure 7. Average pH during all four phases by dietary treatment.

In addition, NH_3 emissions were also reduced ($P < 0.05$) for pigs fed the LNE treatment compared to CSB treatment on a mg/pig/day, mg/min, mg/kg BW, and g/AU basis. No significant effect was observed with increasing SH inclusion (Table 20). However, there was a definite numerical reduction in NH_3 emissions with increasing SH inclusion rates as shown in Table 20 and Figure 7. There was a 49% reduction in NH_3

emission in the rooms receiving LNE, as well as a 55 and a 58% reduction in emission for 7.5 and 15% SH inclusion, respectively.



CSB vs. LNE ($P < 0.05$); LNE linear ($P > 0.10$); SE = 203.6

Figure 8. Average daily NH₃ emission for each dietary treatment.

Discussion

Previous studies suggest that low excretion diets can be utilized to reduce nutrient excretion without negatively influencing pig performance during the finishing period. It has been reported that lowering crude protein by 1% unit can result in a decrease of N excreted by 8-10% (Aarnink et al., 1993; Sutton et al. 1999; Otto et al., 2003). Furthermore, a reduction in 0.1% unit P with the addition of phytase can reduce the amount of P excreted by 20-61% (Harper et al., 1997; Baidoo et al., 2002; Jongbloed et al., 2004; Braña et al., 2006; Veum et al., 2006). The results from this study are also in agreement with work previously completed at Oklahoma State University investigating

feeding LNE diets in order to decrease nutrient excretion in which there was a 35% reduction in P excretion with 0.1% unit reduction of P content with phytase supplementation (Lachmann et al., 2006; Lachmann et al., 2007). These values are comparable with the 29 and 28% reductions in N and P excretion, respectively, with 2.86% unit decreased in CP and a 0.09% unit reduction in P. Lachmann et al. (2007) also reported a 56% reduction in NH_3 on a mg/pig/day basis which is comparable to the 50% reduction achieved when the LNE is compared to CSB in this experiment.

Also, a decrease in the pH of the slurry from pigs fed low excretion diets when compared to control was similar to results from previous experiments conducted at Oklahoma State University, which also suggest a decrease in ammonia volatilization from the LNE pits (Lachmann et al., 2006; Lachmann et al., 2007). Furthermore, other experiments conclude that increasing dietary fiber content in pig diets can further decrease slurry pH (Canh et al., 1998a; Shriver et al., 2003). The further decrease in slurry pH could be a result from additional volatile fatty acid production by increased microbial synthesis. Our findings are also in agreement with Kornegay (1981), who found that the inclusion of soybean hulls at 15% had no negative effect on growth performance. Based on these results, it can be concluded that an inclusion of up to 15% soybean hulls as a source of dietary fiber can be added to low excretion diets with no negative impact on pig performance. A 15% soybean hull inclusion to an LNE diet can improve slurry characteristics by reducing overall excess nutrients excreted as well as reducing pH in order to reduce ammonia volatilization for the entire finishing period.

Implications

Grow-finish diets with CP reduced by 3% units with supplemented limiting AA and reduced P by 0.1% unit with the addition of phytase can be used without affecting ADG, ADFI, and F:G. Furthermore, feeding these LNE diets can have beneficial effects on excretion by reducing P and N excretion by 29 and 28% respectively. In addition, SH can be included in these LNE diets at rates as high as 15% without negatively influencing performance. Even though SH inclusion does not affect N intake, it can influence the form of N excreted, reducing $\text{NH}_4\text{-N}:\text{TN}$ linearly with increasing SH inclusion as high as 15%. Furthermore, SH can lower slurry pH and potentially decrease NH_3 emissions. However, it is also important to note that the rate of SH inclusion may increase DM excretion.

Table 9. Composition of Phase I diets for all treatments.^a

Phase I	Diet ^b			
Ingredient, %	CSB	LNE	LNE+1SH	LNE+2SH
Corn	68.1	76.5	67.0	57.4
Soybean meal	28.8	20.3	20.2	20.2
L-lysine HCL	--	0.27	0.27	0.26
L-threonine	--	0.08	0.09	0.09
DL-methionine	--	0.01	0.03	0.04
L-tryptophan	--	0.01	0.01	0.01
Soybean hulls	--	--	7.5	15.0
Soybean oil	1.0	1.0	3.1	5.2
Dical Phosphate	0.58	0.24	0.32	0.41
Limestone	0.98	0.94	0.8	0.65
Trace mineral premix ^c	0.15	0.15	0.15	0.15
Vitamin premix ^d	0.25	0.25	0.25	0.25
Chloratetracycline	0.10	0.10	0.10	0.10
Phytase ^e	--	0.022	0.022	0.022
Calculated composition				
CP, %	19.3	16.3	16.3	16.3
True dig lysine, %	0.92	0.92	0.92	0.92
P, %	0.50	0.40	0.40	0.40
ME kcal/kg	3,384.2	3,385.2	3,384.6	3,384.5

^aPhases II, III, and IV follow similar formulations among treatments.

^bCSB = Fortified corn-soybean meal diet; LNE = Low nutrient excretion diet; LNE+1SH = Low nutrient excretion diet, with 7.5% soybean hulls included; LNE+2SH = Low nutrient excretion diet, with 15% soybean hulls included.

^cProvided 165.2 mg/kg zinc oxide or sulfate, 165.2 mg/kg ferrous sulfate, 39.7 mg/kg manganese oxide or sulfate, 16.5 mg/kg copper sulfate, 0.3 mg/kg calcium iodate, and 0.3 mg/kg sodium selenite.

^dProvided 11013.2 mg/kg vitamin A, 1652.0 mg/kg vitamin D₃, 44.1 mg/kg vitamin, 4.4 mg/kg of MPB, 0.04 mg/kg B₁₂, 9.9 mg/kg riboflavin, 33.0 mg/kg d-Cal pantothenic acid, and 55.1 mg/kg niacin.

^eProvided 500 FTU/kg phytase.

Table 10. Calculated composition of CSB diets for Phase I-IV.^a

	Phase I	Phase II	Phase III	Phase IV
True dig lysine, %	0.92	0.79	0.65	0.56
P, %	0.50	0.46	0.43	0.40
ME, kcal/kg	3,384	3,389	3,395	3,400

^aAll diets were formulated to contain equal true digestible lysine and metabolizable energy.

Table 11. Analyzed values for crude protein (CP) concentration of each dietary treatment.

%	Diet ^a			
	CSB	LNE	LNE+1SH	LNE+2SH
Phase I, CP	20.00	16.75	16.63	16.31
Phase II, CP	17.13	14.56	14.44	13.94
Phase III, CP	14.69	12.56	12.06	12.44
Phase IV, CP	13.88	10.81	11.00	11.06

^aCSB = Fortified corn-soybean meal diet; LNE = Low nutrient excretion diet; LNE+1SH = Low nutrient excretion diet, with 7.5% soybean hulls included; LNE+2SH = Low nutrient excretion diet, with 15% soybean hulls included.

Table 12. Analyzed P concentration of each dietary treatment.

%	Diet ^a			
	CSB	LNE	LNE+1SH	LNE+2SH
Phase I, P	0.511	0.416	0.402	0.396
Phase II, P	0.426	0.346	0.360	0.333
Phase III, P	0.413	0.336	0.323	0.345
Phase IV, P	0.379	0.259	0.274	0.283

^aCSB = Fortified corn-soybean meal diet; LNE = Low nutrient excretion diet; LNE+1SH = Low nutrient excretion diet, with 7.5% soybean hulls included; LNE+2SH = Low nutrient excretion diet, with 15% soybean hulls included.

