PROTEIN AND AMINO ACID REQUIREMENTS
OF THE 10 TO 20 KG PIG

By

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FORMAT OF THESIS

This Thesis is presented in the Journal of Animal Science style and format, as outlined by the Oklahoma State University graduate college style manual. The use of this format allows for the independent chapters to be suitable for submission to scientific journals. Two papers have been prepared from the data collected for research to partly fulfill the requirements for the M.S. degree. Each paper is complete in itself with an abstract, introduction, materials and methods, results and discussion, implications and literature cited section.

CHAPTER I

INTRODUCTION

The practice of early weaning has become common in modern swine production as it shortens the reproductive cycle of the sow herd and allows the placement of females back into production sooner. This should result in the production of more pigs per sow per year and help maximize profit.

Some of the major problems with early weaning include a reduction of feed intake, decreased gains or weight loss and often diarrhea which is collectively termed "postweaning lag" and generally lasts from five to ten days after weaning. This reduction in performance has been attributed to the drastic change in the diet as well as the environment. Another problem is meeting nutrient requirements in young pigs for maximum growth and feed utilization after the period of postweaning lag.

Not only is it critical to meet the requirements of the 10 to 20 kg pig to maximize growth performance, but it is becoming increasingly more important to do this in the most efficient means possible. The protein required to maximize performance in diets that receive all dietary lysine from natural protein sources may be higher than what the NRC (1988) suggests (Campbell and Biden, 1978; Aherne and Nielsen, 1983; Lin and Jensen, 1985b). But, in typical feed formulations that utilize natural feed ingredients, there is usually an excess of many dispensable and indispensable amino acids. These excess amino acids have been suggested to depress animal performance leading to inefficient and uneconomical pork production (Kerr, 1988). Also an oversupply of amino acids result in wastage since the animal cannot convert the extra amino acids into body proteins and adds to the concern of pollution to the environment through nitrogen excreted in pig waste. These problems led to the formulation of an ideal protein concept in swine diet formulation. An ideal protein is one that is perfectly balanced in terms of its amino acid content and its supply of non-essential nitrogen (Cole, 1980). This was first done by the British ARC in 1981. Since then there has been several attempts to modify the ARC (1981) ideal protein to more specifically meet the ratios of indispensable amino acids relative to lysine (Wang and Fuller, 1989; Chung and Baker, 1991; Chung and Baker, 1992a). The availability of more synthetic forms of indispensable amino acids allows rations to be formulated to specifically meet amino acid requirements. In addition, this is a means to reduce nitrogen excretion by reducing the total crude protein in the diet and meeting amino acid requirements with synthetic amino acids.

The objective of this study was first to determine the protein requirement for maximum gain, feed intake, and efficiency of gain during phase 2 (10-20 kg) of the nursery period in pigs fed corn-soybean meal-dried whey based diets. Four different levels of lysine from dietary protein sources were used to determine the response to dietary lysine level for gain, feed intake, and efficiency of gain variables. Secondly, the effect of diet formulation based upon ideal protein calculated requirements on performance during phase 2 of the nursery period was determined.

CHAPTER II

LITERATURE REVIEW

Numerous experiments have been conducted determining the methionine, lysine and other indispensable amino acid requirements for young pigs. Generally, average daily gain (ADG) is reduced and efficiency of gain is poorer in pigs fed diets that are deficient in indispensable amino acids. Table 2.1. is a summary of studies that estimate the lysine requirement of young pigs. Tables 2.2., 2.3. and 2.4. are similar summaries of the requirements of tryptophan, threonine and methionine which are generally considered the first four most-limiting amino acids for 10 to 20 kg pigs in most typical phase 2 diets.

Studies have shown that crystalline amino acids are more digestible than protein bound amino acids (Sato et al., 1987; Izquierdo et al., 1988) and it is generally accepted that ingredients differ greatly in digestibility. Even though crystalline amino acids are more digestible, research has indicated that free lysine is only approximately 50-60% utilized by growing pigs fed under once daily feeding regimes (Batterham, 1976). Thus it is important to remember that diets formulated with crystalline amino acids must be made available relatively frequently for maximum amino acid utilization.

This review will attempt to summarize results of studies which address the protein and amino acid requirement of nursery age pigs from approximately 10 to 20 kg (Phase 2) as well as several other factors such as dietary energy level, excess levels of amino acids and dietary whey, which have been demonstrated to impact performance.

Table 2.1. Summary of studies estimating the lysine requirement of young pigs

ANIMAL CHARACTERISTICS				DIETARY SPECIFICATIONS		ANIMAL PERFORMANCE		RESPONSE CRITERIA USED	TOTAL LYSINE REQUIREMENT		DIGESTIBLE LYSINE REQUIREMENT		REFERENCE
BODY WEIGHT, KG				C.P.	M.E.	ADG,	ADFI,						
MEAN	INITIAL	FINAL	SEX	%	kcal/kg	g/d	g/d		%	g/d	%	g/d	
10.8	6.1	15.5	MIXED	20.1	3193	335	604	G,FE	1.20	7.25	1.02	6.15	Martinez and Knabe, 1990
12.3	7.4	17.2	MIXED	19.5	3159	350	596	G,FE	1.19	7.09	1.00	5.95	Lin and Jensen, 1985b
13.4	7.0	19.7	MIXED	20.0	3252	454	750	G,FE	1.15	8.63	0.96	7.24	Aherne and Nielsen, 1983
14.0	8.0	20.0	MIXED	16.0	3338	380	690	G,FE	1.10	7.59	0.94	6.5	Thaler et al., 1986
14.0	8.0	20.0	BOAR	18.7	3522	608	950	G,FE,C	1.31	12.45	1.10	10.47	Campbell et al., 1988
14.4	8.6	20.2	MIXED	19.0	3445	315	748	G,FE	1.17	8.75	0.97	7.27	Lin and Jensen, 1985a
15.5	9.2	21.7	MIXED	16.0	3279	445	955	G,FE	0.92	8.79	0.77	7.37	Lunchick et al., 1978
16.0	12.0	20.0	BOAR	16.6	3336	492	1082	G,FE	0.90	9.74	0.76	8.19	Campbell, 1978
21.0	8.0	34.0	MIXED	20.0	3282	555	1121	G,FE	1.17	13.12	0.97	10.83	Fetuga et al., 1975

G-gain, FE-feed efficiency, C-carcass

Table 2.2. Summary of studies estimating the tryptophan requirement of young pigs

ANIMAL CHARACTERISTICS				DIETARY SPECIFICATIONS		ANIMAL PERFORMANCE		RESPONSE CRITERIA USED	TOTAL TRYPTOPHAN REQUIREMENT		DIGESTIBLE TRYPTOPHAN REQUIREMENT		REFERENCE
BODY WEIGHT, KG				C.P.	M.E.	ADG,	ADFI,						
MEAN	INITIAL	FINAL	SEX	%	kcal/kg	g/d	g/d		%	g/d	%	g/d	
10.0	10.0	10.0	NA	NA	NA	NA	NA	NA	0.15	NA	0.14	NA	Mitchel et al., 1968
15.1	10.4	19.7	NA	18.0	3234	398	907	G	0.12	1.09	0.11	0.95	Boomgaardt and Baker, 1973
15.9	9.7	22.0	MIXED	12.0	3149	440	940	G,FE	0.15	1.45	0.13	1.23	Borg et al., 1987

