EFFECTS OF ADDING FIBER SOURCES TO LOW CRUDE PROTEIN, AMINO ACID SUPPLEMENTED DIETS ON NITROGEN EXCRETION, GROWTH PERFORMANCE, AND CARCASS CHARACTERISTICS OF FINISHING PIGS

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NOMENCLATURE

Abbreviation	Meaning
LPPA	Low Protein-Amino Acid Diet
SBH	Soybean Hull
DBP	Dried Beet Pulp
kg	Kilogram
d	Day(s)
NRC	National Research Council
CP	Crude Protein
mL	Milliliter
ADG	Average Daily Gain
ADFI	Average Daily Feed Intake
G:F	Gain:Feed Ratio
F:G	Feed:Gain Ratio
m	Meter(s)
PIC	Pig Improvement Company

FORMAT OF THESIS

This thesis is presented in the Journal of Animal Science style format, as outlined by the Oklahoma State University graduate college style manual. The use of this format allows the independent chapters to be suitable for submission to scientific journals.

CHAPTER I

INTRODUCTION

In the past few decades, environmental pollution has become a major concern. Even though businesses and industry emit the greatest amount of environmental toxins, the livestock industry also plays a large role in pollution. Several harmful compounds are released into the environment each day by production animals; however, nitrogen is one of the largest concerns. Excess nitrogen is excreted by animals into the environment as a potential pollutant of our soils and ground waters.

Excess soil nitrogen is used by microorganism populations for growth. Microorganisms are known converters of nitrogen to ammonium ions, which are then further oxidized to nitrite and nitrate ions. Nitrates can potentially leach through the soil to eventually contaminate ground water supplies. These high levels of nitrates in drinking water have been associated with maethemoglobinea, a potentially lethal blood disorder affecting infants under six months of age (Gangbazo et al., 1995).

Beef and dairy cattle are by far the largest contributors of nitrogen pollution in the livestock industry. In fact, beef and dairy cattle combined are responsible for approximately five million tons of nitrogen waste per year. However, the poultry and swine industries are also responsible for high levels of nitrogen excretion. The poultry industry produces approximately seven-hundred and ninety thousand tons of nitrogen, while the swine industry produces about seven-hundred and thirty thousand tons of nitrogen annually (Sweeten, 1992). Nitrogen-containing compounds are the primary contributors of odorous gases that plague the swine industry. Ammonia and hydrogen sulfide receive the most attention due their offensive odor and effect on human health. Exposure to ammonia and hydrogen sulfide can result in shortness of breath, or increase the risk of pulmonary system diseases. (Donham, 1996).

Most methods of controlling environmental pollution from the swine industry have been centered around treating waste streams against ammonia and effective land application methods. These methods have been essential in limiting pollution; however, the best way to reduce the amount of nitrogen excreted as waste is through dietary manipulation. Altering swine diets, primarily grow-finishing diets, will provide long term solutions to nitrogen pollution from swine facilities. Therefore, these experiments were conducted to evaluate the effects of fiber addition to low crude protein amino acid supplemented diets on nitrogen balance, growth performance, and carcass characteristics of finishing pigs.

CHAPTER II

LITERATURE REVIEW

Dietary manipulation is the best line of defense against excessive nitrogen excretion in the swine industry. By manipulating the diet, producers can: (1) increase nutrient utilization of the diet, reducing excretion products, (2) enhance microbial metabolism in the lower digestive tract, reducing odor causing compounds, and (3) change the physical characteristics of the urine and feces to reduce odor emissions. Reducing crude protein with amino acid supplementation to more closely meet the pigs requirement is one way to reduce excess nitrogen excretion. Furthermore, feeding fermentable carbohydrates will increase nutrient digestion by microbes in the digestive tract while shifting nitrogen excretion from the urine to feces. Urinary nitrogen is composed primarily of urea nitrogen, which is associated with ammonia emission from the slurry. Therefore, by shifting nitrogen excretion from the urine to the feces, less substrate will be available for ammonia emission, reducing potential offensive odors.

Protein is by far one of the more costly nutrients in standard swine diets. Corn is usually the cheapest energy source for swine diets, while soybean meal is generally the cheapest protein source. Therefore, recommended diets include these two feedstuffs as major ingredients in swine diet formulation (Table 1).

Table 1. Nutrients in corn and corn + soybean meal (dehulled) compared with the nutrient requirements of a 40-kg growing pig of high-medium lean growth rate[a].

Nutrient	Corn	Corn + Soybean Meal (74.1%:23.4%)	Requirement (40-kg pig)	Excess (%)
Essential amino acids, %				
Arginine	.37	1.09	.35	74
Histidine	.23	.47	.29	18
Isoleucine	.28	.71	.49	22
Leucine	.99	1.59	.86	73
Lysine	.26	.90	.90	0
Methionine + cystine	.36	.60	.52	8
Phenylalanine + tyrosine	.64	1.46	.83	63
Threonine	.29	.65	.59	6
Tryptophan	.06	.20	.16	4
Valine	.39	.82	.62	20

[a]Table adapted from NRC, 1998.

Properly formulated corn-soybean meal diets will meet the requirements for protein and lysine; however, there will be an excess of other amino acids (Table 1). Therefore, amino acids in excess of the pigs requirement will be metabolized by the body with excess nitrogen excreted in the urine.

The ideal protein concept reduces excess dietary amino acids. An ideal protein for the growing pig must contain an amino acid profile with all 10 essential amino acids required for maintenance and body protein accretion. Furthermore, it must be shown to optimize nitrogen utilization and growth under conditions of both ad libitum intake and monitored feeding (ARC, 1981; Fuller and Wang, 1990).

Chung and Baker (1991) developed a chemically defined amino acid diet that produced weight gains, feed intakes, and nitrogen and energy retention values equal to a 20% crude protein corn-soybean meal-dried whey diet in 10-kg pigs. This diet contained true digestibilities of all amino acids in the diet of essentially 100%, leaving little concern for excess nitrogen excretion in the urine.

Feeding chemically defined amino acid diets has been shown to be effective in reducing excess nitrogen in nursery pigs (Chung and Baker, 1991). However, growing-finishing pigs require much higher levels of amino acids for maintenance and protein accretion, making it economically unfeasible to eliminate intact proteins from the diet. Although, replacing a small portion of crude protein in the diet with crystalline amino acids has shown promising results.

Effects of Low Protein, Amino Acid Supplemented Diets On Nitrogen Excretion

Low crude protein, amino acid supplemented swine diets have been shown to reduce nitrogen excretion. In fact, Aarnink et al. (1993) estimated a 9% reduction of ammonium nitrogen content in the slurry when dietary crude protein of growing pigs was reduced by 10 g/kg. Carter et al. (1996) reported a 35% reduction in nitrogen excretion, primarily urinary nitrogen, of growing pigs fed a low protein, amino acid supplemented diet. This response is consistent with Kerr (1995) who noted that nitrogen excretion can be reduced by 3.2 to 62% in pigs fed reduced protein amino acid diets, depending on the size of the pig. Sutton et al. (1996) found a 28% reduction of ammonium and total nitrogen in fresh excreted manure in growing pigs fed a diet with crude protein reduced by 3% and supplemented with amino acids. This was increased to 40% in nursery diets reduced from 18% crude protein to 10% crude protein with amino acid supplementation. However, Hobbs et al. (1996) showed that reducing crude protein from 19 to 13% in growing diets, with the addition of crystalline amino acids, reduced nitrogen excretion by 40%, while also reducing concentrations of most odorants in the slurry. This agrees with Kay and Lee (1997) who used the same diets as Hobbs et al. (1996) and found a 41% total reduction in slurry nitrogen, and a 59% reduction of ammonia emissions from building air. Turner et al. (1997) completed a following study and found ammonia emissions from manure was reduced 79% by reducing the dietary crude protein level by four percentage units, with the addition of crystalline amino acids during the growing phase, and 58% in the finishing phase.

Reducing crude protein and adding amino acids has been shown to reduce nitrogen excretion in growing-finishing pigs, primarily by reducing urinary nitrogen. However, for low protein, amino acid supplemented diets to be accepted by the swine industry there must be no negative effects on growth performance and carcass characteristics.

Effects of Low Crude Protein, Amino Acid Supplemented Diets On Growth Performance

Research has shown that feeding diets adequate in crude protein throughout the growing period results in optimal weight gains, feed efficiencies, and carcass measurements (Catron et al., 1953; Kornegay et al., 1973). However, a small percentage of soybean meal can be replaced in the diet with the addition of crystalline lysine (Wahlstrom and Libal, 1974; Baker et al., 1975). It has been found that reducing crude protein by two percentage units with supplemental lysine of .12 to .15% does not dramatically change growth performance or carcass characteristics in grow-finishing pigs (Easter and Baker, 1980; Harrison et al., 1989). However, Cromwell et al. (1983) showed that reducing crude protein by more than 2 percentage units, even with supplemental lysine, can be detrimental to pig performance (Table 2).

Table 2. Effect of reducing crude protein by 2 percentage units with lysine supplementation on growth performance and carcass characteristics.

Reference[a]	# of reps	Control % CP	LP % CP	% Change from control ADG	G:F	BF	LEA
Whalstrom et al., 1974	3	17	14	- 2.7	- 10.6[b]	9.5	1.0
Easter et al., 1980	4	13	11	- 1.3	- 3.6	- 5.7	- 1.5
Cromwell et al., 1983	5	14	10	- 23.6[b]	- 17.0[b]	-	-
Harrison et al., 1989	4	14	12	- 2.6	- 2.5	-	-

[a]All researchers supplied .2 - .3% lysine, except Whalstrom who supplied .1%.
[b]Percentages within row with superscript are different than control diet ($P<.05$).