Table 13. Effects of dietary treatment on pig performance.^a

	Diet ^b				SE
	CSB	LNE	LNE+1SH	LNE+2SH	
ADG, kg	0.81	0.80	0.81	0.82	0.02
ADFI, kg	2.47	2.36	2.30	2.22	0.10
F:G	2.90	2.92	2.88	2.86	0.03

^aLeast square means of rooms receiving each dietary treatment.

^bCSB = Fortified corn-soybean meal diet; LNE = Low nutrient excretion diet;
 LNE+1SH = Low nutrient excretion diet, with 7.5% soybean hulls included;
 LNE+2SH = Low nutrient excretion diet, with 15% soybean hulls included.

Table 14. Daily DM, P, and N intake of pigs.^a

	Diet ^b				SE
	CSB	LNE	LNE+1SH	LNE+2SH	
DM, g/p/d	2,026.70	2,024.70	2,021.30	2,014.30	40.17
P, g/p/d ^c	9.93	7.68	7.73	7.70	0.17
N, g/p/d ^c	60.00	49.53	49.03	48.69	0.66

^aLeast square means of rooms receiving each dietary treatment.

^bCSB = Fortified corn-soybean meal diet; LNE = Low nutrient excretion diet;
 LNE+1SH = Low nutrient excretion diet, with 7.5% soybean hulls included;
 LNE+2SH = Low nutrient excretion diet, with 15% soybean hulls included.

^cCSB vs. LNE, $P < 0.05$ **Table 15. Effects of dietary treatment on nutrient concentration of the slurry.^a**

	Diet ^b				SE
	CSB	LNE	LNE+1SH	LNE+2SH	
DM, % ^{de}	1.420	1.440	1.460	1.960	0.103
P, % ^c	0.031	0.022	0.020	0.024	0.002
N, % ^c	0.167	0.123	0.119	0.130	0.009
NH ₄ -N, % ^{cd}	0.117	0.088	0.074	0.065	0.007

^aLeast square means of rooms receiving each dietary treatment.

^bCSB = Fortified corn-soybean meal diet; LNE = Low nutrient excretion diet;
 LNE+1SH = Low nutrient excretion diet, with 7.5% soybean hulls included;
 LNE+2SH = Low nutrient excretion diet, with 15% soybean hulls included.

^cCSB vs. LNE, $P < 0.05$ ^dLNE linear, $P < 0.05$ ^eLNE quad, $P < 0.05$

Table 16. Cumulative nutrient excretion averaged over the four phases.^a

	Diet ^b				SE
	CSB	LNE	LNE+1SH	LNE+2SH	
DM, g/pig ^{de}	5,933.20	5,831.80	6,049.25	7,598.18	168.79
P, g/pig ^c	127.93	92.3	85.4	93.4	5.23
N, g/pig ^c	694.15	499.45	496.53	504.33	14.74
NH ₄ -N, g/pig ^{cd}	488.96	362.76	310.66	249.42	20.24

^aLeast square means of rooms receiving each dietary treatment.^bCSB = Fortified corn-soybean meal diet; LNE = Low nutrient excretion diet; LNE+1SH = Low nutrient excretion diet, with 7.5% soybean hulls included; LNE+2SH = Low nutrient excretion diet, with 15% soybean hulls included.^cCSB vs. LNE, P < 0.05^dLNE linear, P < 0.05^eLNE quad, P < 0.05**Table 17. Daily nutrient excretion for pigs fed each dietary treatment.^a**

	Diet ^b				SE
	CSB	LNE	LNE+1SH	LNE+2SH	
DM, g/pig ^{de}	282.53	277.71	288.06	361.82	8.04
P, g/pig ^c	6.09	4.40	4.07	4.45	0.25
N, g/pig ^c	33.06	23.78	23.65	24.02	0.70
NH ₄ -N, g/pig ^{cd}	23.29	17.28	14.78	11.88	0.96

^aLeast square means of rooms receiving each dietary treatment.^bCSB = Fortified corn-soybean meal diet; LNE = Low nutrient excretion diet; LNE+1SH = Low nutrient excretion diet, with 7.5% soybean hulls included; LNE+2SH = Low nutrient excretion diet, with 15% soybean hulls included.^cCSB vs. LNE, P < 0.05^dLNE linear, P < 0.05^eLNE quad, P < 0.05

Table 18. Nutrient excretion expressed as a percentage of intake and NH₄:total N excretion (TN).^a

	Diet ^b				SE
	CSB	LNE	LNE+1SH	LNE+2SH	
DM, % ^{de}	14.01	13.85	14.28	18.18	0.60
P, %	60.85	57.14	52.7	57.89	2.57
N, % ^c	54.97	48.07	48.18	49.35	1.13
NH ₄ -N:TN ^d	0.71	0.72	0.62	0.49	0.03

^aLeast square means of rooms receiving each dietary treatment.

^bCSB = Fortified corn-soybean meal diet; LNE = Low nutrient excretion diet; LNE+1SH = Low nutrient excretion diet, with 7.5% soybean hulls included; LNE+2SH = Low nutrient excretion diet, with 15% soybean hulls included.

^cCSB vs. LNE, P < 0.05

^dLNE linear, P < 0.05

^eLNE quad, P < 0.05

Table 19. Effects of dietary treatment on slurry characteristics.^a

	Diet ^b				SE
	CSB	LNE	LNE+1SH	LNE+2SH	
pH ^{cd}	6.99	6.69	6.62	6.48	0.03
EC, mS ^c	10.07	7.89	7.46	7.73	0.28
Temperature	18.59	18.61	18.43	18.55	0.08

^aLeast square means of rooms receiving each dietary treatment.

^bCSB = Fortified corn-soybean meal diet; LNE = Low nutrient excretion diet; LNE+1SH = Low nutrient excretion diet, with 7.5% soybean hulls included; LNE+2SH = Low nutrient excretion diet, with 15% soybean hulls included.

^cCSB vs. LNE, P < 0.05

^dLNE linear, P < 0.05

Table 20. NH₃ emissions for each dietary treatment.^a

	Diet ^b				SE
	CSB	LNE	LNE+1SH	LNE+2SH	
NH ₃ , mg/pig/d ^c	1954.9	994.4	880.5	817.2	203.63
NH ₃ , mg/min ^c	71.3	36.4	32.5	30.2	8.12
NH ₃ , mg/kg BW ^c	23.7	12.1	10.3	9.3	1.89
NH ₃ , g/AU ^c	11.8	6.0	5.1	4.6	0.94

^aLeast square means of rooms receiving each dietary treatment.

^bCSB = Fortified corn-soybean meal diet; LNE = Low nutrient excretion diet;
LNE+1SH = Low nutrient excretion diet, with 7.5% soybean hulls included;
LNE+2SH = Low nutrient excretion diet, with 15% soybean hulls included.

^cCSB vs. LNE, P < 0.05

CHAPTER V

CONCLUSION

As environmental concerns continue to arise pertaining to livestock production the demand for applicable research will continue to increase. With the excretion of nutrients being such a large percentage of nutrient intake, the impact of nutritional strategies is a fundamental element for improved efficiency. Also, improvements in environmental control and genetics can assist in lowering the negative impact of livestock production on the environment. The industry has a lot to gain from solid useful research that can in turn be utilized to develop practical means in which to solve problems that arise in regards to lessening the impact of animal production on the environment.