NA-information was not available

G-gain, FE-feed efficiency, C-carcass

Table 2.3. Summary of studies estimating the threonine requirement of young pigs

ANIMAL CHARACTERISTICS				DIETARY SPECIFICATIONS		ANIMAL PERFORMANCE		RESPONSE CRITERIA USED	TOTAL THREONINE REQUIREMENT		DIGESTIBLE THREONINE REQUIREMENT		REFERENCE
BODY WEIGHT, KG				C.P.	M.E.	ADG,	ADFI,						
MEAN	INITIAL	FINAL	SEX	%	kcal/kg	g/d	g/d		%	g/d	%	g/d	
13.6	7.8	19.3	MIXED	13.3	3149	420	875	FE	0.64	5.56	0.47	4.07	Borg et al., 1987
14.3	10.6	17.9	MIXED	18.3	3148	518	835	G,FE	0.71	5.93	0.53	4.43	Gatel and Fekete, 1989

G-gain, FE-feed efficiency

Table 2.4. Summary of studies estimating the methionine requirement of young pigs

ANIMAL CHARACTERISTICS BODY WEIGHT, KG				DIETARY SPECIFICATIONS		ANIMAL PERFORMANCE		RESPONSE CRITERIA USED	TOTAL METHIONINE REQUIREMENT		DIGESTIBLE METHIONINE REQUIREMENT		REFERENCE
MEAN	INITIAL	FINAL	SEX	LYSINE %	M.E. kcal/kg	ADG, g/d	ADFI, g/d		%	g/d	%	g/d	
11.5	7.0	16.0	MIXED	1.30	NA	439	686	G,FE,PUN	NA	NA	0.33	2.26	Owen et al., 1993b
14.0	7.0	21.0	MIXED	1.25	NA	421	593	G,FE,PUN	NA	NA	0.40	2.37	Owen et al., 1993a
13.6	10.0	17.3	MIXED	1.29	3250	518	860	G,FE	0.29	2.49	0.26	2.19	Chung and Baker, 1992b
13.1	7.2	7.2	MIXED	0.95	3900	470	743	G,FE,PUN	0.51	3.79	NA	NA	Reifsnyder et al., 1984

G-gain, FE-feed efficiency, PUN-plasma urea nitrogen

Dietary Protein Level

Research to determine the effect of protein level on performance in nursery age pigs has been extensive. Fetuga et al. (1975) stated that growth rate and feed efficiency improved as the dietary protein levels were increased from 16 to 20% in pigs fed maize, groundnut meal, fishmeal and meatmeal based diets. Fetuga et al. concluded that diets providing between 18 and 20% protein, with proper amino acid balance, would be optimal for pigs between 8 and 50 kg. Campbell and Biden (1978) reported that significant improvement in growth rate and feed conversions was achieved in pigs weighing from 5.5 to 20 kg when the protein level was raised from 164 to 192 g/kg. An additional increase to 219g/kg did not improve performance but did significantly reduce carcass fat measurements. The trial also demonstrated some compensatory gain as pigs offered the 164g/kg/protein diet during the initial treatment period tended to grow faster subsequent to 20 kg, and from 20 to 45 kg had a lower feed conversion ratio than pigs previously offered the two higher protein diets. Furthermore, Campbell et al. (1988) used 43 intact males to determine the pigs tissue requirements for protein and amino acids from 8 to 20 kg. In this study growth performance and rates at which protein and lysine were deposited in the empty body increased linearly with increasing dietary protein concentration up to 187 g/kg and remained relatively constant thereafter. The corresponding dietary protein and lysine intakes required to support maximal protein accretion were 178 g/day and 13.0 g/day, respectively. A seperate study by Lunchick et al. (1978) also showed increased average daily gain and improved feed to gain as dietary protein level increased in a trial initiated to determine the effects of varying dietary lysine at different protein levels. In addition, protein/gain declined linearly as protein level was reduced from 20 to 16% and then plateaued or increased at the lower protein level. Furthermore, in this study the maximum performance was attained at the 16% protein level and at .92% dietary lysine.

Aherne and Nielsen (1983) allotted 144 crossbred pigs weaned at 4 weeks of age at an average initial weight of 7.0 kg to six dietary treatments of two protein levels (18 and 20%) and three lysine levels (1.0, 1.15, 1.30%). Growth rate and feed efficiency of pigs were improved by increasing the protein level in the diet from 18 to 20%. In addition, the response to increasing dietary lysine level was independent of protein level in the diet as the pigs fed the 18% crude protein diet containing 1.15% lysine had a growth rate similar to that observed in pigs fed the 20% protein diet containing 1.15% lysine. Another trial demonstrating that increased performance, with an increasing level of total lysine, does not depend on the total protein content of the diet was reported by Campbell (1978). In this trial, a crude protein level of 16.6% was needed to obtain pig performance equal to that achieved in pigs fed a 20% crude protein control diet. This is consistent with the observation by Asche et al. (1985), who concluded that the reduced protein level (by 2%) of a high lysine corn diets did not reduce the lysine required by pigs compared with those fed a normal corn diet. This would also support the viewpoint that the response to dietary lysine level is independent of protein level within the range of protein levels tested.

Katz et al. (1973) reported that weight gain in 8.5 kg pigs fed a basal 16% crude protein lysine-supplemented corn-soybean meal diet was equivalent to that of pigs fed the 19% crude protein corn-soybean meal control diet. In three 28 day growth trials, Hansen et al. (1993) concluded that for pigs weaned at about 28 days of age, crude protein in sorghum-soybean meal starter diets can be reduced to 17% and good pig performance can be obtained if supplemental lysine, threonine and methionine are added back to levels equal to those found in the 21% crude protein 1.15% total lysine control diet.

Work conducted by Lin and Jensen (1985b) contradicts the theory that dietary lysine level is independent of protein level by concluding that in the range of 17.5 to 21.5% crude protein, the lysine requirement of the weanling pigs increased .04% for each 1 % increase in crude protein. In this research a diet of 19.5% crude protein and 1.19% lysine produced the maximum G:F values.

Research suggests that growth rate and feed efficiency can be improved as the dietary crude protein in the diet is increased up to 20% in a variety of different diets, but that positive response to increased dietary lysine is independent of protein level after a minimum level of about 16% crude protein is met. Furthermore, dietary crude protein can be reduced to 16% and equivalent performance can be obtained if supplemental lysine and other indispensable amino acids are supplied.

Lysine

For some time, lysine has been considered the first limiting amino acid in typical corn-soybean meal based diets fed to swine. Corley and Easter (1980) conducted four growth trials to evaluate the addition of lysine, tryptophan, methionine and threonine to low-protein corn-soybean meal diets for pigs from 4 to 8 weeks of age. The order of most limiting amino acids were lysine, tryptophan, threonine and methionine. In a similar study conducted by Corley and Easter (1983) the order of limiting amino acids were also lysine, tryptophan and threonine with methionine not being tested.