The deficient amino acids in swine diets with crude protein reduced by four percentage units are believed to be lysine, tryptophan, and methionine (Sharda et al., 1971). Corn is low in several of the essential amino acids, but is first limiting in tryptophan, and second in lysine for the growing pig (Baker et al., 1969). Gallo and Pond (1968) demonstrated that finishing pigs display a growth rate response when lysine was added to a corn diet, but only when tryptophan was added simultaneously. However, in a standard corn-soybean meal diet, lysine is considered the most limiting, with tryptophan becoming the second limiting amino acid for growth (Sharda et al., 1976).

Reducing crude protein by four percentage units in grow-finishing diets has shown to moderately decrease growth performance, feed efficiencies, and carcass characteristics (Wahlstrom and Libal, 1974), as shown in Table 3. Corley and Easter (1980) stated that the addition .02% L-tryptophan to lysine fortified low protein diets resulted in similar performance to that of pigs fed a standard diet. However, Cromwell and Stahly (1985) reported that crystalline lysine, tryptophan, threonine and possibly methionine should be included in low protein swine diets to achieve optimal performance. Following research showed that lysine fortified, low protein diets were limiting in tryptophan for growth, and threonine for improved feed efficiency (Russell and Easter, 1985). Russell et al. (1985) also noted that the addition of methionine further improved feed conversion; however, performance with or without methionine was similar to that of pigs fed a standard soybean meal diet.

Due to the limitations in performance found with low protein, amino acid supplemented diets, researchers looked for answers involving the addition of high protein cereal grains such as wheat or triticale to the protein deficient diets. In fact, wheat and triticale are both good alternatives to corn in diets fed to pigs (McConnell et al., 1975; Pond and Maner, 1984; Meyer et al., 1989). Nordby (1929) determined growing pigs fed wheat, if processed correctly, gain up to twenty percent faster than pigs fed corn. Therefore, the question became would these high protein cereal grains eliminate the reduction in growth performance and feed efficiency found in low protein amino acid diets.

Maxwell et al. (1985) found that finishing pigs fed a low protein, wheat based diet including lysine and threonine, showed a slight decrease in daily gain while feed efficiency was similar to that of the control pigs. It was later found that if methionine and isoleucine were included in the diet, along with lysine and threonine, then pigs out performed the control pigs in both gain and efficiency of gain (Maxwell et al., 1987). Myer et al. (1996) found similar results using either wheat or tritical to replace corn in low protein amino acid supplemented diets. However, Shriver et al. (1999) found that finishing pigs fed a low protein diet containing 20% wheat middlings still show a slight reduction in daily gain while feed efficiency was slightly improved.

Effects of Low Crude Protein, Amino Acid Supplemented Diets On Carcass Characteristics

Crystalline amino acids and/or high protein cereal grains can slightly improve growth performance when included in protein deficient diets; however, carcass characteristics are subject to variation (Table 3). It has been shown that reducing crude protein by four percentage units from the starter through finisher phase results in an increase in average backfat, 10^{th} rib fat thickness, marbling, and decreased longissimus muscle area (Easter and Baker, 1980; Stahly et al., 1981; Tuitoek et al., 1997). Other studies found that low protein amino acid diets increased backfat and rib fat; however it did not effect longissimus muscle area (Kerr et al., 1995). However, Knowles et al. (1997) showed a decrease in 10^{th} rib fat and longissimus muscle area while not affecting average backfat in pigs fed low protein amino acid supplemented diets. These results were achieved by supplementing crystalline lysine, tryptophan, threonine, and methionine, and are concurrent with work done by Shriver et al. (1999).

The effects of including wheat or triticale in the diet of finishing pigs also gives variation in carcass traits. Maxwell et al. (1985) found a slight decrease in average backfat with the addition of lysine and threonine to the diet. However, if isoleucine and valine also were included, pigs displayed improved performance in regards to growth and feed efficiency, while backfat was similar to pigs fed the control diet (Maxwell et al., 1987). These results agree with Myer et al. (1996) who found only a slight decrease in feed efficiency, while slightly increasing longissimus muscle area. Although, Shriver et al. (1999) noted a dramatic decrease in longissimus muscle area, while growth performance was similar to that of the control pigs. However, pigs fed the diet containing 20% wheat middlings tended to be leaner in regards to average backfat.

Research involving the effects of low protein amino acid supplemented diets on growth performance and carcass characteristics is somewhat minimal, and even less for diets including wheat or triticale. The reason for variation in results among experiments is not yet determined. However, one explanation could be that by reducing crude protein net energy of the diet is increased due to an increase of cereal grain concentration. An increase of energy concentration leads to excess energy to be deposited as fat. This theory confirms results found by Knowles et al. (1997) and Shriver et al. (1999).

Table 3. Effect of reducing crude protein by 4 percentage units with amino acid supplementation on growth performance and carcass characteristics.

	# of	Control,	LPAA,	% Change from control			
Reference	reps	% CP	% CP	ADG	G:F	BF	LEA
Sharda, et al., 1971	6	16	12	- .6	- 4.3	-	-
Sharda, et al., 1976	7	16	12	- .7	4.7	-	-
Cromwell, et al., 1983	5	14	10	1.8	0	-	-
Maxwell, et al., 1985	7	15	12	- 3.9	- 1.5	- 2.6	-
Russell, et al., 1985	6	15	11	- .6	2.3	-	-
Maxwell, et al., 1987	5	15	12	3.2	5.1	.8	-
Kerr, et al., 1995	6	16	12	- 1.3	- 4.8	6.4[a]	1.6
Myer, et al., 1996	10	16	13	0	-3.2	1.5	3.1
Knowles, et al., 1997	4	13	9	0	4.3	2.1	- 3.3[a]
Tuitoek, et al., 1997	3	14	10	- 3.4	- 5.4	14.3[a]	-
Shriver, et al., 1999	6	17	13	- 1.8	3.5	.8	- 8.6[a]

[a]Percentages within rows with superscripts are different from control diet ($P<.05$).

Low crude protein, amino acid diets reduce nitrogen excretion in growing-finishing pigs. Furthermore, reducing crude protein with supplemental amino acids has been shown to result in similar growth performance to that of pigs fed a standard corn-soybean meal diet. However, carcass traits of pigs fed low crude protein, amino acid supplemented diets do tend to be negatively affected as compared to control pigs. Therefore, researchers began looking at what effects fiber addition to swine diets would have on nitrogen balance and carcass characteristics.

Effect of Fiber Addition to Swine Diets on Nitrogen Balance

Nitrogen enters the body primarily by dietary intake. Once nitrogen enters the body it is either absorbed by the intestine, or passes through the digestive tract to be excreted in the feces. Many factors can affect nitrogen absorption, such as dietary ingredients and excess amino acids. However, once nitrogen is absorbed it has only two fates, either it is retained by the body for maintenance and protein accretion, or it is filtered through the kidneys to be excreted primarily as urinary urea nitrogen.

Low protein, amino acid supplemented diets will reduce nitrogen excretion in swine. However, urinary nitrogen, which is a key contributor to ammonia in the slurry still remains a concern. Urinary nitrogen is primarily composed of urea nitrogen which results in an increase of ammonia from the slurry (Muck and Steenhuis, 1981). Urea is converted into ammonia and carbon dioxide by the enzyme urease found in the feces of swine (Stevens et al., 1989). The ammonia concentration and pH of slurry are important factors influencing ammonia volatilization (Freney et al., 1983). Urea excretion can be decreased by reducing dietary nitrogen intake which can be accomplished by feeding low crude protein, amino acid supplemented diets (Gatel and Grosjean, 1992).

However, the addition of fermentable carbohydrates to diets fed to growing-finishing swine has been shown to affect the partitioning of nitrogen excretion between the urine and the feces (Mroz et al., 1993; Bakker, 1996). Furthermore, fermentable carbohydrates have been reported to reduce urinary urea excretion (Schulze et al., 1995; Canh et al., 1997). Soybean hulls and dried beet pulp are both excellent sources of fermentable carbohydrates (Van Soest, 1967).

The digestibility of dry matter and energy is slightly depressed when sources of fiber are included in the diet, however the effect on nitrogen digestibility varies (Morgan and Whittemore, 1988). Wood cellulose supplements have been shown to reduce nitrogen digestibility (Partridge et al., 1982), while oatfeed showed no effect on nitrogen excretion in the urine and feces (Potkins et al., 1984). However, Morgan et al. (1984) found a reduction of urinary nitrogen resulting in an increase in fecal nitrogen when 45% oatfeed was included in the diet of growing pigs.

Including fermentable carbohydrates such as soybean hulls and dried beet pulp in the diet as a fiber source allows the microorganisms in the hind gut to retain more nitrogen for their own growth (Malmlof and Hakansson, 1984). The fermentation of fiber in the hind gut of the pig is effected by a proliferation of bacteria which retain nitrogen during their growth. Eventually the bacteria are passed out through the feces resulting in decreased nitrogen digestibility (Malmlof and Hakansson, 1984). Nitrogen retained in the hind gut leads to an increase in fecal nitrogen output (Cummings et al. 1976; Beams and Eggum, 1981; Bergner, 1982). This effect of dietary fiber on the ability of microorganisms to retain nitrogen within the gut also has been demonstrated to depress daily urinary nitrogen output (Cummings et al. 1976).