The nutrients of most concern in regards to environmental pollution are N and P. An interesting aspect about these elements is that they are often times considered the most expensive ingredients in the diets. The common most expensive ingredients in swine production are the major protein, energy, and phosphorus sources. The research conducted in this thesis can have implications that pertain to each of these expenses. As synthetic AA production becomes more refined and cost effective the ability to economically benefit from reducing CP content while also reducing the amount of excess N excreted can be a common practice. The inclusion of phytase has definite useful applications for reducing the need of inorganic P supplementation which may eventually be limited in supply. Also, as the competition for corn, the common energy source in

United States pork production, finding alternative feedstuffs will become another increasing demand in swine production. As shown in experiment 2, SH inclusion at 15% with the addition of a fat source can decrease the need for corn without affecting performance and improving ammonia emissions.

REFERENCES

- Aarnink, A.J.A. and M.W.A. Verstegen. 2007. Nutrition, key factor to reduce environmental load from pig production. *Livest. Sci.* 109:194-203.
- Aarnink, A.J.A., P. Hoeksma, and E.N.J. van Ouwerkerk. 1993. Factors affecting ammonium concentration in slurry from fattening pigs. Pages 413-420 in *Nitrogen Flow in Pig Production and Environmental Consequences*. M.W.A. Verstegen, L.A. den Hartog, G.J.M. van Kempen, and J.H.M. Metz, ed. EAAP Publ. No.69, Pudoc, Wageningen, The Netherlands.
- AOAC. 1998. *Official Methods of Analysis*. 16th ed. Assoc. Offic. Anal. Chem., Arlington, VA.
- Augspurger, N.R., D.M. Webel, and D.H. Baker. 2007. An *Escherichia coli* phytase expressed in yeast effectively replaces inorganic phosphorus for finishing pigs and laying hens. *J. Anim. Sci.* 85:1192-1198.
- Baidoo, S.K., Q.M. Yang, and R.D. Walker. 2003. Effects of phytase on apparent digestibility of organic phosphorus and nutrients in maize-soya bean meal based diets for sows. *Anim. Feed Sci. and Technol.* 104:133-141.
- Braña, D.V., M. Ellis, E.O. Castañeda, J.S. Sands, and D.H. Baker. 2006. Effect of novel phytase on growth performance, bone ash, and mineral digestibility in nursery and grower-finisher pigs. *J. Anim. Sci.* 84:1839-1849.
- Canh, T.T., A.J.A. Aarnink, M.W.A. Verstegen, and J.W. Schrama. 1998a. Influence of dietary factors on the pH and ammonia emission of slurry from growing-finishing pigs. *J. Anim. Sci.* 76:1123-1130.
- Canh, T.T., A.L. Sutton, A.J.A. Aarnink, M.W.A. Verstegen, J.W. Schrama, and G.C.M. Bakker. 1998b. Dietary carbohydrates alter the fecal composition and pH and ammonia emission from slurry of growing pigs. *J. Anim. Sci.* 76:1887-1895.
- Canh, T.T., M.W.A. Verstegen, A.J.A. Aarnink, and J.W. Schrama. 1997. Influence of dietary factors on nitrogen partitioning and composition of urine and feces of fattening pigs. *J. Anim. Sci.* 75:700-706.

- Carter, S.D., Cromwell, M.D. Lindemann, L.W. Turner, and T.C. Bridges. 1996. Reducing N and P excretion by dietary manipulation in growing and finishing pigs. *J. Anim. Sci.* 74 (Suppl. 1):59(Abstr.)
- Cromwell, G.L., T.S. Stahly, V. Gomez-Rojas, and H.J. Monegue. 1983. Amino acid supplementation of a low-protein diet for finishing pigs. *J. Anim. Sci.* 57 (Suppl. 1):88. (Abstr.)
- Cromwell, G.L., T.S. Stahly, R.D. Coffey, H.J. Monegue, and J.H. Randolph. 1993. Efficacy of phytase in improving the bioavailability of phosphorus in soybean meal and corn-soybean meal diets for pigs. *J. Anim. Sci.* 71:1831-1840.
- Figuerola, J.L., A.J. Lewis, P.S. Miller, R.L. Fischer, and R.M. Diedrichsen. 2003. Growth, carcass traits, and plasma amino acid concentrations of gilts fed low-protein diets supplemented with amino acids including histidine, isoleucine, and valine. *J. Anim. Sci.* 81:1529-1537.
- Harper, A.F., E.T. Kornegay, and T.C. Schell. 1997. Phytase supplementation of low-phosphorus growing-finishing pig diets improves performance, phosphorus digestibility, and bone mineralization and reduces phosphorus excretion. *J. Anim. Sci.* 75:3174-3186.
- Jongbloed, A.W., J.T.M van Diepen, P.A. Kemme, and J. Broz. 2004. Efficacy of microbial phytase on mineral digestibility in diets for gestating and lactating sows. *Livest. Prod. Sci.* 91:143-155.
- Jones, D.B. and T.S. Stahly. 1999. Impact of amino acid nutrition during lactation on body nutrient mobilization and milk nutrient output in primiparous sows. *J. Anim. Sci.* 77:1513-1522.
- Johnston, L.J., M. Ellis, G.W. Libal, V.B. Mayrose, W.C. Weldon, and NCR-89 Committee on Swine Management. 1999. Effect of room temperature and dietary amino acid concentration on performance of lactating sows. *J. Anim. Sci.* 77:1638-1644.
- Kemme, P.A., J.S. Radcliffe, A.W. Jongbloed, and Z. Mroz. 1997. The effects of sow parity on digestibility of proximate components and minerals during lactation as influenced by diet and microbial phytase supplementation. *J. Anim. Sci.* 75:2147-2153.
- Kerr, B.J., F.K. McKeith, and R.A. Easter. 1995. Effect on performance and carcass characteristics of nursery to finisher pigs fed reduced crude protein, amino acid-supplemented diets. *J. Anim. Sci.* 73:433-440.