An increase in the level of lysine in the diet of starter pigs above the NRC (1988) requirement generally increases weight gain and improves feed efficiency. Several research trials have reported these results. Mahan (1992) found that pigs fed a .90% lysine level in a corn-soybean meal and a corn-soybean meal-dried whey diet had poorer gains and feed intakes when compared with those fed a diet containing 1.30% lysine. Lewis et al. (1981) also observed improved ADG and G:F as well as a tendency for increased average daily feed intake (ADFI) when lysine was added to the diet. These results came from a trial in which weanling crossbred pigs with an average initial weight of 5 kg were fed diets containing two levels of fat and six levels of lysine to determine the lysine requirement of young pigs fed practical diets with and without added fat. The findings indicate that pigs weighing 5 to 15 kg fed 19% crude protein diets require 1.15 to 1.25% lysine. Furthermore, there was no indication that the addition of fat increased the lysine requirement. Martinez and Knabe (1990) also reported an increase in ADG and G:F of both starter (6 kg BW initially) and grower pigs (21 kg BW initially) fed a basal corn-peanut meal diet when dietary lysine level was increased. ADG and G:F were optimized at 1.10 to 1.20% total lysine for the starter pigs.

There are a number of trials that conclude that a minimum level of crude protein is required to realize the improved performance from the addition of supplemental lysine. Aherne and Nielsen (1983) found that at both the 18 and 20% dietary protein levels there was a significant improvement in growth rate and feed efficiency as dietary lysine level increased from 1.0 to 1.15%, but an increase from 1.15 to 1.30% tended to decrease performance. This data suggests that rapidly growing pigs fed barley-wheat-soybean meal diets have a dietary requirement of 20% protein and approximately 1.15% lysine over the range of 7-19 kg liveweight. Fetuga et al. (1975) observed that only pigs fed 16 and 18% crude protein corn-soybean meal diets showed significant responses in growth rate and feed efficiency to additional lysine. Similarly, the best overall gain and efficiency of gain for pigs between 8 and 50 kg was achieved in pigs fed a 20% protein diet and total dietary lysine level of 1.17%. They also reported that carcass leanness increased and fatness decreased as protein and lysine levels were increased to 1.41% dietary lysine. Katz et al. (1973) conducted two trials, involving 175 pigs of mixed breeding and averaging 5 weeks of age and 8.5 kg to determine the efficacy of supplemental lysine added to a low-protein starter diet. In the first trial, lysine addition increased rate and efficiency of gain, in pigs fed a 16% crude protein lysine-supplemented diet, to a level of performance equivalent to that of pigs fed the 19% crude protein corn-soybean meal control diet. In a second trial there were no differences in gain among treatments but lysine addition increased G:F.

Campbell (1978) reported that a minimum protein level was needed to maintain carcass quality, but that growth response to added lysine was independent of the level of protein. In this study, 20 day old pigs were fed a 20% crude protein 1.1% lysine control diet or a 14.6 or 16.6% crude protein diet supplemented with different levels of synthetic lysine. The experimental diets were four 14.6% crude protein diets with .54, .72, .90 and 1.08% total lysine and four 16.6% crude protein diets with .72, .90, 1.08 and 1.26% total lysine. In pigs weighing 5.5 to 20 or 12 to 20 kg, liveweight gains and G:F improved with increasing total lysine (to 1.08 and .90% lysine, respectively) and at these levels of lysine, pig performance was equal to that achieved on the 20% crude protein control diet containing 1.10% lysine. Campbell also reported that the growth response to lysine was independent of the level of protein but that carcass quality did not respond to lysine supplementation independently of protein level. In order to obtain carcass quality equal to that observed in pigs fed the 20% crude protein 1.10% lysine control diet, a 16.6% CP level was needed. However, at this protein level, carcass quality improved as dietary lysine increased and at 1.26% lysine, carcass quality was superior to that observed in pigs fed the 20% crude protein 1.10% lysine control diet.

There are some research results which contradicts the concept that the addition of supplemental lysine enhances gain or feed performance responses. Mahan et al. (1993) completed a regional cooperative study which evaluated the efficacy of supplemental dried whey and L-lysine HCL in a corn-soybean meal-based diet for weanling pigs. The experiment involved 5 research institutions using a total of 960 crossbred pigs weaned between 3 and 4 weeks of age. Test results showed that performance was not improved when L-lysine HCL was added to either the .95 or 1.10% lysine corn-soybean meal diets, and lysine addition elicited a small, nonsignificant, gain response when added to the corn-soybean meal-dried whey diets. Thus, these researchers concluded that the addition of L-lysine HCL to a corn-soybean meal diet with or without dried whey did not enhance gain or feed efficiency and that lysine was not the limiting factor in these type diets containing .95 or 1.10% lysine from natural protein sources. Lepine et al. (1991) also reported that growth responses during the 0-21 day period postweaning was independent of dietary lysine level, suggesting that a dietary lysine level of 1.10% is not the limiting nutrient in a corn-soybean meal or a corn-soybean meal-dried whey diet. However, from day 22 to 35 postweaning, a linear growth response to lysine level was observed when the dried whey diet was fed, but no response was detected when lysine was added to the corn-soybean meal diet. These results suggest that a component of dried whey other than lysine was the most limiting nutrient in a corn-soybean meal based diet, but when dried whey was supplememted, growth responses to crystalline lysine occurred during the latter phase of the starter period.

There are also a number of trials which the main objective was to determine the lysine requirement of the weanling pig. Thaler et al. (1986) conducted experiments to estimate the lysine requirement of pigs weighing 8 to 20 kg and to determine the effect of dietary lysine level during this early growth period on subsequent performance and carcass characteristics. A 16% crude protein corn-soybean meal based diet with total lysine ranging from .75 to 1.25% was used during the nursery period. A dietary lysine level of 1.10% was necessary for optimum pig performance to 20 kg. The addition of lysine significantly improved FE in all experiments and weight gain in experiment 1 and 2 during the 8 to 20 kg period. However, the increased performance of pigs fed supplemental lysine to 20 kg was not sustained to market weight when pigs were fed diets containing NRC (1979) recommended levels of lysine from 20 kg to slaughter (93 or 100 kg). Furthermore, carcass characteristics were unaffected by starter lysine level. Cera and Mahan (1987) conducted a 2 by 4 factorial experiment, in five replicates, with 264 pigs weaned at approximately 6 kg bodyweight to evaluate the lysine requirement of corn-soybean meal-dried whey diets with and without supplemental corn oil (0 vs 6%) during a 4 week starter period. The results indicate that pigs weighing from 6 to 16 kg require 1.15% dietary lysine in practical corn-soybean meal-dried whey starter diets and 1.22% in diets with 6% supplemental corn oil to support maximum growth rate and efficient utilization of dietary lysine. Lin and Jensen (1985a) also reported an increase in percent dietary lysine needed to meet maximum gain and feed efficiency if corn oil is added to the diet. In the diet without fat addition, 17.5%CP with 1.11% lysine was adequate for postweaning, a linear growth response to lysine level was observed when the dried whey diet was fed, but no response was detected when lysine was added to the corn-soybean meal diet. These results suggest that a component of dried whey other than lysine was the most limiting nutrient in a corn-soybean meal based diet, but when dried whey was supplememted, growth responses to crystalline lysine occurred during the latter phase of the starter period.

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Liebholz and Parks (1987) used basal corn diets containing peanut meal and wheat gluten with or without dried milk as the protein supplements and determined that the lysine required for maximum performance and nitrogen retention was at least 12.7 g/kg DM for pigs between 7 and 28 days of age and not greater than 12 g/kg DM between 28 and 56 days of age. Campbell et al. (1988) stated the corresponding dietary protein and lysine intakes required to support maximum protein accretion were 178g/day (11.7 g/MJDE) and 13.0 g/day (.84 g/MJDE), respectively for 8 to 20 kg pigs.