Recently, Canh et al. (1997) reported that pigs fed a diet including 30% dried beet pulp lowered the slurry pH by .97 units, and the ammonia emission from the slurry by 47%. Pigs fed the dried beet pulp based diet excreted less nitrogen in the urine while nitrogen excreted in the feces was increased. As a result, apparent fecal nitrogen digestibility was higher in grain (barley, wheat, or corn) diets than in the beet pulp based diet by 10.6%. Canh et al. (1997) also noted that nitrogen retention was also higher in pigs fed the dried beet pulp diet than pig fed grain diets.

Slurry pH is negatively correlated to volatile fatty acid content (Canh et al., 1998a). Production of volatile fatty acids occurs mainly by the microbial fermentation of dietary fiber in the large intestine (Imoto and Namioka, 1978), and during slurry storage (Spoelstra, 1979; Canh et al., 1998a). Feedstuffs high in fiber, such as soybean hulls and dried beet pulp, increase volatile fatty acids in the slurry over a 7-d period by approximately 67% as compared to grain based diets (Canh et al. 1998b). Canh et al. (1998b) also noted that slurry pH was reduced .8 to .9 units, and total nitrogen losses in the slurry were 38% lower in pigs fed diets containing 30% dried beet pulp or soybean hulls.

As shown in Table 4, similar results have been found by including fermentable carbohydrates to a low protein, amino acid supplemented diets. Sutton et al. (1997) found a reduction in fresh slurry ammonium of 49% from pigs fed a low crude protein, amino acid supplemented diet with 5% cellulose included in the diet. Furthermore, Sutton et al. (1997) also found a 33% reduction in total nitrogen losses in the slurry.

Table 4. Effect of dietary fiber addition on nitrogen balance of growing pigs.

	# of	%	% Change from control[a]					
Reference	reps	Fiber	pH	NH_3	TN	FN	URN	VFA
Canh, et al., 1997	4	30	- 12.7[b]	- 47.2[b]	- 14.6[b]	7.0	- 25.9[b]	45.6[b]
Canh, et al., 1998a	4	30	---	---	---	---	---	67.2[b]
Canh, et al., 1998b	3	30	- 11.9[b]	---	- 16.1[b]	---	---	43.2[b]
Sutton et al., 1999	4	5	- 6.4	- 49.4[b]	---	---	---	---

[a]pH = pH of fresh slurry; NH_3 = slurry ammonia; TN = total nitrogen excretion; FN = fecal nitrogen excretion; URN = urinary nitrogen excretion; VFA = volatile fatty acid production in the slurry.

[b]Percentages within rows with different superscripts are different from control diet ($P<.05$).

Fiber addition to swine diets did resulted in a shift in nitrogen excretion from the urine to the feces. By shifting nitrogen excretion from the urine to the feces less nitrogen was excreted as urinary urea nitrogen, reducing ammonia emissions from the slurry. Therefore the question is what effects does fiber addition to swine diets have on growth performance and carcass traits?

Effect of Fiber Addition on Growth Performance and Carcass Characteristics

Many fibrous feed sources are considered by the feed industry as by-products. Soybean hulls, dried beet pulp, and cottonseed hulls are all common by-products derived from the process of removing the more demanded kernel from the outside hull. The hull-free cracked kernel can then be heat conditioned, extracted, and then sold for a higher price than the entire seed. The remaining hull is relatively low in nutritive value, however the livestock industry has found a use for them as dietary fiber sources (Smith, 1977).

Normally high fiber products are considered to be poorly digested by nonruminants (Bentley et al. 1958). Although, Baird et al. (1975) confirmed previous reports by others (Teague and Hanson, 1954; Cole et al., 1967; Baird et al., 1970) that pigs can tolerate a wide range of crude fiber in the diet provided energy density is sufficient. These reports suggest that unless prevented by bulk, or perhaps palatabililty of the diet, the pig will eat until it satisfies its energy requirement. Increased daily feed consumption associated with reduced energy content of high fiber diets has been reported by Merkel et al. (1958) and Cole et al. (1967).

Kornegay (1978) found that up to 12% soybean hulls can be included in a swine diet without affecting growth performance. Pigs fed diets containing 2 to 12% soybean hulls displayed similar gain, intake, and efficiency of gain as pigs fed a standard corn-soybean meal diet. However, Kornegay (1978) also found that performance was depressed in pigs fed diets containing 24% soybean hulls as compared to pig fed the control diet.

Similar results were found by Knowles et al. (1998) who included 3% fiber from rice hulls to a low crude protein, amino acid supplemented diet. Knowles et al. (1998) noted that pigs fed the low protein diet containing 3% rice hulls showed no differences in gain, intake, or efficiency of gain as compared to pigs fed a standard corn-soybean meal diet. However, pigs fed the low protein fiber diet did display a reduction in carcass characteristics with regards to average backfat thickness and longissimus muscle area as compared to the pigs fed the control diet. Although, pigs fed the low protein fiber diet displayed an improvement in carcass traits when compared to pigs fed a low protein, amino acid supplemented diet without the addition of fiber.

Finishing pigs fed low crude protein, amino acid supplemented diets tend to have increased backfat when compared to pigs fed amino acids from intact protein sources (Noblet et al., 1987; Schoenherr, 1992; Kerr et al., 1995). Speculation for the increase in fat deposition is uncertain, but may be a result of an increased net energy content of low crude protein diets. Pigs fed low protein, amino acid supplemented diets have reduced plasma urea nitrogen levels (Lopez et al., 1994; Kerr et al., 1995), which is an indication of a reduced need for deamination of excess amino acids, an energy requiring process (Noblet, et al., 1987).

Including crystalline amino acids, especially lysine, in swine diets is common because feed costs can be reduced by replacing a portion of the protein source with amino acids. However, the means of preventing increased backfat thickness when low crude protein, amino acid supplemented diets are fed are still being determined. Although, one possibility may be decrease the net energy content of the diet by including dietary fiber in the diet.

Diets that contain dietary fiber have been shown to reduce backfat in pigs (Pond et al., 1988, 1989). The effect of fiber in reducing backfat may not be a directly related to the presence of the fiber, but an effect of fiber as it reduces the energy content of the diet (Baird et al., 1970). Therefore, fiber may dilute dietary energy, leaving less excess energy to be deposited as fat in pigs fed low protein, amino acid supplemented diets.

Feeding low crude protein, amino acid supplemented diet to grow-finishing pigs has been shown to markedly reduce nitrogen excretion, primarily by reducing urinary nitrogen (Carter et al., 1996; Kerr, 1995; Hobbs et al., 1996). However, feeding reduced crude protein diets with supplemental amino acids tends to reduce growth performance and carcass characteristics (Sharda et al., 1976; Maxwell et al., 1987; Tuitoek et al., 1997, Shriver et al., 1999). Although, the addition of fiber to swine diets resulted in a further reduction of urinary nitrogen by shifting nitrogen excreted from the urine to the feces (Cahn et al., 1997; Schulze et al., 1995). Furthermore, pigs fed diets including fiber sources have been shown to display similar growth performance and carcass characteristics to that of pigs fed standard corn-soybean meal diets (Kornegay 1978; Knowles et al., 1998; Pond et al., 1988).

Therefore two experiments were conducted at Oklahoma State University to determine the effects of fiber addition to low crude protein, amino acid supplemented diets on nitrogen balance, growth performance, and carcass traits of finishing pigs.

CHAPTER III

Experiment 1

Effects of Adding Fiber Sources to Low Crude Protein, Amino Acid Supplemented Diets on Nitrogen Balance of Growing-Finishing Pigs.

ABSTRACT

An experiment was conducted to evaluate the effects of adding fiber sources to low crude protein, amino acid supplemented diets on nitrogen excretion of finishing pigs. The experiment consisted of six sets of four littermate barrows with an initial body weight of 36 kg. Pigs were allotted to one of four dietary treatments to determine nitrogen balance. Dietary treatments were: (1) fortified corn-soybean meal control, (2) as 1 with crude protein lowered by 4 percentage units and supplemented with lysine, threonine, methionine, tryptophan, isoleucine, and valine (LPAA), (3) as 2 plus 10% soybean hulls (SBH), and (4) as 2 with 10% dried beet pulp (DBP). Soybean hulls and beet pulp were added to Diets 3 and 4 at the expense of corn and soybean meal. Crystalline amino acids were added to Diets 2-4 to achieve an ideal ratio to digestible lysine (Chung and Baker, 1991). Pigs were housed in metabolism chambers to allow for the total, but separate, collection of urine, feces, and refused feed. Pigs were fed dietary treatments for a 9-d adjustment period, followed by a 5-d total collection period of feces, urine, and feed refusals. Chromic oxide was fed on d 0 and d 5 of the collection period to be used as a marker for the beginning and end of the collection period. Pigs had ad

libitum access to feed and water, and pigs and feeders were weighed on d 0 and 5 to monitor ADG, ADFI, and F:G. Feed, feces, and urine were collected daily to be analyzed for nitrogen content by Kjeldahl methodology. Lowering crude protein and adding crystalline amino acids reduced nitrogen intake as would be expected, however the addition of SBH or DBP to the LPAA diet did not affect nitrogen intake. Absorbed nitrogen was also reduced in pigs fed the LPAA diet. Total nitrogen excretion was reduced by 49% in pigs fed the LPAA diet, this was primarily do to the marked reduction in nitrogen intake. Neither absorbed nitrogen or total nitrogen excreted were affected by the addition of fiber to the LPAA diet. However, addition of SBH or DBP to the LPAA diet shifted nitrogen excretion from the urine to the feces. These results suggest that reducing crude protein by four percentage units with supplemented amino acids can dramatically decrease total nitrogen excretion, primarily by reducing urinary nitrogen. The addition of fiber to a low crude protein, amino acid supplemented diet will not effect total nitrogen excretion, however will shift nitrogen excretion from the urine to the feces.