- Kerr, B.J. and R.A. Easter. 1995. Effect of feeding reduced protein, amino acid-supplemented diets on nitrogen and energy balance in grower pigs. *J. Anim. Sci.* 73:3000-3008.
- Kerr, B.J., L.L. Southern, T.D. Bidner, K.G. Friesen, and R.A. Easter. 2003. Influence of dietary protein level, amino acid supplementation, and dietary energy levels on growing-finishing pig performance and carcass composition. *J. Anim. Sci.* 81:3075-3087.
- Kerr, B.J., C.J. Ziemer, S.L. Trabue, J.D. Crouse, and T.B. Parkin. 2006. Manure composition of swine as affected by dietary protein and cellulose concentrations. *J. Anim. Sci.* 84:1584-1592.
- Kies, A. W.J.J. Gerrits, J.W. Schrama, M.J.W. Heetkamp, K.L. van der Linden, T. Zandstra, and M.W.A. Verstegen. 2005. Mineral absorption and excretion as affected by microbial phytase, and their effect on energy metabolism in young piglets. *J. Nutr.* 135,5: 1131-1138.
- Kornegay, E.T. 1981. Soybean hull digestibility by sows and feeding value for growing-finishing swine. *J. Anim. Sci.* 53:138-145.
- Kornegay, E.T., and A.F. Harper. 1997. Environmental nutrition: Nutrient management strategies to reduce nutrient excretion of swine. *Prof. Anim. Sci.* 13: 99-111.
- Kornegay, E.T. and M.W.A. Verstegen. 2001. Swine nutrition and environmental pollution and odor control. *Swine Nutrition (2nd Edition)*. pp 609-630. CRC Press LLC, Boca Raton, FL
- Lachmann, M, S. Carter, T. Buhay, S. Jenkins, J. Bundy, and Z. Marable. 2007. Effects of reduced dietary crude protein and P on DM, N, and P excretion of finisher pigs. *J. Anim. Sci.* 85 (Suppl. 2):74 (Abstr.)
- Lachmann, M., S. Carter, T. Buhay, S. Jenkins, and Z. Marable. 2006 Influence of dietary manipulation on DM, N, and P excretion of pigs during an entire finishing period. *J. Anim. Sci.* 84 (Suppl. 2):95 (Abstr.)
- Le, P.D., A.J.A. Aarnink, A.W. Jongbloed, C.M.C. van der Peet Schwering, N.W.M. Ogink, and M.W.A. Verstegen. 2007. Effects of crystalline amino acid supplementation to the diet on odor from pig manure. *J. Anim. Sci.* 85:791-801.
- Mroz, Z., A.J. Moeser, K. Vreman, J.T.M. van Diepen, T. van Kempen, T.T. Canh, and A.W. Jongbloed. 2000. Effects of dietary carbohydrates and buffering capacity on nutrient digestibility and manure characteristics in finishing pigs. *J. Anim. Sci.* 78:3096-3106.

- Nelson, T.S., L.W. Ferrara, and N.L. Storer. 1968. Phytate phosphorus content of feed ingredients derived from plants. *Poult. Sci.* 47:1372-1374.
- NRC. 1998. *Nutrient Requirements of Swine* (10th Ed.). National Academy Press. Washington, D.C.
- O'Leary, M., George Rehm and Michael Schmitt . *Understanding Nitrogen in Soils*. 1994. U.S. Department of Agriculture, Extension Service, under special project number 89-EWQI-1-9180. produced by Communication and Educational technology Services. University of Minnesota Extension.
- Otto, E.R., M. Yokoyama, P.K. Ku, N.K. Ames, and N.L. Trottier. 2003. Nitrogen balance and ileal amino acid digestibility in growing pigs fed diets reduced in protein concentration. *J. Anim. Sci.* 81:1743-1753.
- Rotz, C.A. 2004. Management to reduce nitrogen losses in animal production. *J. Anim. Sci.* 82(E. Suppl.):E119-E137.
- Sharpley, A.N., T.C. Daniel, and D.R. Edwards. 1994. Phosphorus movement in the landscape. *J. Prod. Agric.* 6(4):492-500.
- Shelton, J.L., L.L. Southern, F.M. LeMieux, T.D. Bidner, and T.G. Page. 2004. Effects of microbial phytase, low calcium and phosphorus, and removing the dietary trace mineral premix on carcass traits, pork quality, plasma metabolites, and tissue mineral content in growing-finishing pigs. *J. Anim. Sci.* 82:2630-2639.
- Shriver, J.A., S.D. Carter, A.L. Sutton, B.T. Richert, B.W. Senne, and L.A. Pettey. 2003. Effects of adding fiber sources to reduced-crude protein, amino acid-supplemented diets on nitrogen excretion, growth performance, and carcass traits on finishing pigs. *J. Anim. Sci.* 81:492-502.
- Smil, V. 2000. Phosphorus in the environment: natural flows and human interferences. *Annu. Rev. Energy Environ.* 25:53-88.
- Sutton, A.L., K.B. Kephart, M.W.A. Verstegen, T.T. Canh, and P.J. Hobbs. 1999. Potential for reduction of odorous compounds in swine manure through diet modification. *J. Anim. Sci.* 77:430-439.
- Touchette, K.J., G.L. Alee, M.D. Newcomb, and R.D. Boyd. 1998. The use of synthetic lysine in the diet of lactating sows. *J. Anim. Sci.* 76:1437-1442.
- Tuitoek, K., L.G. Young, C.F.M. de Lange, and B.J. Kerr. 1997. The effect of reducing excess dietary amino acids on growing-finishing pig performance: an evaluation of the ideal protein concept. *J. Anim. Sci.* 75:1575-1583.

- Traylor, S.L., G.L. Cromwell, M.D. Lindemann, and D.A. Knabe. 2001. Effects of level of supplemental phytase on ileal digestibility of amino acids, calcium, and phosphorus in dehulled soybean meal for growing pigs. *J. Anim. Sci.* 79:2634-2642.
- Varel, V.H., and J.T. Yen. 1997. Microbial perspective on fiber utilization by swine. *J. Anim. Sci.* 75:2715-2722.
- Veum, T.L., D.W. Bollinger, C.E. Buff, and M.R. Bedford. 2006. A genetically engineered *Escherichia coli* phytase improves nutrient utilization, growth performance, and bone strength of young swine fed diets deficient in available phosphorus. *J. Anim. Sci.* 84:1147-1158.
- Zervas, S. and R.T. Zijlstra. 2002. Effects of dietary protein and fermentable fiber in nitrogen excretion patterns and plasma urea in grower pigs. *J. Anim. Sci.* 80:3247-3256.

APPENDIX

Appendix Table 21.

Barn means for Days, number of sows (Sows), sow weight at day 110 of gestation (110W), and sow weight change during lactation (WCHG) – Experiment 1.

Room	TRT	REP	Days	Sows	110W, kg	WCHG, Kg
2	1	1	26	7	179.59	32.01
1	1	2	27	8	189.91	41.66
2	1	3	23	14	173.78	33.93
2	1	4	28	14	198.87	29.77
1	2	1	26	5	176.42	40.27
2	2	2	27	11	178.07	26.38
1	2	3	23	13	182.83	33.28
1	2	4	28	14	191.25	26.24

TRT 1: Fortified corn-soybean meal diet.

TRT 2: Low nutrient excretion diet.

Appendix Table 22.

Analysis of variance for Days, number of sows (Sows), sow weight at day 110 of gestation (110W), and sow weight change during lactation (WCHG) – Experiment 1.

Source	Df	Mean Squares			
		Days	Sows	110W	WCHG
Total	7				
Trt	1	0.00	0.00	23.05	15.68
Rep	3	9.33	28.17	127.06	24.14
Error	3	0.00	2.33	40.68	47.20
CV, %		0.0	14.2	3.5	20.9

Appendix Table 23.

Barn means for number of piglets born alive (NBA), number of piglets weaned (NW), number of piglets weaned per sow (NW/S), and average litter weight at birth (LW) – Experiment 1.

Room	TRT	REP	NBA	NW	NW/S	LW
2	1	1	51	46	6.57	34.42
1	1	2	101	83	10.38	67.94
2	1	3	122	118	8.43	42.72
2	1	4	121	110	7.86	45.37
1	2	1	45	43	8.60	43.99
2	2	2	113	106	9.64	28.87
1	2	3	130	111	8.54	48.30
1	2	4	132	114	8.14	48.03

TRT 1: Fortified corn-soybean meal diet.

TRT 2: Low nutrient excretion diet.

Appendix Table 24.