Asche et al. (1985) concluded that weanling pigs from 5 to 14 kg require at least 1.10% lysine. Lin and Jensen (1985b) suggest that a diet with 19.5% CP and 1.19% lysine would result in maximal G:F in 7.4 kg, 29 day old pigs fed corn, soybean meal-sesame meal and whey diets.

The source of lysine may also have an affect on performance response in young pigs. Batterham (1976) noted a significant interaction between response to free lysine and frequency of feeding. The growth response of pigs fed free lysine under a regime of once daily feeding was only 43% of that achieved with frequent feeding. More recent research has indicated that free lysine is only approximately 50-60% utilized by growing pigs fed under once daily feeding plans. A study by Lunchick et al. (1978) used corn-soybean meal diets formulated to contain 20, 18, 16 or 14% crude protein with L-lysine HCL added to the lower protein levels to provide total lysine equal to that contained in the 20% crude protein diet (1.08% total lysine) less .02 and .04% lysine for each 1% reduction in protein level. They concluded that pigs consuming diets in which the soybean meal to corn ratio was adjusted to supply equivalent lysine grew more rapidly and consumed more feed, but required more feed per unit gain, than pigs fed diets supplemented with L-lysine HCL.

The lysine to gain ratio declined linearly as lysine level was reduced. Performance was also significantly affected by the source of lysine. Rosell and Zimmerman (1984) reported that pigs fed corn-soybean meal diets utlized feed more efficiently than those fed a corn-fishmeal-dried whey diet. The author's theorized that the improved feed efficiency was due to the higher lysine content in the corn-soybean meal diet. They also concluded that the lysine requirement of 5 kg 21 day old weanling pig fed corn-soybean meal-dried whey and sorghum grain-soybean meal based diets is at least 1.15 or 1.20% of the diet.

Batterham et al. (1990) suggested that values for the ileal digestibility of lysine in protein concentrates are unsuitable in dietary formulations as the assay does not reflect the proportion of lysine that can be utilized by the pig. He noted that with heat-processed meals, a considerable proportion of the lysine is absorbed in a form that is inefficiently utilized.

The research reviewed suggests that as dietary lysine is increased in 10 to 20 kg pigs, there is an increase in ADG, an improvement in gain to feed and a tendency to increase feed intake. There is also considerable evidence to suggest that a minimum level of crude protein in the diet must be met in order to gain these improvements. A level of at least 1.15% total dietary lysine seems to be required to maximize performance.

Ideal Protein

An ideal protein is one that is perfectly balanced in terms of its amino acid content and its supply of non-essential nitrogen (Cole, 1980). H. H Mitchell and H. M. Scott, at the University of Illinois, first conceptualized an ideal protein in the late fifties and early sixties and worked to develop an ideal protein pattern of indispensable amino acids for chicks. This eventually resulted in the Modified Reference Standard, which is the current chick requirement standard for amino acids (Baker and Chung, 1992). In 1981 the British ARC proposed an ideal protein for swine in which indispensable amino acids were listed as ratios to lysine (Baker and Chung, 1992). Since then there have been numerous attempts to modify the ARC (1981) ideal protein to more specifically meet the ratios of indispensable amino acids relative to lysine (Wang and Fuller, 1989; Chung and Baker, 1991; Chung and Baker, 1992a). Chung and Baker's (1992a) Illinois ideal amino acid pattern was determined by testing performance in pigs placed on diets with patterns of indispensible amino acids which met the criteria for the Illinois final amino acid pattern (IFP, Chung and Baker, 1991) , the Wang and Fuller ideal amino acid pattern (WFIP, Wang and Fuller, 1989), the Illinois ideal amino acid pattern (IIP, Chung and Baker,1992a), or the 1988 National Research Council (NRCP, NRC,1988) amino acid requirement pattern for 10 kg pigs. Regardless of which amino acid pattern was fed, pigs had similar daily gains, daily feed intakes and G:F when the pigs were given ad libitum access to the experimental diets. In a second experiment, all levels of indispensible and dispensible amino acids were reduced to 50% of levels present in experiment 1. When pigs had ad libitum access to these diets, daily gains of pigs fed IIP were superior to those of pigs fed IFP or NRCP, but similar weight gains occurred in pigs fed IFP, WFIP and NRCP. In addition, grams of nitrogen retained per gram of nitogen intake from indispensible amino acids was greater for IIP than for either IFP or WFIP. The pattern of indispensible amino acids in the IIP (grams of AA/100 g lysine) was as follows: lysine (100), methionine + cystine (60), threonine (65), tryptophan (18), phenylalanine + tyrosine (95), leucine (100), isoleucine (60), valine (68), arginine (42) and histidine (32).

Methionine

There is renewed interest in research relating to the methionine requirement of swine due to the interest in formulating more economical, lower crude protein diets with soybean meal which is suboptimal in total sulfur amino acids and first-limiting in methionine.

Chung and Baker's (1992a) Illinois ideal amino acid pattern suggests that methionine and cystine should be 60% of the lysine requirement. In corn-soybean meal based diets, the total methionine requirements in the literature all fall within a close range. Owen et al. (1993b) concluded that .36% dietary methionine was required during day 7 to 14 postweaning to maximize growth performance when pigs were fed a corn-soybean meal based diet containing 1.3% dietary lysine. The optimum dietary level of methionine decreased to between .30 and .33% from day 14 to 28 postweaning. In contrast, Chung and Baker (1992b) estimated the digestible methionine requirement of 10 to 20 kg pigs at .255% for maximal weight gain. Assuming an 89% digestibility of methionine in practical corn-soybean meal diets, the total methionine level in practice would be .29%. Furthermore, if 50% of the sulfur amino acid requirement can be furnished by cystine, the total sulfur amino acid requirement of the young pig (5 to 20 kg) would be .58% of the diet. In a trial performed by Katz et al. (1973) no increase in production traits occurred when synthetic methionine was added to 16% crude protein basal corn-soybean meal diets containing .8 and 1.0% lysine and .52 and .62% total sulfur amino acid levels, respectively.

Fetuga et al.(1975) concluded that the best overall gain and efficiency of gain was achieved in pigs from 8 to 50 kg fed a maize-groundnut cake-fishmeal and meatmeal based diet with 20% crude protein, 1.17% total lysine and a total dietary methionine and cystine of .66%.

Mitchell et al. (1968) reported that total sulfur-bearing amino acids should account for .74% of a semisynthetic diet in a 10 kg pig, with cystine being able to replace at least 70% of the need for total sulfur-bearing amino acids. Nitrogen balance was used to determine the sulfur amino acid requirement. The semisynthetic diet had crystalline amino acids added to meet or exceed the needs of a baby pig fed a 22% crude protein diet as reported by Becker et al. (1963). For three week old pigs fed a 13.5% crude protein, semipurified diet supplemented with DL-methionine, Ong and Allee (1985) suggested that .56% total sulfur amino acids was adequate, whereas, Reifsnyder et al. (1984) reports a requirement of .51% of the dietary solids when feeding a 9% crude protein milk diet supplemented with amino acids to 21 day old pigs.

Owen et al. (1993a) concluded that a porcine plasma based diet must contain .40 to .44% dietary methionine to maximize growth performance from day 0 to14 postweaning.

In general at least .30% total dietary methionine and .60% total sulfur amino acids in the diet are recommended to maximize growth in 10 kg pigs fed practical corn-soybean meal diets. Some research suggests to maximize G:F, levels of total sulfur amino acids equal to 60% of the total lysine requirement should be fed.