INTRODUCTION

Nitrogen excretion is currently a major pollution concern in the swine industry. Excess nitrogen in the diet of finishing pigs is excreted primarily as urinary nitrogen. It has been reported that reducing dietary protein by four percentages units with addition of lysine, methionine, threonine, and tryptophan results in a marked reduction in urinary nitrogen excretion from growing-finishing pigs (Carter et al., 1996). Urinary nitrogen is composed primarily of urea nitrogen, which is associated with ammonia emission from the slurry. Feeding soybean hulls or beet pulp to finishing pigs reduces slurry pH and ammonia emissions (Canh et al., 1998). Furthermore, including fermentable carbohydrates, such as soybean hulls or beet pulp (Van Soest, 1967), in the diet will shift nitrogen excretion from the urine to the feces (Morgan and Whittemore, 1988). Therefore, an experiment was conducted to evaluate the effects of fiber addition to low crude protein, amino acid supplemented diets on nitrogen balance of growing-finishing pigs.

MATERIALS AND METHODS

Animals and Housing

Six sets of four littermate barrows (PIC, Hennesey, OK) with an initial body weight of 36.3 kg were used in a randomized complete block design to evaluate the effects of dietary fiber in low protein amino acid supplemented diets on nitrogen excretion. Pigs were housed individually in an evironmentally controlled room in metabolism chambers. Metabolism chambers allowed the separate, but total collection of urine, feces, and refused feed. Chamber sizes were .76 x .91 m (width x length), and each chamber contained a stainless steel feeder, a nipple waterer, galvanized grated flooring, a feces and urine separation screen, and a urine collection pan. The room temperature was maintained at 24° Celsius to achieve optimal animal performance. The 14-d sampling period consisted of a 9-d adaptation period to allow pigs to become accustomed to the chambers and to their dietary treatments, followed by a 5-d collection period. During the collection period urine, feces, and refused feed were collected daily.

Dietary Treatments and Feeding

Pigs within litter were randomly allotted to one of four dietary treatments. Dietary treatments were: (1) fortified corn-soybean meal based diet serving as the control, (2) as Diet 1 with crude protein lowered by four percentage units with the addition of L-lysine HCL, DL-methionine, L-threonine, L-tryptophan, and L-isoleucine (LPAA), (3) as Diet 2 plus L-valine and 10% soybean hulls (SBH, 11.4% CP), and (4) as Diet 2 plus L-valine and 10% dried beet pulp (DBP, 8.6% CP) (Table 5). Soybean hulls or beet pulp were added to Diets 3 and 4 at the expense of corn and soybean meal. The control diet contained 15% crude protein respectively, in Diets 2-4 crude protein was reduced by four percentage units. Crystalline amino acids were added to Diets 2-4 to achieve an ideal ratio to digestible lysine (Chung and Baker, 1991). Pigs had ad libitum access to feed and water, and pigs and feeders were weighed on d 0 and 5 of the collection period to monitor ADG, ADFI, and G:F.

Collection Procedures

Chromic oxide was utilized as a marker for the beginning and end of the collection period. On d 0 and d 5 of the collection period chromic oxide was included at .15% of the diet to alter the fecal color so that an exact beginning and endpoint of the collection period could be established for each pig. Fecal and urine collection began when feces first exhibited signs of altered color, and stopped when feces turned back to a normal appearance. During the urine collection process 15 mL of concentrated hydrochloric acid was added to the urine collection pans to prohibit nitrogen volatilization. Prior to the beginning of the collection period on d 0, all excess feed, feces, and urine were removed from the chambers. Fecal output, urine volume, and refused feed were collected and recorded daily, with feces and urine being stored in a cooler maintained at – 4^{o} Celsius.

Table 5. Diet composition (as fed basis) – Experiment 1.

	Diet[a]			
Ingredients, %	Control	LPAA	SBH	DBP
Corn, dent grain	70.66	69.42	70.92	70.53
SBM, dehulled	25.54	14.40	14.42	14.41
Soybean hulls	--	--	10.00	--
Beet pulp	--	--	--	10.00
Corn starch	--	10.00	--	--
Casein, dried	--	1.54		.53
Soybean oil	1.00	1.00	1.00	1.00
Dicalcium phosphate	1.23	1.58	1.55	1.57
Limestone	.87	.75	.66	.59
Salt	.25	.25	.25	.25
Vit/TM premix	.25	.25	.25	.25
Antibiotic	.20	.20	.20	.20
L-lysine HCl	--	.29	.35	.32
L-threonine	--	.15	.17	.16
DL-methionine	--	.12	.12	.11
L-tryptophan	--	.04	.05	.04
L-isoleucine	--	.02	.04	.03
L-valine	--	--	.04	.02
Calculated Analysis				
Crude Protein, %	18.00	14.00	14.00	14.00
Lysine, %	.96	.96	.96	.96
Digestible AA, %				
Lysine	.78	.82	.80	.78
Threonine	.51	.55	.54	.53
Methionine + Cystine	.51	.54	.52	.50
Tryptophan	.16	.16	.16	.15

[a]Control = fortified corn-soybean meal diet; LPAA = low protein, amino acid supplemented diet; SBH = LPAA + 10% soybean hulls; DBP = LPAA + 10% dried beet pulp.

At the end of the collection period the feces was removed from the collection bag labeled with the appropriate pen number and date and placed in a large container for a sub-sample to be taken. Feces from each day of the collection period was thoroughly mixed together for a for a representative sub-sample. The sub-sample was then ground and placed in another bag labeled with the appropriate pen number to later be analyzed.

Urine samples were handled in a similar manner, first being thawed and then pored into a container to be stirred thoroughly for an accurate sub-sample. Three representative sub-samples of feces and urine were taken for each pen, with the average of the three being reported. Feed, feces, and urine were analyzed for nitrogen content by Kjeldahl methodology after the end of the collection period.

RESULTS

Pigs receiving the low protein, amino acid supplemented diet tended to have lower dry matter excretion than pigs fed the control diet (Table 6). Dry matter excretion tended to be higher with the addition of fiber to the low protein diet; however this effect was more pronounced for pigs fed the SBH diet than pigs fed the diet containing dried beet pulp. Lowering crude protein and adding crystalline amino acids reduced nitrogen intake ($P<.01$) by 25% as compared to pigs fed the control diet.

Furthermore, nitrogen excretion was reduced ($P<.01$) by 49% in pigs fed the LPAA diet (Table 6). These responses were not affected ($P>.10$) by the addition of fiber source to the low crude protein, amino acid supplemented diet. Even though the control pigs absorbed more nitrogen ($P<.01$), the amount of nitrogen retained was not affected ($P>.10$) by diet.

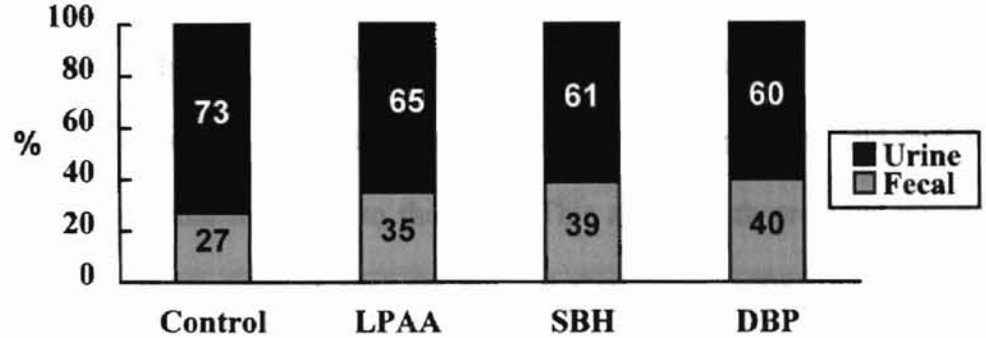
Table 6. Effects of reducing crude protein with amino acid supplementation and fiber addition on nitrogen balance – Experiment 1[a].

Item	Diet[b]				SE
	Control	LPAA	SBH	DBP	
DM excretion, g/d	7.8	6.2	9.6	7.8	1.0
Apparent N balance, g/d					
N intake[c]	58.4	43.8	46.3	45.6	1.5
Fecal N excretion	6.1	4.4	5.6	5.4	.85
Urinary N excretion[c]	16.9	9.5	8.7	8.1	1.2
Total N excretion[c]	23.1	13.9	14.3	13.5	1.4
Absorbed N[c]	52.2	39.1	40.8	41.0	1.8
Retained N[c]	35.3	31.1	32.2	32.9	1.9
Apparent N balance, %					
Absorption, % of int.	89.4	89.9	88.1	88.4	.83
Retention, % of int.[c]	60.5	71.2	69.3	70.7	.02
Retention, % of abs.[c]	67.7	79.1	78.5	79.8	.01

[a]Least squares means for six individually-penned pigs per treatment.
[b]Control = fortified corn-soybean meal diet; LPAA = low protein, amino acid supplemented diet; SBH = LPAA + 10% soybean hulls; DBP = LPAA + 10% dried beet pulp.
[c]LPAA vs Control, $P<.10$.