Analysis of variance for number of piglets born alive (NBA), number of piglets weaned (NW), number of piglets weaned per sow (NW/S), and average litter weight at birth (LW) – Experiment 1.

Source	Df	Mean Squares			
		NBA	NW	NW/S	LW
Total	7				
Trt	1	78.125	36.125	0.353	9.548
Rep	3	2744.792	2111.458	2.244	213.712
Error	3	34.790	88.460	0.676	32.161
CV, %		5.79	10.29	9.65	11.64

Appendix Table 25.

Barn means for average daily feed intake (ADFI), daily dry matter intake (DMI), daily nitrogen intake (NI), and daily phosphorus intake (PI) – Experiment 1.

Room	TRT	REP	ADFI, kg	DMI, g	NI, g	PI, g
2	1	1	3.30	2680.26	90.20	18.69
1	1	2	3.99	3293.50	111.86	22.81
2	1	3	2.83	2448.87	84.24	16.96
2	1	4	3.22	3179.15	108.54	20.69
1	2	1	3.71	2726.19	92.16	15.32
2	2	2	3.83	3284.50	112.62	19.25
1	2	3	3.32	2833.70	92.45	16.59
1	2	4	3.50	3418.94	102.77	18.90

TRT 1: Fortified corn-soybean meal diet.

TRT 2: Low nutrient excretion diet.

Appendix Table 26.

Analysis of variance for average daily feed intake (ADFI), daily dry matter intake (DMI), daily nitrogen intake (NI), and daily phosphorus intake (PI) – Experiment 1.

Source	Df	Mean Squares			
		ADFI	DMI	NI	PI
Total	7				
Trt	1	0.130	54706.05	3.328	10.329
Rep	3	0.242	259042.37	262.509	8.798
Error	3	0.042	16395.31	16.410	1.119
CV, %		5.92	4.29	4.08	5.67

Appendix Table 27.

Barn means for pH, slurry temperature (Temp), electroconductivity (EC), and slurry volume (VOL) – Experiment 1.

Room	TRT	REP	pH	Temp, °C	EC, mS	Vol, L/sow
2	1	1	7.76	18.65	6.16	18.79
1	1	2	7.61	22.00	6.77	9.23
2	1	3	7.54	24.90	6.98	21.24
2	1	4	7.41	16.60	9.53	17.76
1	2	1	7.82	18.00	5.17	21.62
2	2	2	7.56	22.13	7.25	14.87
1	2	3	7.50	25.00	6.51	28.20
1	2	4	7.40	16.43	10.79	12.63

TRT 1: Fortified corn-soybean meal diet.

TRT 2: Low nutrient excretion diet.

Appendix Table 28.

Analysis of variance for pH, slurry temperature (Temp), electroconductivity (EC), and slurry volume (VOL) – Experiment 1.

Source	Df	Mean Squares			
		pH	Temp	EC	VOL
Total	7				
Trt	1	0.0002	0.0435	0.0098	13.261
Rep	3	0.0522	28.5715	7.4726	62.189
Error	3	0.0012	0.0652	0.4999	14.676
CV, %		0.46	1.25	9.56	21.23

Appendix Table 29.

Barn means for dry matter (DM), nitrogen (N), ammonium-N(NH₄-N), and phosphorus (P) concentration in the slurry – Experiment 1.

Room	TRT	REP	DM, %	N, Ppm	NH ₄ -N, ppm	P, Ppm
2	1	1	0.54	861.36	612.38	187.20
1	1	2	0.76	999.45	680.25	246.43
2	1	3	0.72	989.25	699.33	227.48
2	1	4	0.88	1023.33	1348.17	422.17
1	2	1	0.46	643.10	458.00	136.59
2	2	2	1.06	1074.95	705.38	224.63
1	2	3	0.91	864.43	552.33	193.92
1	2	4	1.12	1631.00	1372.33	340.72

TRT 1: Fortified corn-soybean meal diet.

TRT 2: Low nutrient excretion diet.

Appendix Table 30.

Analysis of Variance for dry matter (DM), nitrogen (N), ammonium-N(NH₄-N), and phosphorus (P) concentration in the slurry – Experiment 1.

Source	Df	Mean Squares			
		DM	N	NH ₄ -N	P
Total	7				
Trt	1	0.0528	14457.65	7943.67	4390.78
Rep	3	0.0948	116460.99	283852.41	17844.64
Error	3	0.0141	68210.16	5128.34	335.90
CV, %		14.72	25.84	8.91	7.41

Appendix Table 31.

Barn means for nitrogen (N), ammonium-N(NH₄-N), and phosphorus (P) concentration in the slurry on a dry matter basis – Experiment 1.

Room	TRT	REP	N, %	NH ₄ -N, %	P, %
2	1	1	16.76	12.00	3.62
1	1	2	14.63	10.42	3.11
2	1	3	15.35	24.97	8.12
2	1	4	11.73	48.13	15.07
1	2	1	16.46	12.16	2.87
2	2	2	12.14	8.28	2.20
1	2	3	10.14	6.59	2.27
1	2	4	15.03	48.99	12.16

TRT 1: Fortified corn-soybean meal diet.

TRT 2: Low nutrient excretion diet.

Appendix Table 32.

Analysis of Variance for nitrogen (N), ammonium-N(NH₄-N), and phosphorus (P) concentration in the slurry on a dry matter basis – Experiment 1.

Source	Df	Mean Squares		
		N	NH ₄ -N	P
Total	7			
Trt	1	2.761	47.531	13.572
Rep	3	6.097	667.538	51.526
Error	3	6.467	41.351	2.823
CV, %		18.13	29.99	27.20

Appendix Table 33.

Barn means for daily dry matter (DM), nitrogen (N), and phosphorus (P) excretion per pig – Experiment 1.

Room	TRT	REP	DM, g/pig	N, g/pig	P, g/pig
2	1	1	436.85	71.83	15.57
1	1	2	472.73	61.62	15.37
2	1	3	380.00	49.23	12.08
2	1	4	344.94	41.02	16.75
1	2	1	416.86	61.85	12.33
2	2	2	553.33	53.55	11.62
1	2	3	361.34	34.71	8.14
1	2	4	343.47	50.13	10.57

TRT 1: Fortified corn-soybean meal diet.

TRT 2: Low nutrient excretion diet.

Appendix Table 34.

Analysis of variance for daily dry matter (DM), nitrogen (N), ammonium-N(NH₄-N), and phosphorus (P) excretion per pig – Experiment 1.

Source	Df	Mean Squares		
		DM	N	P
Total	7			
Trt	1	204.829	68.796	36.594
Rep	3	11147.092	259.573	6.521
Error	3	1139.443	53.492	0.848
CV, %		8.16	13.80	7.19

Appendix Table 35.

Barn means for dry matter (DMEPI), nitrogen (NEPI), and phosphorus (PEPI) excretion as a percentage of intake – Experiment 1.

Room	TRT	REP	DMEPI, %	NEPI, %	PEPI, %
2	1	1	16.30	79.63	83.29
1	1	2	14.35	55.08	67.39
2	1	3	15.52	58.44	71.23
2	1	4	10.85	37.79	80.96
1	2	1	15.29	67.11	80.48
2	2	2	16.85	47.55	60.36
1	2	3	12.75	37.54	49.06
1	2	4	10.05	48.78	55.93

TRT 1: Fortified corn-soybean meal diet.