Tryptophan

Corley and Easter (1983) conducted an experiment that indicated that tryptophan is the second-limiting amino acid in a low-protein, corn-soybean meal diet for starter pigs with an initial weight of 8.38 kg. Another study by Corley and Easter (1980) also determined tryptophan to be the second-limiting amino acid for 4-8 week old pigs.

Borg et al. (1987) conducted two trials and concluded that the minimum dietary tryptophan requirement of the 6 to 22 kg pig was approximately .16%. Sato et al. (1987) had similar results and suggested that the tryptophan requirement for maximal growth is .16% of the diet for a 10 to 20 kg pig fed a 17.5% crude protein corn and gelatin based diet. However, Boomgardt and Baker (1973) estimated the need for tryptophan to range from .071 to .119% as the protein level increased from 10 to 18%. According to the Illinois ideal amino acid pattern (IIP) for 10 kg pigs, (Chung and Baker, 1992a) the requirement for tryptophan based on a 1.15% lysine diet would be .207%.

Burgoon and Knabe (1990) listed total dietary tryptophan requirements, estimated by broken-line regression analyses to be .18 and .16% for starter pigs with an initial weight of 6 kg fed corn-fishmeal-corn gluten meal based diets containing 22% crude protein and 1.38% lysine and 15.5% crude protein and .90% lysine based on ADG and

G:F, respectively. They also estimated digestible tryptophan requirements at .14% for starter pigs based on ileal tryptophan digestibility values for the basal diet and performance data.

Liebholz (1981) determined that the tryptophan requirement of pigs for maximum weight gain and feed conversion ratio in pigs fed maize-meat meal based diets was met by 1.64-1.67 g/kg of diet between 28 and 56 days of age. Liebholz concluded that the tryptophan requirement was met by 1.64 g/kg of diet based on the concentration of urea and tryptophan in the blood plasma.

The research shows strong consistent evidence that the total dietary tryptophan requirement for maximal growth of the 10 to 20 kg pig is at least .16% of the diet but that levels as high as 18% of the total lysine requirement have been suggested to maximize efficiency when an ideal protein indispensable amino acid pattern is used to calculate the requirement.

Threonine

Threonine has been listed as the third-limiting amino acid in a low-protein corn-soybean meal diet for starter pigs in two seperate experiments (Corley and Easter, 1983; and Corley and Easter, 1980). More specifically, Borg et al. (1987) completed trials that indicate that the minimum dietary threonine requirement of the young weaned pig (8 to 21 kg) is approximately .63%. Gatel and Fekete estimated the threonine requirement for weaned piglets 10 to 25 kg liveweight fed cereal based diets at 65-70% of the lysine requirement. Chung and Baker (1992a) have a similar suggested requirement of 65% of the lysine requirement. Furthermore, Cole and Bong (1990) estimated that the threonine requirement was between 65 to 70% of the lysine requirement, when they used 72 female pigs in a growth experiment to determine the optimum balance of threonine to lysine in the ideal protein for young pigs from 10 to 25 kg liveweight under restricted feeding conditions. Lewis and Peo (1986) determined the threonine requirement of young pigs fed diets similar to those used in commercial swine production using weanling crossbred pigs with an average initial weight of 6.4 kg. Six levels of threonine were fed in diets containing 16% crude protein and calculated to be adequate in all nutrients except threonine and crude protein. Their results indicated that young pigs weaned at 3 to 4 weeks of age require approximately .70% threonine.

The total dietary threonine requirement of the 10 to 20 kg pig has consistently been estimated at 65% of the total lysine requirement in the literature reviewed or more specifically at least .63% of the total diet in one experiment.

Arginine and Other Indispensable Amino Acids

Southern and Baker (1983) concluded that the arginine requirement of the weanling pig is .48% of the diet. In other papers relating to arginine, Edmonds and Baker (1985) reported that excess lysine does not appear to effect the arginine requirement in the young rapidly growing pig and Rosell and Zimmerman (1984) concluded that added arginine and threonine to corn-soybean meal and corn-fishmeal-dried whey diets did not adversely affect pig performance.

Izquierdo et al. (1988) used a histidine-deficient, feather meal-corn-dried whey basal diet (19% protein and 3200 Kcal ME/kg), supplemented with lysine, methionine and tryptophan, to determine the histidine (HIS) requirement of the growing pig between 10 and 20 kg live weight. The experiments suggest that the bioavailable HIS requirement of the 10 to 20 kg pig was .31% of the diet. Assuming an 85% bioavailability of HIS in commercial diets based on corn and soybean meal, the total HIS level needed in practice would be .36%.

Little information is available on the proline requirement of 10 to 20 kg pigs, but a trial by Ball et al. (1986) suggests that the dietary proline requirement of 2.5 kg pigs is 14 g/kg.

The effect of supplemental dietary glycine on growth performance of weanling pigs was evaluated by El-Kandelgy et al. (1993). In this study, the pigs initial weight averaged 5.5 kg at an average age of 21 days. Diets included were 10% whey, 10% whey plus .5% glycine, 20% whey, corn-soybean meal and corn-soybean meal plus .5% glycine. There were 7 replicates of the 4 week trial and all diets were formulated to contain 1.2 % lysine and 21.5% crude protein. The results imply that the addition of .5% glycine to either a corn-soybean meal or a 10% whey diet improved feed efficiency of weanling pigs. Also, a 10% whey plus .5% glycine diet improved growth performance (ADG, ADFI,and G:F) relative to a 20 % whey diet.

Meier et al. (1993) conducted trials to determine the effects of supplemental free L-glutamine(GLN) on growth performance, intestinal morphology and recovery of GLN in duodenal digesta in the 21 day old pig. In the growth trials GLN did not affect ADG, ADFI or G:F.

There is little documented literature on the absolute total dietary requirements of many of the non-essential amino acids. Some of the suggested requirements are .48% for arginine, .36% for histidine and 1.4% for proline.

Other Factors Affecting Pig Performance

Energy

It is well accepted that animals eat feed to meet a minimum energy requirement and thus the nutrient levels of a diet must be adjusted depending on the energy density of the diet. Nam and Aherne (1993) reported in a study of weanling pigs (with an average body weight of 9.1 kg) replicated five times that there was a linear decrease in feed intake ($p<.05$) as the energy intake of the diet increased. Also, feed intake was not affected by the lysine to digestible energy ratio, but a positive linear effect of lysine to digestible energy ratio on ADG was observed. Furthermore, ADG increased linearly with an increase in DE level and increases in DE level and the lysine:DE ratio in the diet resulted in linear improvements in G:F. Nam and Aherne then suggested that the combination of DE level and ratio of lysine to DE which produced maximum ADG (612 g/day) was 14.13 MJ DE/kg and .95g of lysine/MJ DE, respectively for pigs from 9.1 to 25.7 kg of bodyweight. Lin and Jensen (1985a) also reported a linear increase in G:F and a linear decrease in feed intake with increasing dietary energy level.

Brendemuhl and Harrison (1990) tested 276 three-week old crossbred pigs fed over a five-week period to evaluate the effects of lysine:calorie ratio on growth rate in diets containing 0 and 5% added corn oil. In this experiment, ADG improved with increasing lysine:calorie ratio, but tended to plateau in diets with no added corn oil. No plateau was reached in those diets containing added corn oil. The addition of corn oil, however, had no overall effect on ADG. Average daily feed intake and G:F were not affected by lysine:calorie ratio, but were affected by the addition of corn oil.