Addition of SBH or DBP to the LPAA diet resulted in a shift in nitrogen excretion from the urine to the feces. Pigs fed the control diet excreted 73% of total nitrogen as urinary nitrogen, while pigs fed the LPAA, SBH, and DBP excreted 65%, 61%, and 60% as urinary nitrogen (Figure 1). Urinary urea nitrogen was reduced ($P<.01$) in pigs fed the LPAA diet, and a further reduction ($P<.10$) was observed when fiber was added to the LPAA diet. Urinary urea nitrogen is a substrate for the enzyme urease found in the feces, which is associated with ammonia emissions from the slurry. Therefore by reducing urinary urea nitrogen less substrate is present in the slurry for ammonia production (Cahn et al., 1998).

Figure 1. Proportion of total nitrogen excretion attributed to the urine and feces - Experiment 1.



DISCUSSION

Reducing crude protein by four percentage units with the addition of crystalline amino acids has been shown to reduce nitrogen excretion in finishing pigs (Aarnink et al., 1993; Kerr, 1995; Hobbs et al., 1996 Sutton et al., 1999). In this experiment, pigs fed the low crude protein, amino acids supplemented diet had a marked reduction in nitrogen excretion as compared to pigs fed the control diet. Agreeing with Carter et al. (1996), the reduction of excreted nitrogen excreted could primarily be attributed to a dramatic reduction in urinary nitrogen. In fact, urinary nitrogen was reduced by 49% in pig fed the LPAA diet as compared to the control pigs. The addition of fiber sources to the LPAA diet had little affect on nitrogen balance.

The addition of fermentable carbohydrates such as soybean hulls and dried beet pulp to diets fed to growing-finishing swine has been shown to affect the partitioning of nitrogen excretion between the urine and the feces (Mroz et al., 1993; Bakket, 1996). Furthermore, fermentable carbohydrates have been reported to decrease urinary urea nitrogen excretion (Schulze et al., 1995; Canh et al., 1997). Although, Potkins et al.

(1984) reported that pigs fed fiber from oatfeed showed no changes in nitrogen excretion patterns.

In this study pigs fed Diets 3 and 4, the low crude protein, amino acid supplemented diets with 10% soybean hulls or dried beet pulp added, did tend to shift nitrogen excretion from the urine to the feces. This agrees with previous reports from Cummings et al. (1976), Morgan et al. (1984), and Canh et al. (1998). Furthermore, pigs the diets containing dried beet pulp excreted less urinary urea nitrogen than pigs fed the control or LPAA diets. This was less pronounced for pigs fed the soybean hull diet. These results agree with Canh et al. (1998a), Canh et al. (1998b), and Sutton et al. (1999).

Even though pigs fed the control diet absorbed more nitrogen, retained nitrogen was not affected by dietary treatment. This is conflicting with reports from Molmlof and Hakansson (1984) and Bergner (1982) who reported that pigs fed fermentable carbohydrates retain more nitrogen for growth of microorganisms in the hind gut. However, Molmlof and Hakansson (1984), Bergner (1982), and Cummings et al. (1976) also reported that nitrogen retained in the hind gut leads to an increase in fecal nitrogen output. In this experiment pigs fed the diets containing 10% soybean hulls or dried beet pulp did excrete a higher proportion of nitrogen in the feces than in the urine.

IMPLICATIONS

Reducing crude protein by four percentage units with supplemental amino acids can reduce nitrogen excretion in growing-finishing pigs by 49%. This marked reduction in nitrogen excretion is primarily due to the decrease in urinary nitrogen. Furthermore, these results suggest that including a fiber source such as soybean hulls in the low protein, amino acid supplemented diet will shift nitrogen excretion from the urine to the feces. Also, fiber addition to the LPAA diet reduced urinary urea nitrogen. Urinary urea nitrogen is a substrate for the enzyme urease found in the feces, which is associated with ammonia emissions from the slurry. Therefore, by reducing urinary urea nitrogen less substrate is present in the slurry for ammonia production.

CHAPTER IV

Experiment 2

Effects of Adding Fiber Sources to Low Crude Protein, Amino Acid Supplemented Diets on Growth Performance and Carcass Characteristics of Finishing Pigs.

ABSTRACT

An experiment was conducted to evaluate the effects of adding fiber sources to low crude protein, amino acid supplemented diets on growth performance and carcass characteristics of finishing pigs. The experiment consisted of seventy-two pigs with an initial body weight of 35 kg that were blocked by weight, sex, and litter, and allotted randomly to one of three dietary treatments. There were six pen replicates per treatment of four pigs per pen. Dietary treatments were: (1) fortified corn-soybean meal control, (2) as 1 with crude protein lowered by 4 percentage units and supplemented with lysine, threonine, methionine, tryptophan, isoleucine, and valine (LPAA), and (3) as 2 plus 10% soybean hulls (SBH). Pigs were fed diets in three dietary phases. Phase 1 diets (35 – 50 kg) were formulated to .95% lysine, Phase 2 (51 – 82 kg) diets contained .80% lysine, and Phase 3 (83 – 113 kg) diets contained .65% total lysine. Dietary crude protein of the control diet was 18, 16, and 14% for the three phases, respectively. Dietary crude protein of Diets 2-4 was reduced by four percentage units in each phase. All other nutrients met or exceeded NRC (1998) standards. Pigs were allowed ad libitum access to feed and

water throughout the test period, with pigs and feeders being weighed in two-week intervals for the determination of ADG, ADFI, and G:F. Pigs were bled by jugular venipuncture at the end of each dietary phase. Blood was centrifuged and plasma harvested for plasma urea nitrogen analyses. When pigs reached approximately 113 kg they were transported to a commercial packing plant and were humanely killed to determine carcass measurements. Standard carcass measures including backfat and longissimus muscle area at the 10^{th} rib were collected. Growth performance, lean gain, and most carcass characteristics were not affected by dietary treatment. However, pigs fed the LPAA diet had slightly smaller longissumus muscle area and an increase in average backfat and 10^{th} rib fat depth. The addition of soybean hulls to the LPAA reduced backfat and 10^{th} rib fat depth to that of the control pigs. These data suggest that reducing crude protein by four percentage units with supplemented amino acids, with or without the addition of fiber, will not affect growth performance. However, carcass performance were reduced in pigs fed a LPAA diet. Although, the addition of SBH to a LPAA diet gives similar carcass characteristics to that of pigs fed a standard finishing diet.

INTRODUCTION

It is well known that the crude protein concentration of diets for growing-finishing swine can be reduced by two percentage units with the addition of crystalline lysine without sacrificing growth performance. Reducing dietary protein by more than two percentage units requires the addition of crystalline lysine, methionine, threonine, and tryptophan in corn-soybean meal diets. Reduction of dietary protein by four percentage units with the addition of crystalline amino acids results in a significant decrease in nitrogen excretion from growing-finishing pigs as shown in Experiment 1. However, reducing crude protein by four percentage units may decrease daily gain and increase backfat in finishing pigs (Tuitoek, et al., 1997). The increase in backfat may be explained by a decrease in the energy required to metabolize excess amino acids thereby increasing the energy available for fat deposition. Therefore, an experiment was conducted to evaluate the effects of reducing net energy by fiber addition in low crude protein amino acid supplemented diets on growth performance and carcass traits of finishing pigs.

MATERIALS AND METHODS

Animals and Housing

Seventy-two crossbred pigs with an initial body weight of 35 kg were used in a randomized block design to evaluate the effects of the addition of dietary fiber to low crude protein, amino acid supplemented diets. There were six pen replicates per treatment and four pigs per pen. Pigs were housed in a well ventilated enclosed finishing barn with concrete slatted floors. Pen sizes were 2.0 x 2.5 meters and contained two nipple wateres and a two-hole Smidley feeder.

Dietary Treatments and Feeding

Pigs were allotted randomly by body weight, sex, and litter to one of three dietary treatments. Dietary treatments were: (1) fortified corn-soybean meal based diet serving as the control, (2) as Diet 1 with crude protein lowered by four percentage units with the addition of L-lysine HCL, DL-methionine, L-threonine, L-tryptophan, L-isoleucine, and L-valine (LPAA), and (3) as Diet 2 plus 10% soybean hulls. Soybean hulls used in Diet 3 contained 11.4% crude protein, and were added at the expense of corn and soybean meal (Table 7). Crystalline amino acids were added to Diets 2 and 3 to achieve an ideal ratio to digestible lysine (Chung and Baker, 1991).

Table 7. Composition of Phase 1 (35 – 50 kg) diets (as fed basis)[a] – Experiment 2.

		Diet[b]	
Ingredient, %	Control	LPAA	SBH
Corn, dent grain	68.59	77.62	68.74
SBM, dehulled	25.60	15.62	14.56
Soybean hulls	--	--	10.00
Corn Starch	--	.05	.05
L-lysine HCl	--	.35	.34
L-threonine	--	.16	.17
DL-methionine	--	.11	.12
L-tryptophan	--	.04	.04
L-isoleucine	--	.03	.04
L-valine	--	.02	.03
Dicalcium phosphate	1.25	1.48	1.56
Limestone	.86	.81	.65
Soybean oil	3.00	3.00	3.00
Salt	.25	.25	.25
TM & Vitamin premix	.25	.25	.25
Tylan 40	.20	.20	.20
Calculated Analysis			
Crude Protein, %	18.0	14.0	14.0
Lysine, %	.95	.95	.95
Digestible AA, %			
Lysine	.77	.81	.80
Threonine	.51	.54	.53
Methionine + Cystine	.50	.52	.51
Tryptophan	.16	.15	.15
Isoleucine	.61	.48	.48
Valine	.68	.55	.54

[a]Phase 2 & 3 diets were formulated to .80% lysine, .65% Ca, and .55% P for 51 to 82 kg; and .65% lysine, .60% Ca, and .50% P for 83 to 113 kg.
[b]Control = fortified corn-soybean meal diet; LPAA = low protein, amino acid supplemented diet; SBH = LPAA + 10% soybean hulls; DBP = LPAA + 10% dried beet pulp.