TRT 2: Low nutrient excretion diet.

Appendix Table 36.

Analysis of variance for dry matter (DMEPI), nitrogen (NEPI), and phosphorus (PEPI) excretion as a percentage of intake – Experiment 1.

Source	Df	Mean Squares		
		DM	N	P
Total	7			
Trt	1	0.5408	112.200	406.695
Rep	3	12.2684	355.558	180.218
Error	3	2.4169	91.107	60.323
CV, %		11.11	17.68	11.32

Appendix Table 37.

Room means for average daily gain (ADG), average daily feed intake (ADFI), and feed conversion (F:G) – Experiment 2.

Phase	Room	TRT	ADG (kg)	ADFI (kg)	F:G
1	3	1	0.831	1.795	2.160
2	2	1	0.762	2.543	3.012
3	4	1	0.847	2.507	2.959
4	1	1	.	.	.
1	2	2	0.783	1.817	2.319
2	1	2	.	.	.
3	3	2	0.806	2.352	2.918
4	4	2	0.819	2.930	3.575
1	1	3	0.804	1.760	2.189
2	4	3	0.806	2.192	2.806
3	2	3	0.809	2.555	3.156
4	3	3	0.806	2.709	3.360
1	4	4	0.852	1.799	2.110
2	3	4	0.791	1.901	2.872
3	1	4	0.883	2.507	2.838
4	2	4	0.735	2.662	3.620

TRT 1: Fortified corn-soybean meal diet.

TRT 2: Low nutrient excretion diet.

TRT 3: Low nutrient excretion diet, with 7.5% soybean hulls included.

TRT 4: Low nutrient excretion diet, with 15% soybean hulls included.

Appendix Table 38.

Analysis of variance for average daily gain (ADG), average daily feed intake (ADFI), and feed conversion (F:G) – Experiment 2.

Source	Df	Mean Squares		
		ADG	ADFI	F:G
Total	13			
Room	3	0.01210	0.1743	0.03171
Phase	3	0.00679	2.9971	0.90579
Trt	3	0.00066	0.1565	0.00204
CSB vs LNE	1	0.00095	0.0824	0.00066
SH linear	1	0.00154	0.1438	0.00568
SH Quad	1	0.00004	0.0027	0.00043
Error	4	0.00445	0.0985	0.00765
CV, %		3.73	6.22	3.07

Appendix Table 39.

Room means for dry matter (DM), phosphorus (P), nitrogen (N), and ammonium-N (NH₄-N) concentration in the slurry and slurry volume (VOL) – Experiment 2

Phase	Room	TRT	DM (%)	P (%)	N (%)	NH ₄ -N (%)	VOL (L/pig)
1	3	1	1.151	0.022	0.129	0.093	20.684
2	2	1	1.349	0.024	0.175	0.135	20.642
3	4	1	1.436	0.036	0.177	0.120	18.969
4	1	1	1.758	0.042	0.185	0.120	19.407
1	2	2	1.364	0.018	0.115	0.074	17.233
2	1	2	1.764	0.022	0.146	0.097	16.261
3	3	2	1.240	0.023	0.121	0.100	21.376
4	4	2	1.375	0.025	0.109	0.081	23.557
1	1	3	1.514	0.021	0.128	0.074	14.701
2	4	3	1.473	0.017	0.123	0.084	20.130
3	2	3	1.057	0.016	0.090	0.056	28.304
4	3	3	1.778	0.027	0.136	0.083	18.782
1	4	4	1.600	0.017	0.099	0.034	21.215
2	3	4	1.826	0.023	0.134	0.076	18.854
3	1	4	2.194	0.027	0.145	0.070	16.330
4	2	4	2.215	0.030	0.143	0.079	18.305

TRT 1: Fortified corn-soybean meal diet.

TRT 2: Low nutrient excretion diet.

TRT 3: Low nutrient excretion diet, with 7.5% soybean hulls included.

TRT 4: Low nutrient excretion diet, with 15% soybean hulls included.

Appendix Table 40.

Analysis of variance for dry matter (DM), phosphorus (P), nitrogen (N), and ammonium-N (NH₄-N) concentration in the slurry and total volume (VOL) – Experiment 2

Source	Df	Mean Squares				
		DM	P	N	NH ₄ -N	VOL
Total	15					
Phase	3	0.3203	0.0001029	0.00061	0.00062	6.0709
Room	3	0.3068	0.0000261	0.00048	0.00008	17.1008
Trt	3	0.8148	0.0000888	0.00188	0.00207	2.2829
CSB vs LNE	1	0.0003	0.0001620	0.00383	0.00168	0.2032
SH linear	1	0.5471	0.0000101	0.00011	0.00108	1.7326
SH quad	1	0.1558	0.0000220	0.00014	0.00001	4.7731
Error	6	0.0422	0.0000141	0.00034	0.00018	13.0096
CV, %		13.10	15.40	13.68	15.70	18.34

Appendix Table 41.

Room means for phosphorus (P), nitrogen (N), and ammonium-nitrogen (NH₄-N)
concentration of slurry on a dry matter basis – Experiment 2.

Phase	Room	TRT	P (%)	N (%)	NH ₄ -N (%)
1	3	1	1.911	11.216	8.073
2	2	1	1.752	12.966	9.972
3	4	1	2.525	12.296	8.384
4	1	1	2.361	10.528	6.832
1	2	2	1.352	8.427	5.427
2	1	2	1.228	8.289	5.501
3	3	2	1.879	9.754	8.086
4	4	2	1.822	7.932	5.907
1	1	3	1.409	8.445	4.918
2	4	3	1.132	8.354	5.668
3	2	3	1.543	8.530	5.291
4	3	3	1.544	7.633	4.668
1	4	4	1.068	6.215	2.139
2	3	4	1.244	7.338	4.147
3	1	4	1.232	6.592	3.203
4	2	4	1.349	6.437	3.576

TRT 1: Fortified corn-soybean meal diet.

TRT 2: Low nutrient excretion diet.

TRT 3: Low nutrient excretion diet, with 7.5% soybean hulls included.

TRT 4: Low nutrient excretion diet, with 15% soybean hulls included.

Appendix Table 42.

Analysis of variance for phosphorus (P), nitrogen (N), and ammonium-nitrogen (NH₄-N)
concentration of slurry on a dry matter basis – Experiment 2.

Source	Df	Mean Squares		
		P	N	NH ₄ -N
Total	15			
Phase	3	0.2145	1.239	1.593
Room	3	0.0192	0.322	1.065
Trt	3	0.6237	18.274	17.808
CSB vs LNE	1	0.6497	19.858	8.694
SH linear	1	0.2408	7.644	17.571
SH quad	1	0.0002	1.017	0.401
Error	6	0.030	0.333	0.746
CV, %		10.81	6.55	15.06

Appendix Table 43.

Room means for dry matter (DM), phosphorus (P), nitrogen (N), and ammonium-N (NH₄-N) cumulative excretion per pig per phase (21 days), and the ratio of ammonium-N to total N (NH₄-N:N) – Experiment 2.