Lin and Jensen (1985a) also conducted a study to determine the crude protein-lysine requirement of weanling (8.6 kg) pigs fed diets formulated to contain three different energy levels. Average daily gain was not significantly affected by crude protein level in low (3657 kcal/kg) and medium (3957 kcal/kg) energy diets, but increased with crude protein level in pigs fed the high (4257 kcal/kg gross energy) energy diets. Feed intake was not affected by crude protein level but decreased linearly with increases in dietary energy level. Similarly, G:F increased linearly up to 18.5 and 20.5% CP with medium and high energy diets, respectively and there was a trend for improving G:F at higher energy levels, for the higher protein diets. They also reported an increase in percent dietary lysine needed to meet maximum gain and feed efficiency if corn oil is added to the diet. In the diet without fat addition, 17.5% CP with 1.11% was adequate for maximum gain and efficiency. However, 18.5% CP and 1.15% lysine was required for maximum G:F if 4.0% corn oil was added and 19.5% CP and 1.19% lysine was required when 8% corn oil was added.

Cera and Mahan (1987) conducted a trial to evaluate the lysine requirement of corn-soybean meal-dried whey diets with and without supplemental corn oil (0 vs 6%) in 6 kg pigs during a 4 week starter period. Pigs fed a corn-soybean meal-dried whey starter diet with supplemental corn oil required higher lysine levels to support maximum growth rate and efficient utilization of dietary lysine.

These trials indicated that feed intake was decreased in nursery age pigs when energy density of the diet was increased, but that feed intake was not affected by the lysine:digestible energy ratio of the diet. In addition there was a linear increase in ADG as the digestible energy and lysine:digestible energy ratio increased. Gain to feed was improved with an increase in digestible energy and lysine to digestible energy ratio. Furthermore, when energy was increased in the diet an increase in the percent dietary lysine was needed for maximum gain and efficiency of gain.

Excess Amino Acids

Edmonds et al. (1987) conducted six experiments with 8 kg pigs to evaluate the effects of 4% excesses of DL-methionine, L-tryptophan, L-threonine, L-lysine or L-arginine on growth, feed intake and self selection when added to 20% protein corn-soybean meal diets. In the growth study, gain was reduced 52, 31, 28, 16, and 5% by addition of methionine, arginine, tryptophan, lysine and threonine, respectively. Small decreases in G:F occurred in pigs fed diets with excess methionine or lysine. Feed intake depressions were evident in pigs fed excess methione or excess tryptophan within 1 day after initiation of the growth trial. Selection studies revealed that pigs strongly preferred the control diet over any of the diets containing excess amino acids. This is consistent with observations by Corley and Easter (1980) who observed a depression ($p<.05$) in both gain and gain to feed when excess DL-methionine was fed.

Edmonds and Baker (1985) reported that pigs fed twice the recommended level of lysine (2.30%) exhibited weight gains, feed intakes and G:F similar to those of pigs fed the basal diet containing 1.15% lysine. However, levels of dietary lysine three to four times the basal level caused decreases in both weight gain and voluntary feed intake with no noticable decrease in feed efficiency.

The performance of 10 to 20 kg pigs fed excess amino acids has not been researched extensively. Research would suggest that twice the recommended level of lysine is not problematic, but that levels of 4% excesses in methionine, tryptophan, threonine, lysine and arginine result in reduced growth.

Whey

There is some research that suggests that a highly available carbohydrate is the limiting component in starter pig diets which contain cereal grains but not dried whey and that the response to supplemental amino acids is a secondary response.

Mahan et al. (1993) conducted a regional cooperative study that evaluated the efficacy of supplemental dried whey and L-lysine HCL in a corn-soybean meal-based diet for weanling pigs. Their results suggest that gain and feed efficiency responses of weanling pigs improved when diets contained dried whey. Also, lysine was not the limiting factor in either the corn-soybean meal or the corn-soybean meal-dried whey diet formulated at either .95 or 1.10% lysine. These researchers concluded that another factor in dried whey appeared to be responsible for its growth promotion effect.

Mahan (1992) completed two experiments to determine the efficacy of lactalbumin and lactose components of dried whey on gain, feed efficiency and nitrogen retention of weanling swine. In the first trial, growth rate, feed intake, nitrogen retention and apparent nitrogen digestibility were increased significantly when pigs were fed a corn-soybean meal-dried whey diet when compared with those fed a corn-soybean meal diet. Replacing dried whey with lactose and the amino acid supplement resulted in a higher growth rate and an improved G:F relative to the corn-soybean meal-dried whey diets. The .90% lysine level in the corn-soybean meal and corn-soybean meal-dried whey diets resulted in poorer gains and feed intakes when compared with the 1.30% lysine level, but not when lactose and(or) lactalbumin and lactose replaced the dried whey component. The results from these experiments would suggest that the lactose component of dried whey is the primary cause of improved gain and feed intake responses when dried whey is added to pig starter diets.

Lepine et al. (1991) also experienced improved daily gain and feed intake when dried whey was fed. Furthermore, growth responses during the first 21 day period postweaning were independent of dietary lysine level. Lepine also suggested that dietary lysine at a level of 1.10% is not the limiting nutrient in a corn-soybean meal or a corn-soybean meal-dried whey diet. However a linear growth response to lysine level did occur when the dried whey diet was fed from day 22 to 35 postweaning. There was no response detected when lysine was added to the corn-soybean meal diet. Thus, these results suggest that a component of dried whey other than lysine was the most limiting nutrient in a corn-soybean meal-based diet, but when dried whey was supplemented with L-lysine HCL, growth responses occurred during the later phase of the starter period.

These combined trials suggests that a highly available carbohydrate such as lactose is the most limiting nutrient in the phase 1 period and possibly the early part of phase 2 but that lysine becomes a limiting factor in phase 2 which normally begins at about 10 kg.

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CHAPTER III

Effect of Increasing Dietary Lysine Level From Dietary Protein on Performance During Phase 2 of the Nursery Period