Pigs were fed in three dietary phases. Phase 1 diets (35-50 kg) were formulated to .95% lysine, Phase 2 diets (51-82 kg) contained .80% lysine, and Phase 3 diets (83-113 kg) were formulated to contain .65% total lysine. Dietary crude protein for the control diet was 17, 15, and 13% for the three phases, respectively. Dietary crude protein for Diets 2 and 3 was reduced by four percentage units in each phase. All other nutrients met or exceeded NRC (1998) requirements. Pigs had ad libitum access to feed and water, and pigs and feeders were weighed in two week intervals to monitor ADG, ADFI, and G:F.

Measurements

Pigs were bled by jugular venipuncture at the end of each dietary phase. Blood was centrifuged and plasma harvested for plasma urea nitrogen analysis. Plasma urea nitrogen was determined by colorimetric procedures. When pigs reached approximately 113 kg, they were transported to a commercial packing plant and were humanely killed by electrocution followed by exsanguination. Following scalding, scraping, and eviceration, the carcass were weighed and chilled for 24 hours. Standard carcass measures including backfat and longissimus muscle area at the 10^{th} rib were collected. Dressing percent was calculated by dividing hot carcass weight by live weight. Carcass lean percentage (containing 5% fat) was calculated using hot carcass weight, 10^{th} rib backfat and longissimus muscle area (NPPC, 1991).

Data were analyzed as a randomized complete block design using analysis of variance procedures as described by Steele and Torrie (1997). Pen served as the experimental unit. Non-orthoganal contrasts were used to compare treatment means.

RESULTS

The effect of dietary treatment on pig performance is shown in Table 8. Pigs fed the low crude protein, amino acid supplemented diet showed a slight reduction in performance during Phase 2. However, overall performance of gain and efficiency of gain was similar to that of the pigs fed the control diet. The addition of 10% soybean hulls to the low crude protein, amino acid supplemented diet had no effect (P>.10) on pig performance.

Table 8. Growth performance and carcass characteristics[a] – Experiment 2.

	Diet[b]			
Item	Control	LPAA	SBH	SE
Performance				
ADG, kg	.82	.78	.77	.79
ADFI, kg	2.24	2.12	2.25	.06
G:F	.37	.36	.34	.01
Plasma Urea N, mg/dl				
Phase I[d]	10.14	4.76	4.35	.53
Phase II[d]	8.51	4.40	4.07	.63
Phase III[d]	8.23	4.38	3.51	.82
Carcass traits[c]				
Dressing %	75.3	75.5	74.1	.29
Avg. backfat, cm [d,e]	2.98	3.29	2.87	.08
10^{th} rib BF, cm	2.24	2.27	2.03	.11
LMA, cm^2	44.07	41.95	41.46	1.24
Fat-free lean, %	50.30	49.55	50.13	.01
Fat-free lean, g/d	340.8	335.7	330.8	8.21

[a] Least squares means for 6 pens/trt of 4 pigs/pen.
[b]Control = fortified corn-soybean meal diet; LPAA = low protein, amino acid supplemented diet; SBH = LPAA + 10% soybean hulls.
[c]Hot carcass weight used as covariate for carcass traits.
[d]LPAA vs Control, P<.10.
[e]SBH vs LPAA, P<.10.

No effects of dietary treatment on carcass characteristics were observed, with the exception of average backfat. Pigs fed the low crude protein, amino acid supplemented diet had increased (P<.01) backfat as compared to pigs fed the control diet. However, the addition of soybean hulls to the low protein, amino acid supplemented diet tended to reduce average backfat (P<.10) and 10^{th} rib fat depth. Longissimus muscle area and fat-free lean gain were not affected by treatment, although pigs fed the low crude protein, amino acid supplemented diet tended to have slightly smaller longissimus muscle area (Table 8).

As expected, plasma urea nitrogen concentrations were reduced (P<.01) markedly by lowering crude protein and adding amino acids. Addition of soybean hulls to the low crude protein, amino acid supplemented diet only had small effects on PUN.

DISCUSSION

Pigs fed diets with crude protein reduced by two percentage units with the addition of crystalline lysine have been shown to perform similar to pigs fed a standard corn-soybean meal diet during the grow-finishing phase (Wahlstrom and Libal, 1974; Baker et al., 1975). However, reducing crude protein by more than two percentage units with only supplementing lysine can be detrimental to growth and carcass performance in finishing pigs (Cromwell, et al., 1983). The limiting amino acids in swine diets with crude protein reduced by four percentage units are believed to be lysine, tryptophan, and methionine (Sharda et al., 1971). Although, it has been observed that pigs fed diets with crude protein reduced by four percentage units, supplemented with crystalline lysine, threonine, tryptophan, and methionine still exhibit a reduction in growth performance as compared to pigs fed a fortified corn-soybean meal diet (Wahlstrom and Libal, 1974; Maxwell et al., 1985).

Furthermore, pigs fed LPAA diets tend to be fatter and have a smaller longissimus muscle area than pigs fed a standard finishing diet (Easter and Baker, 1980; Stahly et al., 1980; Tuitoek et al., 1997). However, Shriver et al. (1999) noted that pigs fed a reduced crude protein, amino acid supplemented diet with 20% wheat middlings tended to be leaner in regards to backfat. Although, longissimus muscle area was smaller in pigs fed the LPAA diet with 20% wheat middlings as compared to the control pigs.

In this experiment, pigs fed the diet with crude protein reduced by four percentage units and supplemented with crystalline amino acids displayed gains and efficiency of gains similar to the control pigs. This response agrees with Russell and Easter (1985), Maxwell et al. (1987), and Myer et al. (1996) who supplemented crystalline lysine, threonine, tryptophan, and methionine in the diet. Isoleucine and valine were also included in the diets of this experiment. The addition of fiber to the diet did not affect growth performance.

However, pigs fed the LPAA diet did have increased backfat; although, the addition of soybean hulls to the LPAA diet tended to decrease average backfat and 10th rib fat depth. This reduction is thought to be due to the reduction in net energy in the diet more than the presence of the fiber itself. By including a fiber source in the diet at the expense of corn and soybean meal there was less energy to be deposited as fat in pigs fed the LPAA diet with soybean hulls included.

Longissimus muscle area and fat-free lean gain were not affected by treatment. However, pigs fed the LPAA diet tended to have slightly smaller LMA. These results are consistent with other recent reports (Freisen et al., 1999; Lui et al., 1999). The reduction in plasma urea nitrogen in pigs fed the low crude protein, amino acid supplemented diet is indicative of a reduction in excess amino acids in these diets, agreeing with the reduction in urinary urea nitrogen in Experiment 1.

IMPLICATIONS

Feeding diets with crude protein reduced by four percentage units and supplemented with crystalline amino acids tends to reduce carcass characteristics in finishing pigs, while not affecting overall growth performance. Pigs fed low protein, amino acid supplemented diets tend to be fatter than pigs fed a fortified corn-soybean meal diet. However, the addition of a low cost fiber source such as soybean hulls to the low protein, amino acid supplemented diet improves carcass characteristics, while not affecting growth performance. The addition of fiber to the LPAA diet reduces the net energy content of the diet, leaving less energy to be deposited as fat. Therefore, pigs fed LPAA diets with the addition soybean hulls to the diet display backfat and 10^{th} rib fat depth thickness similar to that of pigs fed standard corn-soybean meal diets.

CHAPTER V

SUMMARY

Protein is by far the most expensive dietary ingredient in swine diets. Also, high protein levels supply excess amino acids to be excreted as waste through the urine and feces. This leads to an increase of urinary urea nitrogen to combine with the enzyme urease in the feces, thereby increasing ammonia emission from the slurry.

By reducing crude protein concentration of the diet of growing-finishing pigs with crystalline amino acid supplementation, urinary nitrogen can be markedly reduced. However, it has been shown that pigs fed low crude protein, amino acid diets tend to be fatter than pigs fed standard fortified corn-soybean meal diets. The reason for increased backfat and 10^{th} rib fat thickness in pigs fed low protein, amino acid supplemented diets is unknown; however, the increase in net energy concentration of these diets due to increased cereal grain concentrations could be one explanation.

Including fiber sources to the low crude protein, amino acid supplemented diet decreases the net energy concentration of the diet, resulting in less energy to be deposited as fat. In fact, pigs fed the low protein amino acid supplemented diet with the addition of 10% soybean hulls displayed similar backfat and 10^{th} rib fat depth as pigs fed the control diet. Furthermore, the addition of fiber to the low protein amino acid supplemented diet resulted in a shift in nitrogen excretion from the urine to the feces, reducing urinary urea nitrogen. This reduction in urinary urea nitrogen reduces the substrate for the enzyme urease in the feces, therefore reducing ammonia emission from the slurry.

The addition of a low cost feedstuff such as soybean hulls to a low protein, amino acid supplemented diet did not affect average daily gain or efficiency of gain of growing-finishing pigs.

CHAPTER VI

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APPENDIX TABLES

Appendix Table 9.