Phase	Room	TRT	DM (g/pig)	P (g/pig)	N (g/pig)	NH ₄ -N (g/pig)	NH ₄ -N:N
1	3	1	5000.9	95.6	560.9	403.74	0.720
2	2	1	5847.7	102.5	758.2	583.12	0.769
3	4	1	5718.6	144.4	703.1	479.43	0.682
4	1	1	7165.6	169.2	754.4	489.54	0.649
1	2	2	4934.9	66.7	415.9	267.79	0.644
2	1	2	6025.5	74.0	499.5	331.48	0.664
3	3	2	5567.2	104.6	543.1	450.15	0.829
4	4	2	6799.6	123.9	539.3	401.63	0.745
1	1	3	4673.6	65.9	394.7	229.86	0.582
2	4	3	6228.9	70.5	520.3	353.05	0.678
3	2	3	6283.0	69.9	535.9	332.41	0.620
4	3	3	7011.5	108.3	535.2	327.30	0.612
1	4	4	7127.8	76.1	443.0	152.48	0.344
2	3	4	7228.3	89.9	530.4	299.79	0.565
3	1	4	7523.8	92.7	495.9	240.95	0.486
4	2	4	8512.8	114.9	548.0	304.46	0.556

TRT 1: Fortified corn-soybean meal diet.

TRT 2: Low nutrient excretion diet.

TRT 3: Low nutrient excretion diet, with 7.5% soybean hulls included.

TRT 4: Low nutrient excretion diet, with 15% soybean hulls included.

Appendix Table 44.

Analysis of variance for dry matter (DM), phosphorus (P), nitrogen (N), and ammonium-N (NH₄-N) cumulative excretion per pig per phase (21 days), and the ratio of ammonium-N to total N (NH₄-N:N) – Experiment 2.

Source	Df	Mean Squares				
		DM	P	N	NH ₄ -N	NH ₄ -N:N
Total	15					
Phase	3	2519903.0	2346.00	16467.93	14416.17	0.00728
Room	3	50621.1	48.75	606.47	2132.26	0.00588
Trt	3	2787475.0	1460.77	37696.80	41468.87	0.45378
CSB vs LNE	1	20563.9	2538.28	75816.18	31850.36	0.00048
SH linear	1	6240161.3	2.42	47.53	25693.04	0.10835
SH quad	1	1181883.8	148.01	76.68	55.54	0.00095
Error	6	113960.9	109.24	869.62	1638.53	0.00434
CV, %		5.31	10.48	5.38	11.47	10.40

Appendix Table 45.

Room means for pH, electroconductivity (EC), and temperature (Temp) – Experiment 2					
Phase	Room	TRT	Ph	EC (mS)	Temp (°C)
1	3	1	7.00	8.29	17.83
1	2	2	6.70	7.31	17.87
1	1	3	6.69	7.49	17.87
1	4	4	6.43	6.37	18.15
2	2	1	7.07	10.43	17.70
2	1	2	6.71	8.65	17.70
2	4	3	6.77	8.16	17.80
2	3	4	6.62	8.12	17.73
3	4	1	6.95	10.68	17.90
3	3	2	6.70	8.28	17.90
3	2	3	6.54	7.05	17.40
3	1	4	6.45	8.86	17.40
4	1	1	6.94	10.88	20.93
4	4	2	6.65	7.30	20.97
4	3	3	6.48	7.15	20.63
4	2	4	6.43	7.60	20.93

TRT 1: Fortified corn-soybean meal diet.

TRT 2: Low nutrient excretion diet.

TRT 3: Low nutrient excretion diet, with 7.5% soybean hulls included.

TRT 4: Low nutrient excretion diet, with 15% soybean hulls included.

Appendix Table 46.

Analysis of variance for pH, electroconductivity (EC), and temperature (Temp) – Experiment 2.

Source	Df	Mean Squares		
		pH	EC	Temp
Total	15			
Phase	3	0.02097	1.79224	9.62907
Room	3	0.00021	0.84634	0.04787
Trt	3	0.18377	5.76324	0.02761
CSB vs LNE	1	0.18000	9.54845	0.00080
SH linear	1	0.08611	0.04351	0.00661
SH quad	1	0.00304	0.32434	0.06510
Error	6	0.00469	0.31248	0.02842
CV, %		1.02	6.74	0.91

Appendix Table 47.

Room means for dry matter intake (DMI), dry matter excretion (DMEX), and dry matter excretion as a percentage of intake (DMEXPI) – Experiment 2.

Phase	Room	TRT	DMI (g/d)	DMEX (g/d)	DMEPI (%)
1	3	1	1581.17	238.14	15.06
2	2	1	1986.20	278.46	14.02
3	4	1	2158.65	272.31	12.61
4	1	1	2380.62	341.22	14.33
1	2	2	1604.41	235.00	14.65
2	1	2	1913.36	286.93	15.00
3	3	2	2035.00	265.11	13.03
4	4	2	2546.18	323.79	12.72
1	1	3	1561.02	222.55	14.26
2	4	3	1965.23	296.61	15.09
3	2	3	2209.65	299.19	13.54
4	3	3	2349.24	333.88	14.21
1	4	4	1592.58	339.42	21.31
2	3	4	1972.82	344.21	17.45
3	1	4	2177.53	358.27	16.45
4	2	4	2314.21	405.37	17.52

TRT 1: Fortified corn-soybean meal diet.

TRT 2: Low nutrient excretion diet.

TRT 3: Low nutrient excretion diet, with 7.5% soybean hulls included.

TRT 4: Low nutrient excretion diet, with 15% soybean hulls included.

Appendix Table 48.

Analysis of variance for dry matter intake (DMI), dry matter excretion (DMEX), and dry matter excretion as a percentage of intake (DMEXPI) – Experiment 2.

Source	Df	Mean Squares		
		DMI	DMEX	DMEPI
Total	15			
Phase	3	468391.563	5713.865	4.209
Room	3	4725.292	114.705	0.228
Trt	3	118.634	6320.690	17.256
CSB vs LNE	1	7.392	46.561	0.048
SH linear	1	218.510	14148.984	37.541
SH quad	1	8.390	2680.552	8.085
Error	6	6454.144	258.443	1.455
CV, %		3.97	5.31	8.00

Appendix Table 49.

Room means for nitrogen intake (NI), nitrogen excretion (NEX), and nitrogen excretion as a percentage of intake (NEPI) – Experiment 2.

Phase	Room	TRT	NI (g/d)	NEX (g/d)	NEPI (%)
1	3	1	57.46	26.71	46.48
2	2	1	62.94	36.11	57.36
3	4	1	58.84	33.48	56.91
4	1	1	60.75	35.93	59.14
1	2	2	48.79	19.80	40.59
2	1	2	51.43	23.78	46.25
3	3	2	47.27	25.86	54.71
4	4	2	50.62	25.68	50.74
1	1	3	46.77	18.79	40.18
2	4	3	52.23	24.78	47.44
3	2	3	49.35	25.52	51.72
4	3	3	47.77	25.49	53.36
1	4	4	47.02	21.10	44.87
2	3	4	50.80	25.26	49.72
3	1	4	49.88	23.62	47.35
4	2	4	47.06	26.09	55.44

TRT 1: Fortified corn-soybean meal diet.

TRT 2: Low nutrient excretion diet.

TRT 3: Low nutrient excretion diet, with 7.5% soybean hulls included.

TRT 4: Low nutrient excretion diet, with 15% soybean hulls included.

Appendix Table 50.

Analysis of variance for nitrogen intake (NI), nitrogen excretion (NEX), and nitrogen excretion as a percentage of intake (NEPI) – Experiment 2.