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ABSTRACT

Weanling pigs at 10 to 14 d postweaning (average weight and age of 10.14 kg and 37.7 d, respectively) were fed diets containing four levels of lysine from dietary protein to determine the protein requirement of 10 to 20-kg pigs. The study was conducted as a completely randomized design in two experiments and involved a total of 111 pigs. The four diets were formulated by altering the ratio of corn to soybean meal and contained lysine levels ranging from .95% to 1.40% in .15% increments. The trial was for 21 d with gain and efficiency of gain estimates obtained weekly. Weight gain (G), average daily gain (ADG), feed intake (ADFI), and feed efficiency (G:F) were the response criteria evaluated. Pigs were housed in an environmentally controlled nursery in elevated pens with temperature initially maintained at 30°C, with a 1°C reduction in temperature each week until the temperature reached 26°C. All pigs were fed the same complex phase 1 diet containing 1.40% lysine and 19.40% crude protein for the first 14 (Exp. 1) or 10 (Exp. 2) days following weaning. Average daily gain, ADFI and G:F during the 14 d phase 1 adjustment period following weaning was .674 kg, .910 kg, and .739 kg gain/kg feed, respectively for Exp. 1 and .529 kg, 1.18 kg, .454 kg gain/kg feed, respectively for the 10 d phase 1 adjustment period in Exp. 2, performance was similar ($P > .28$) among treatment groups within experiment. There was no week by treatment, experiment by treatment or experiment by treatment by week interaction for the dependent variables of G, ADG, ADFI, and G:F in this experiment. Average daily gain increased linearly ($P < .03$) with increasing levels of lysine in the 3-wk experimental period. Least square means for ADG for Treatments 1 through 4 were .506, .520, .539, and .568 kg/day, respectively for the the 3-wk period. Pigs fed the highest lysine level (Treatment 4) grew 12.25% faster ($P < .04$) than those fed the lowest lysine level (Treatment 1). Average daily gain was greater in wk 2 ($P < .05$) and wk 3 ($P < .0001$) than in wk 1. Similarly, pigs grew faster in wk 3 than in wk 2 ($P < .005$). Although ADFI increased slightly with increasing levels of dietary lysine, differences were not significant ($P > .10$). Average daily feed intake was greater in wk 2 ($P < .002$) and wk 3 ($P < .001$) than in wk 1. Pigs in wk 3 consumed slightly more ($P > .14$) than those in wk 2, although the difference was not significant. Gain:feed increased linearly ($P < .002$) as lysine level increased in the diet. Least square means for G:F for Treatments 1 through 4 were .562, .599, .614 and .633 kg gain/kg feed, respectively, for the 3-wk experimental period. Gain:feed decreased ($P < .02$) from wk 1 to wk 2 and improved ($P < .12$) from wk 2 to wk 3, but wk 1 and wk 3 G:F was similar ($P > .43$). The results of this study indicate that lysine additions from dietary crude protein to a phase 2 corn-soybean meal-dried whey based diet may improve performance in high lean growth genotype pigs. The linear response of ADG and G:F to increasing levels of lysine indicate that 10 to 20-kg pigs of this genotype fed practical diets require at least 1.40% total lysine. More research is needed to determine if adding higher levels of lysine will continue to increase performance.

Key Words: Pigs, Amino Acids, Dietary Lysine, Protein

Introduction

Several experiments have been conducted to determine the protein and lysine needs of 10 kg pigs (Campbell, 1978; Aherne and Nielsen, 1983; Martinez and Knabe, 1990). These pigs are normally weaned at 3 to 4 wk of age and have completed a 7 to 14-d phase 1 adjustment period before being placed on a phase 2 diet. However, there is still lack of agreement concerning the lysine requirement during phase 2 of the nursery period (10 to 20-kg pigs). The NRC (1988) lists the lysine and protein requirements of 10 to 20-kg pigs as .95% and 18% of the diet, respectively. Estimates of nutrient requirements in other countries and values used commercially in the United States are much higher than the NRC (1988) value. It is essential that reliable recommendations for lysine be established for the economical production of pork. This is especially true since lysine is regarded as the first limiting amino acid in the starter pig diet (Corley and Easter, 1980; 1983). Some differences in requirement estimates may be explained by the fact that lysine requirements may be influenced by other dietary factors, such as energy density (Lin and Jensen, 1985; Cera and Mahan, 1987; Nam and Aherne, 1993) protein level (Baker et al., 1975; Lin and Jensen, 1985; Kerr, 1988) and whey (Lepine et al., 1991; Mahan, 1992). The objective of this study was to determine the protein and lysine requirement for maximum gain, feed intake, and efficiency of gain during phase 2 (10 to 20 kg) of the nursery period in pigs fed corn-soybean meal-dried whey based diets. Four different levels of lysine from dietary protein were used to determine the response to dietary lysine level.

Materials and Methods

Two experiments involving a total of 111 Yorkshire, Hampshire and Crossbred (Yorkshire X Hampshire) pigs were used in a 21-day study to determine the effect of level of lysine from dietary protein on performance in 10 to 20-kg pigs. Fifty-four pigs in Exp. 1 and fifty-seven in Exp. 2 were allotted by sex (boars and gilts), litter and weight into 12 pens with five pigs per pen. Pigs were weaned at an average of 25.7 d of age (ranging from 21 to 32 d) and an average weight of 6.79 kg. Pens were randomly allotted to one of the four dietary treatments and the experiment was conducted as a completely randomized design. During the first 10 d in Exp. 1 and the first 14 d in Exp. 2, all pigs were placed on a common phase 1 diet (Tables 3.1 and 3.2), respectively containing 1.40% lysine and 19.40% crude protein. During phase 2 (average weight of 10.14 kg) pigs were fed one of the treatment diets formulated by varying the ratio of corn to soybean meal to contain .95, 1.10, 1.25 or 1.40% lysine. All four diets contained .90% calcium and .75% phosphorus which exceeded current NRC (1988) requirements. Pigs were allowed ad libitum access to diets and water.

Pigs were housed in an environmentally controlled nursery in elevated pens (4' 11" X 5') with woven wire floors, nipple waterers and open front self feeders. Environmental temperature was initially 30°C, with a 1°C reduction in temperature each week until the temperature reached 26°C. During the 3-wk trial, individual pig weight was recorded, pen feed intake was measured, and pen feed efficiency (G:F) was calculated weekly.

Statistics. Pen was considered the experimental unit and data were analyzed by least squares analysis of variance procedures (Steel and Torrie, 1980) using the GLM procedure of SAS (1985). The statistical model for gain (G), average daily gain (ADG), average daily feed intake (ADFI) and feed efficiency (G:F) included experiment, treatment, week, and the experiment * treatment, experiment * week, treatment * week and experiment * treatment * week interactions. The difference between means was determined by t-test. Orthogonal polynomials were used to test for linear, quadratic and cubic effects.

Results and Discussion

In Exp. 1 five pigs died during the initial period in which the phase 1 diet was being fed. In addition, one pig was removed from the trial because his total weight gain throughout the 3-wk period was more than three standard deviations lower than the mean gain. This pig was eliminated from the gain calculations but was included when determining pen feed efficiency.

In Exp. 2, two pigs were removed from the trial at the end of wk 1 since they lost weight and were more than three standard deviations lower than the mean gain for wk 1. These pigs were not included in the gain or efficiency calculations. In addition, one pig died before completing wk 3 of the trial. This pigs gain values were within the range of three standard deviations from the mean up to this point so his values were included in determining the performance values for that pen. The total number of pigs in Treatments 1 through 4 were 24, 29, 28, and 30, respectively.

Average daily gain, ADFI, and G:F during the 14-d phase 1 adjustment period following weaning were .674 kg, .9104 kg, and 739 g gain/kg feed, respectively for Exp. 1 and .529 kg, 1.18 kg, 454 g gain/kg feed, respectively for the 10-d phase 1 period in Exp. 2; performance was similar ($P > .10$) among the treatment groups within the experiment.

No experiment by treatment or week by treatment interactions were observed (Table 3.3), therefor data from the two experiments and over the three weeks of the experiment were combined for analysis. Also there was no experiment by treatment by week interaction for the dependent variables of G, ADG, ADFI, and G:F in this experiment. The effect of lysine level from dietary protein on average daily gain is shown in Table (3.4). Average daily gain (ADG) over the entire 21-day experimental period increased linearly ($P < .03$) with increasing level of natural lysine in the diet. Pigs fed Treatment 4 (1.40% lysine) grew 12% faster than those fed the diet the .95% lysine diet (Treatment 1, $P < .04$) and 6.5% faster than those fed the 1.10% lysine diet (Treatment 2, $P < .10$). Least squares means for average daily gain for Treatments 1 to 4 were .506, .520, .539, and .568 kg/d, respectively. These results indicate that increasing the level of dietary lysine improved gain and had the greatest effect on gain when added at the highest level (1.40%) in the diet. Pigs in Exp. 1 had higher mean ADG ($P < .0001$) values than those in Exp. 2 (.574 kg/day vs. .493 kg/day). Average daily gain was greater in wk 2 (P had higher mean ADFI (P < .0001) values when compared to those in Exp. 2 (.933 and .830 kg/day). Average daily feed intake for pigs in Exp. 1 was different (P < .05) in wk 1, 2 and 3.