Pen Means for Average Daily Gain (ADG), Average Daily Feed (ADF), and Gain:Feed (G:F) – Experiment 1.

PEN	TRT	REP	ADG (g/d)	ADF (g/d)	G:F
1	3	1	1154.46	1792.89	.6439
2	1	1	1206.34	1912.81	.6307
3	4	1	1316.60	1997.50	.6591
4	2	1	1589.00	2197.10	.7232
5	1	1	1135.00	2034.77	.5578
6	2	1	895.03	2003.06	.4468
7	3	2	1186.89	1996.20	.5946
8	4	2	1199.86	1969.44	.6092
9	4	2	966.37	1951.66	.4952
10	3	2	985.83	1991.54	.4950
11	1	2	784.77	1778.69	.4412
12	2	2	968.53	1953.98	.4957
13	4	3	940.43	1563.09	.6017
14	2	3	1504.69	1997.71	.7532
15	3	3	933.94	1863.06	.5013
16	1	3	985.83	2039.63	.4833
17	2	3	895.03	1806.49	.4955
18	3	3	933.94	1787.57	.5225
19	1	4	940.43	2027.07	.4639
20	4	4	1122.03	1938.84	.5787
21	1	4	1011.77	1994.93	.5072
22	3	4	1013.93	1869.85	.5423
23	4	4	976.10	2110.56	.4625
24	2	4	836.66	1663.99	.5028

TRT 1: Fortified corn-soybean meal diet.

TRT 2: Low protein, amino acid supplemented diet.

TRT 3: Low protein, amino acid supplemented diet, with 10% soybean hulls included.

TRT 4: Low protein, amino acid supplemented diet, with 10% dried beet pulp included.

Appendix Table 10.

Analysis of Variance for Average Daily Gain (ADG), Average Daily Feed (ADF), and Gain:Feed (G:F) – Experiment 1.

		Mean Squares		
Source	df	ADG	ADF	G:F
Total	23			
Rep	5	83422.826	10586.128	.01783
Trt	3	13561.846	6871.210	.00398
Cont vs LPAA	1	32531.253	2284.452	.00924
LPAA vs Fiber	1	11646.007	4725.646	.00058
SBH vs DBP	1	8132.813	4407.567	.00095
Trt x Rep	15	29406.022	25541.539	.00451
CV, %		16.15	8.29	12.21

Appendix Table 11.

Pen Means for Dry Matter Intake (DMI), Dry Matter Excretion (DMEX), Nitrogen Intake (NINT), Urinary Nitrogen Excretion (UNEX), Fecal Nitrogen Excretion (FNEX), and Total Nitrogen Excretion (TNEX) – Experiment 1.

PEN	TRT	REP	DMI (g/d)	DMEX (g/d)	NINT (g/d)	UNEX (g/d)	FNEX (g/d)	TNEX (g/d)
1	3	1	1595.67	122.59	44.10	8.88	4.94	13.83
2	1	1	1702.40	153.10	56.81	16.44	6.63	23.07
3	4	1	1777.78	123.55	47.34	6.61	5.26	11.87
4	2	1	1955.42	142.32	49.65	9.99	6.25	16.01
5	1	1	1810.95	146.06	60.43	23.36	6.39	29.74
6	2	1	1782.72	67.05	45.27	6.80	2.59	9.39
7	3	2	1776.62	155.82	49.11	10.47	6.72	17.19
8	4	2	1752.80	99.19	46.68	7.81	4.43	12.24
9	4	2	1736.97	132.61	46.25	7.76	4.57	12.33
10	3	2	1772.47	166.16	48.99	7.76	6.48	14.24
11	1	2	1583.03	115.53	52.83	12.78	7.18	19.96
12	2	2	---	---	---	---	---	---
13	4	3	---	---	---	---	---	---
14	2	3	1777.97	85.32	45.15	10.48	3.05	12.80
15	3	3	1658.12	79.29	45.83	8.27	2.79	11.06
16	1	3	1815.27	152.26	60.58	13.19	6.03	19.22
17	2	3	1607.78	138.17	40.83	7.91	5.25	11.36
18	3	3	1590.94	---	43.97	7.38	2.64	10.01
19	1	4	1804.09	111.32	60.20	19.16	4.06	23.22
20	4	4	1725.57	172.40	45.95	10.34	7.10	17.44
21	1	4	1775.49	147.41	59.25	16.59	6.59	23.18
22	3	4	1664.17	268.61	46.00	9.51	9.88	19.39
23	4	4	---	---	---	---	---	---
24	2	4	1480.95	106.00	37.61	9.53	4.41	13.92

TRT 1: Fortified corn-soybean meal diet.
TRT 2: Low protein, amino acid supplemented diet.
TRT 3: Low protein, amino acid supplemented diet, with 10% soybean hulls included.
TRT 4: Low protein, amino acid supplemented diet, with 10% dried beet pulp included.

Pens 12, 13, and 23 were removed from analysis due to poor collection samples.
Missing value for dry matter excretion, pen 18.

Appendix Table 12.

Analysis of Variance for Dry Matter Intake (DMI), Dry Matter Excretion (DMEX), Nitrogen Intake (NINT), Urinary Nitrogen Excretion (UNEX), Fecal Nitrogen Excretion (FNEX), and Total Nitrogen Excretion (TNEX) – Experiment 1.

		Mean Squares						
Source	df	DMEX	df	DMI	NINT	UNEX	FNEX	TNEX
Total	19		20					
Rep	5	1821.50	5	9545.84	6.79	4.50	3.30	8.75
Trt	3	2360.97	3	5871.75	245.86	100.75	2.79	133.96
Cont vs LPAA	1	2556.87	1	2764.31	582.84	183.93	8.20	300.14
LPAA vs Fiber	1	5009.57	1	217.88	24.77	.11	3.62	6.54
SBH vs DBP	1	1454.99	1	8839.56	.01	.96	.08	1.48
Trt x Rep	11	1773.68	12	13459.7	10.37	6.57	3.37	11.25
CV, %		31.37		6.74	6.55	23.30	34.08	20.63

Appendix Table 13.

Pen Means for Nitrogen Absorbed (NABS), Nitrogen Retained (NRET), Nitrogen absorbed as a Percent of Intake (NABSint), Nitrogen Retention as a Percent of Intake (NRETint), and Nitrogen Retention as a Percent of Absorption (NRETabs) – Experiment 1.

PEN	TRT	REP	NABS (g/d)	NRET (g/d)	NABSint (%)	NRETint (%)	NRETabs (%)
1	3	1	39.16	30.28	88.79	68.65	77.32
2	1	1	50.18	33.74	88.32	59.39	67.24
3	4	1	42.08	35.47	88.88	74.92	84.30
4	2	1	43.40	33.64	87.41	67.75	77.51
5	1	1	54.05	30.69	89.43	50.78	56.78
6	2	1	42.68	65.88	94.27	79.25	84.07
7	3	2	42.39	31.91	86.32	64.99	75.29
8	4	2	42.25	34.44	90.52	73.78	81.51
9	4	2	41.68	33.92	90.11	73.34	81.39
10	3	2	42.52	34.75	86.78	70.93	81.74
11	1	2	45.65	32.87	86.41	62.22	72.00
12	2	2	---	---	---	---	---
13	4	3	---	---	---	---	---
14	2	3	42.10	32.34	93.25	71.64	76.82
15	3	3	43.05	34.77	93.92	75.87	80.78
16	1	3	54.54	41.35	90.04	68.27	75.82
17	2	3	35.58	29.47	87.15	72.18	82.82
18	3	3	41.34	33.96	94.00	77.23	82.16
19	1	4	56.15	36.98	93.62	61.43	65.87
20	4	4	38.85	28.51	84.54	62.05	73.39
21	1	4	52.66	36.07	88.88	60.87	68.49
22	3	4	36.12	26.61	78.52	57.85	73.68
23	4	4	---	---	---	---	---
24	2	4	33.20	23.69	88.28	62.98	71.35

TRT 1: Fortified corn-soybean meal diet.

TRT 2: Low protein, amino acid supplemented diet.

TRT 3: Low protein, amino acid supplemented diet, with 10% soybean hulls included.

TRT 4: Low protein, amino acid supplemented diet, with 10% dried beet pulp included.

Pens 12, 13, and 23 were removed from analysis due to poor collection samples.

Appendix Table 14.

Analysis of Variance for Nitrogen Absorbed (NABS), Nitrogen Retained (NRET), Nitrogen absorbed as a Percent of Intake (NABSint), Nitrogen Retention as a Percent of Intake (NRETint), and Nitrogen Retention as a Percent of absorption (NRETabs) – Experiment 1.

		Mean Squares				
Source	df	NABS	NRET	NABSint	NRETint	NRETabs
Total	20					
Rep	5	15.3315	17.0599	17.8905	42.0498	21.6578
Trt	3	204.7334	17.9758	3.7920	138.3814	183.7534
Cont vs LPAA	1	452.8311	46.4808	.7008	301.0905	344.7845
LPAA vs Fiber	1	9.4568	5.8616	8.708	4.4196	.0067
SBH vs DBP	1	.1328	1.7014	.2110	4.4426	4.0586
Trt x Rep	12	10.43	12.7415	14.2603	38.4766	27.8754
CV, %		7.38	10.84	4.24	9.20	6.97

Appendix Table 15.

Pen Means for Urea Nitrogen (UREAN), and Nitrogen as Ammonia (NAMM) – Experiment 1.