Source	Df	Mean Squares		
		NI	NEX	NEPI
Total	15			
Phase	3	13.313	37.371	103.319
Room	3	1.752	1.372	7.766
Trt	3	119.610	85.534	42.828
CSB vs LNE	1	219.242	172.144	95.220
SH linear	1	1.403	0.113	3.239
SH quad	1	0.016	0.172	0.760
Error	6	1.769	1.979	6.896
CV, %		2.57	5.38	5.24

Appendix Table 51.

Room means for phosphorus intake (PI), phosphorus excretion (PEX), and phosphorus excretion as a percentage of intake (PEPI) – Experiment 2.

Phase	Room	TRT	PI (g/d)	PEX (g/d)	PEPI (%)
1	3	1	9.17	4.55	49.60
2	2	1	9.79	4.88	49.87
3	4	1	10.35	6.88	66.46
4	1	1	10.40	8.06	77.47
1	2	2	7.56	3.18	42.02
2	1	2	7.64	3.52	46.09
3	3	2	7.92	4.98	62.92
4	4	2	7.61	5.90	77.52
1	1	3	7.08	3.14	44.30
2	4	3	8.15	3.36	41.22
3	2	3	8.25	4.62	55.92
4	3	3	7.43	5.16	69.41
1	4	4	7.07	3.62	51.28
2	3	4	7.56	4.28	56.62
3	1	4	8.65	4.41	51.04
4	2	4	7.53	5.47	72.60

TRT 1: Fortified corn-soybean meal diet.

TRT 2: Low nutrient excretion diet.

TRT 3: Low nutrient excretion diet, with 7.5% soybean hulls included.

TRT 4: Low nutrient excretion diet, with 15% soybean hulls included.

Appendix Table 52.

Analysis of variance for phosphorus intake (PI), phosphorus excretion (PEX), and phosphorus excretion as a percentage of intake (PEPI) – Experiment 2.

Source	Df	Mean Squares		
		PI	PEX	PEPI
Total	15			
Phase	3	0.7681	5.3268	638.6222
Room	3	0.1235	0.1098	26.8552
Trt	3	4.9446	3.3117	45.2290
CSB vs LNE	1	10.0801	5.7630	27.5653
SH linear	1	0.0008	0.0050	1.1175
SH quad	1	0.0033	0.3267	61.4080
Error	6	0.1175	0.2499	26.4018
CV, %		4.15	10.52	8.99

Appendix Table 53.

Room means for ammonia emitted on a mg/pig/d basis, ammonia concentration leaving the room per minute, ammonia emitted on a mg/kg/d basis, and ammonia emitted on a g/d/500 kg (AU) – Experiment 2.

Phase	Room	TRT	NH ₃ , mg/pig/d	NH ₃ , mg/min	NH ₃ , mg/kg/d	NH ₃ , g/d/AU
1	3	1	534.39	24.493	12.7087	6.3544
2	2	1	1467.92	44.853	21.7511	10.8755
3	4	1	3184.36	139.000	35.2257	17.6128
4	1	1	2633.00	76.796	25.0887	12.5444
1	2	2	257.20	11.788	6.1449	3.0725
2	1	2	740.47	21.940	12.4680	6.2340
3	3	2	1609.91	73.938	17.9090	8.9545
4	4	2	1370.08	38.058	11.8021	5.9011
1	1	3	262.64	12.037	6.2614	3.1307
2	4	3	598.43	18.285	8.8249	4.4125
3	2	3	1242.19	60.186	13.7112	6.8556
4	3	3	1418.87	39.413	12.3978	6.1989
1	4	4	170.85	7.831	4.0425	2.0212
2	3	4	645.43	19.722	9.4428	4.7214
3	1	4	998.16	50.932	11.1562	5.5781
4	2	4	1454.34	42.418	12.6264	6.3282

TRT 1: Fortified corn-soybean meal diet.

TRT 2: Low nutrient excretion diet.

TRT 3: Low nutrient excretion diet, with 7.5% soybean hulls included.

TRT 4: Low nutrient excretion diet, with 15% soybean hulls included.

Appendix Table 54.

Analysis of variance for ammonia emitted on a mg/pig/d basis, ammonia concentration leaving the room per minute, ammonia emitted on a mg/kg/d basis, and ammonia emitted on a g/d/500 kg (AU) – Experiment 2.

Source	Df	Mean Squares			
		NH ₃ , mg/pig/d	NH ₃ , mg/min	NH ₃ , mg/kg/d	NH ₃ , g/d/AU
Total	15				
Phase	3	1983952.75	3471.48	104.24	26.06
Room	3	5842.24	119.91	2.53	0.63
Trt	3	1983952.747	1488.59	177.49	44.37
CSB vs LNE	1	1845130.99	2429.67	269.70	67.43
SH linear	1	62814.06	77.01	15.20	3.80
SH quad	1	1703.38	1.92	0.43	0.11
Error	6	165858.20	263.45	14.23	3.56
CV, %		35.06	38.10	27.24	27.24

VITA

Justin Wade Bundy

Candidate for the Degree of

Master of Science

Thesis: EFFECTS OF DIET MODIFICATION DURING THE LACTATION AND
FINISHING PERIODS ON PERFORMANCE AND NUTRIENT EXCRETION FOR
SWINE HOUSED IN COMMERCIAL CONDITIONS

Major Field: Animal Science

Biographical:

Education:

Graduated from Latta High School, Ada, Oklahoma in May, 2001.

Associate of Science from Eastern Oklahoma State College, Wilburton,
Oklahoma in May, 2003.

Bachelor of Science in agricultural education from Oklahoma State University,
Stillwater, Oklahoma in May, 2005

Completed the requirements for the Master of Science in animal science at
Oklahoma State University, Stillwater, Oklahoma in December, 2007.

Experience: Graduate assistant at Oklahoma State University, Stillwater
Oklahoma. August, 2005 – December, 2007.

Professional Memberships: American Society of Animal Scientists

Name: Justin Wade Bundy

Date of Degree: December, 2007

Institution: Oklahoma State University

Location: Stillwater, Oklahoma

Title of Study: EFFECTS OF DIET MODIFICATION DURING THE LACTATION
AND FINISHING PERIODS ON PERFORMANCE AND NUTRIENT
EXCRETION FOR SWINE HOUSED IN COMMERCIAL
CONDITIONS

Pages in Study: 68

Candidate for the Degree of Master of Science

Major Field: Animal science

Scope and Method of Study:

Two experiments were conducted during the lactation and finishing phases to determine the effects of dietary manipulation on nutrient excretion. Diets fed included a control and a low nutrient excretion (LNE) diet with reductions in protein and phosphorus content and supplemental phytase. Experiment 2 also included additional LNE diets with increasing soybean hull inclusion.

Findings and Conclusions:

Feeding a LNE diet during lactation reduced nitrogen excretion by 10% and decreased phosphorus excretion by 28% compared to a more traditional diet. The LNE diet did not affect sow or litter performance.

Finishing LNE diets reduced phosphorus and nitrogen excretion by 29 and 28%, respectively. In addition, soybean hulls included in these diets at rates as high as 15% did not negatively influence performance. Inclusion of soybean hulls influenced the form of nitrogen excreted, reducing the $\text{NH}_4\text{-N}:\text{TN}$ linearly with increasing soybean hull inclusion. Furthermore, soybean hulls lowered slurry pH and potentially decreased ammonia emissions.

ADVISER'S APPROVAL: Scott D. Carter