PEN	TRT	REP	UREAN (g/d)	NAMM (g/d)
1	3	1	7.03	1.58
2	1	1	15.05	.52
3	4	1	4.54	2.04
4	2	1	9.90	---
5	1	1	24.69	.44
6	2	1	---	1.24
7	3	2	8.75	1.72
8	4	2	8.33	---
9	4	2	4.93	1.19
10	3	2	5.41	1.18
11	1	2	9.26	.22
12	2	2	2.87	1.04
13	4	3	4.36	1.43
14	2	3	9.24	1.92
15	3	3	8.07	.96
16	1	3	14.00	.32
17	2	3	7.20	1.62
18	3	3	6.21	1.47
19	1	4	19.09	.46
20	4	4	7.47	20.7
21	1	4	13.02	---
22	3	4	7.12	1.51
23	4	4	3.84	1.04
24	2	4	8.45	.89

TRT 1: Fortified corn-soybean meal diet.
TRT 2: Low protein, amino acid supplemented diet.
TRT 3: Low protein, amino acid supplemented diet, with 10% soybean hulls included.
TRT 4: Low protein, amino acid supplemented diet, with 10% dried beet pulp included.

Missing value for urea nitrogen, pen 6.
Missing values for nitrogen as ammonia, pens 4,8, and 21.

Appendix Table 16.

Analysis of Variance for Urea Nitrogen (UREAN), and Nitrogen as Ammonia (NAMM) – Experiment 1.

		Mean Squares		
Source	df	UREAN	df	NAMM
Total	22		20	
Rep	5	22.9502	5	.2019
Trt	3	124.4796	3	1.5376
Cont vs LPAA	1	146.4017	1	2.661
LPAA vs Fiber	1	14.6432	1	.0262
SBH vs DBP	1	6.9312	1	.0752
Trt x Rep	14	6.0768	12	.0895
CV, %		27.15		25.27

Appendix Table 17.

Pen Means for Initial Weight, Final Weight, Average Daily Gain (ADG), Average Daily Feed (ADF), and Gain:Feed (G:F) – Experiment 2.

PEN	TRT	REP	Initial Wt (kg)	Final Wt (kg)	ADG (kg)	ADF (kg)	G:F
1	1	6	---	---	---	---	---
2	2	5	28.24	117.48	.652	1.98	.330
3	1	5	25.93	112.19	.816	2.21	.369
4	3	4	27.67	112.49	.822	2.31	.355
5	2	4	26.31	121.56	.665	2.01	.331
6	1	3	28.20	112.95	.790	2.22	.356
7	2	3	28.73	114.31	.831	2.49	.334
8	3	2	30.69	113.56	.812	2.24	.362
9	2	1	32.21	103.87	.798	2.11	.379
10	3	6	24.34	114.61	.814	2.17	.375
11	2	6	25.17	122.02	.835	2.30	.363
12	3	5	26.03	113.29	.730	2.31	.316
13	1	4	27.89	120.43	.746	2.25	.332
14	3	3	29.59	115.44	.719	2.63	.317
15	1	2	30.92	108.41	.816	2.16	.378
16	2	2	32.21	125.50	.898	2.26	.398
17	1	1	33.11	114.46	.876	2.34	.375
18	3	1	32.36	114.45	.728	2.19	.332

TRT 1: Fortified corn-soybean meal diet.

TRT 2: Low protein, amino acid supplemented diet.

TRT 3: Low protein, amino acid supplemented diet with 10% soybean hulls included.

Pen 1 was removed from analysis due to poor performance.

Appendix Table 18.

Analysis of Variance for Initial Weight, Final Weight, Average Daily Gain (ADG), Average Daily Feed (ADF), and Gain:Feed (G:F) – Experiment 2.

		Mean Squares				
Source	df	Initial Wt	Final Wt	ADG	ADFI	G:F
Total	16					
Rep	5	22.3905	19.9384	.0058	.0088	.0011
Trt	2	.2561	22.0048	.0033	.0061	.0007
Cont vs LPAA	1	.3586	27.5688	.0040	.0066	.0003
LPAA vs SBH	1	.3918	36.4227	.0002	.0109	.0005
Trt x Rep	9	.8336	31.0430	.0046	.0205	.0004
CV, %		3.17	4.84	8.68	6.43	5.40

Appendix Table 19.

Pen Means for Plasma Urea Nitrogen for Phase 1 (PUN 1), Phase 2 (PUN 2) and Phase 3 (PUN 3) – Experiment 2.

Pen	Trt	Rep	PUN 1 mg/dl	PUN 2 mg/dl	PUN 3 mg/dl
1	1	6	11.67	12.34	4.14
2	2	5	4.99	5.04	5.86
3	1	5	9.55	9.35	8.96
4	3	4	2.95	2.83	2.14
5	2	4	4.94	3.28	3.66
6	1	3	7.64	10.59	11.36
7	2	3	5.83	5.55	4.67
8	3	2	3.92	3.18	3.26
9	2	1	3.43	---	3.35
10	3	6	3.98	3.74	4.84
11	2	6	4.67	5.01	3.56
12	3	5	5.66	4.48	3.98
13	1	4	11.72	8.48	6.89
14	3	3	3.47	6.21	4.52
15	1	2	10.14	4.36	11.01
16	2	2	4.72	3.97	5.22
17	1	1	10.12	5.93	7.03
18	3	1	6.17	4.02	2.33

TRT 1: Fortified corn-soybean meal diet.
TRT 2: Low protein, amino acid supplemented diet.
TRT 3: Low protein, amino acid supplemented diet with 10% soybean hulls included.

Missing value for pen 9, phase 2.

Appendix Table 20.

Analysis of Variance for Plasma Urea Nitrogen for Phase 1 (PUN 1), Phase 2 (PUN 2) and Phase 3 (PUN 3) – Experiment 2.

		Mean Squares			
Source	df	PUN 1	PUN 3	df	PUN 2
Total	17			16	
Rep	5	.5303	4.9582	5	6.3312
Trt	2	62.5002	37.8281	2	36.0332
Cont vs LPAA	1	86.7256	43.3521	1	46.0576
LPAA vs SBH	1	.4921	2.2969	1	.1378
Trt x Rep	10	1.9877	2.4804	9	2.5014
CV, %		21.96	29.29		27.33

Appendix Table 21.

Pen Means for Hot Carcass Weight (HCW), Average Back Fat (AVGBF), 10th Rib Fat Depth (10th RF), Longissimus Muscle Area (LEA), Percentage Lean (% LN), and Carcass Fat Free Lean Gain (CFFLG) – Experiment 2.

Pen	Trt	Rep	HCW (kg)	AVGBF (cm)	10th RF (cm)	LEA (cm^2)	% LN (%)	CFFLG (g/d)
1	1	6	---	---	---	---	---	---
2	2	5	88.22	3.39	2.22	41.15	49.35	316.94
3	1	5	85.73	2.91	2.12	44.38	50.87	350.27
4	3	4	83.91	2.85	1.73	38.25	50.52	331.89
5	2	4	92.08	3.60	2.79	38.31	46.08	335.91
6	1	3	84.51	2.95	2.45	39.69	48.32	312.14
7	2	3	87.54	3.36	2.20	46.01	51.06	348.36
8	3	2	84.67	2.82	1.78	42.96	51.73	334.41
9	2	1	77.71	2.78	2.20	40.14	50.06	322.89
10	3	6	86.63	2.77	2.20	41.93	49.66	327.88
11	2	6	92.53	3.56	2.35	41.67	48.62	366.35
12	3	5	---	---	---	---	---	---
13	1	4	91.40	3.00	2.16	42.86	49.64	336.88
14	3	3	87.54	2.84	2.17	40.76	49.38	310.24
15	1	2	81.34	2.95	1.99	47.58	52.96	325.23
16	2	2	94.49	3.43	2.03	48.80	51.34	376.68
17	1	1	85.42	3.00	2.37	45.96	50.65	367.78
18	3	1	75.75	2.74	2.20	40.27	50.36	313.11

TRT 1: Fortified corn-soybean meal diet.

TRT 2: Low protein, amino acid supplemented diet.

TRT 3: Low protein, amino acid supplemented diet with 10% soybean hulls included.

Pens 1 and 12 were removed from analysis due to poor performance.

Appendix Table 22.

Analysis of Variance for Hot Carcass Weight (HCW), Average Back Fat (AVGBF), 10th Rib Fat Depth (10th RF), Longissimus Muscle Area (LEA), Percentage Lean (% LN), and Carcass Fat Free Lean Gain (CFFLG) – Experiment 2.

		Mean Squares					
Source	df	HCW	AVGBF	10th RF	LEA	% Ln	CFFLG
Total	15	---					
Rep	5	---	.0008	.0598	15.6446	.0003	358.468
HCW	1	---	.0930	.0227	11.6646	.0001	1725.671
Trt	2	---	.1787	.0602	8.8341	.0001	103.194
Cont vs LPAA	1	---	.2253	.0016	10.5768	.0001	60.651
LPAA vs SBH	1	---	.3062	.1010	.4326	.0001	42.143
Trt x Rep	7	---	.0264	.0586	6.4509	.0002	317.124
CV, %		---	5.31	11.08	5.97	2.85	5.30

VITA

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Master of Science

Thesis: EFFECTS OF ADDING FIBER SOURCES TO LOW CRUDE PROTEIN, AMINO ACID SUPPLEMENTED DIETS ON NITROGEN EXCRETION, GROWTH PERFORMANCE, AND CARCASS CHARACTERISTICS OF FINISHING PIGS

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