Average daily feed intake does not appear to change as dietary protein level increases in the diet of the 10 to 20-kg pig (Campbell and Biden, 1978; Lunchick et al., 1978; Aherne and Nielsen, 1983). Lewis et al. (1981) observed a tendency for increased ADFI when lysine was added to the diet, but otherwise no changes in ADFI were observed as dietary lysine was increased.

The ADFI reported here (.861 kg/day) for 10 to 20-kg phase 2 nursery pigs is intermediate when compared to the values reported by other researchers (.596 to 1.082 kg/day) who have attempted to estimate the lysine and protein requirement for pigs from 10 to 20 kg (Campbell, 1978; Lunchick et al., 1978; Aherne and Nielsen, 1983; Lin and Jensen, 1985a; Lin and Jensen, 1985b; Thaler et al., 1986; Campbell et al., 1988).

Efficiency of feed utilization increased linearly (P < .002) with increasing lysine level in the diet over the entire 21-day experimental period (Table 3.3). Pigs fed Diet 4 gained 18% more per kg of feed (P < .002) than those fed Diet 1, 10.8% more per kg of feed (P < .04) than those fed Diet 2, and 7.99% more per kg (P < .12) than those fed Diet 3 during the overall 21-day experimental period. There was also a trend (P < .10) for pigs on Treatment 3 (1.25% lysine) to utilize feed more efficiently than those on Treatment 1 (.95% lysine). Least squares means for Treatments 1 to 4 were .562, .599, .614, and .663 kg gain/kg feed respectively (Table 3.4). These results indicate that increasing the level of dietary lysine improved gain to feed and had the greatest effect on G:F when added at the highest level (1.40%) in the diet. Feed efficiency was similar between the two experiments (P > .23) and G:F was affected by week (P < .0649). Least square means for wk 1 to 3 were 638, 574, and 616 g gain/kg feed (Table 3.5). Gain:feed was higher in wk 1 than in wk 2 (P < .022), but G:F was similar (P > .43) in wk 1 and 3. There is also a trend for improving G:F from wk 2 to wk 3 (P < .12).

Similar to our results, other research has reported an improvement in feed efficiency as dietary protein levels increase (Lunchick et al., 1978; Aherne and Nielsen, 1983; Campnell and Biden, 1988). Also other studies (Aherne and Nielsen, 1983; Martinez and Knabe, 1990; Mahan, 1992) reported an improvement in feed efficiency as dietary lysine increased up to about 1.15% dietary lysine in nursery pigs.

The G:F values (663 g gain/kg feed) reported here are higher than those reported by other workers, which range from 421 to 640 g gain/kg feed, in similar trials (Campbell, 1978; Lunchick et al., 1978; Aherne and Nielsen, 1983; Lin and Jensen, 1985a; Lin and Jensen, 1985b; Thaler et al., 1986; Campbell et al., 1988).

Initial pig weights averaged 10.22, 10.01, 10.24, and 10.05 kg for Treatments 1 through 4, respectively. Least squares means for wk 3 weights were 20.83, 20.92, 21.51, and 21.97 kg for Treatments 1 through 4 at the completion of the three week study. Pigs fed the higher lysine diet weighed more at the completion of the trial when compared to the other dietary treatments, however, differences were not significant.

Implications

In general, the results of this study indicate that faster growth and a higher gain to feed ratio can be achieved in 10 to 20-kg high lean growth genotype pigs if natural lysine content from dietary crude protein is increased to 1.40% in a corn-soybean meal-dried whey based diets. Further studies are necessary to evaluate the effect of higher lysine from crude protein on the growth and performance of 10 to 20-kg high lean growth genotype pigs. In addition, more research should be conducted to determine the limits of substitution of synthetic lysine for natural lysine sources.

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Table 3.1. Composition of experimental diets [a]

	Phase 1 diet	Phase 2 diets			
		Treatments			
Ingredient		1	2	3	4
AP300	0.00	2.75	2.75	2.75	2.75
Whey,Dehydrated	20.00	5.00	5.00	5.00	5.00
Dried Skim Milk	10.00	0.00	0.00	0.00	0.00
SBM,44%	15.00	11.00	16.50	22.00	27.75
Corn,Ground	38.415	75.025	69.605	64.175	58.505
Fishmeal,Menhaden	5.00	3.00	3.00	3.00	3.00
Lysine, HCL	0.25	0.00	0.00	0.00	0.00
DL-Methionine	0.02	0.00	0.00	0.00	0.00
Tallow	8.00	0.00	0.00	0.00	0.00
Tylan 40 [b]	0.00	0.125	0.125	0.125	0.125
Ethoxyquin	0.025	0.00	0.00	0.00	0.00
FOA 390** [c]	1.00	0.00	0.00	0.00	0.00
Flavor, Berry	0.10	0.00	0.00	0.00	0.00
Salt	0.00	0.40	0.40	0.40	0.40
Copper Sulfate	0.10	0.075	0.075	0.075	0.075
Calcium Carbonate	0.00	0.35	0.42	0.45	0.47
Dicalcium phosphate	1.35	1.90	1.75	1.65	1.55
Vitamin TM PMX [d]	0.74	0.38	0.38	0.38	0.38

[a] As fed basis.

[b] Supplied 100 g of tylosin per ton of complete feed.

[c] Supplied 200g Furazolidone, 100g Oxytetracycline, 90g Arsanilic acid per ton of complete feed.

[d] Premix supplied 4, 160 IU vitamin A, 416 IU vitamin D, 18 IU vitamin E, 20 mg pantothenic acid, 28 mg niacin, 4.0 mg riboflavin, .02 mg vitamin B_{12}, 1.3 mg biotin, .6 mg pyridoxine, .9 m folic acid, 3.9 mg thiamin, 267 mg choline, .1 mg selenium, .03 g manganese, .1 g zinc, .1 g iron, .01 g copper, .43 g potassium and .2 mg iodine, per lb. of feed in phase 1 and 3,000 IU vitamin D, 12.8 IU vitamin E, 15 mg pantothenic acid, 20.3 mg niacin, 3.0 mg riboflavin, .01 mg vitamin B_{12}, 193 mg choline, .07 mg selenium, .02 g manganese, .07 g zinc, .07 g iron, .07 g copper, .17mg iodine, per lb. of feed in phase 2.

Table 3.2. Calculated analysis of experimental diets [a]

	Phase 1 diet	Phase 2 diet Treatment 1	2	3	4
Lysine, %	1.40	.95	1.10	1.25	1.40
Crude Protein, %	19.40	16.19	18.15	20.11	22.16
Calcium, %	.99	.90	.90	.90	.90
Phosphorus, %	.85	.75	.75	.75	.75
M.E. (Kcal/kg)	3536.51	3277.36	3268.96	3260.42	3251.63
Tryptophan, %	.25	.21	.24	.27	.30
Threonine, %	.86	.69	.77	.84	.92
Met & Cyst, %	.70	.58	.62	.67	.71

[a] as fed basis

Table 3.3. Interactions for response variables

	Interactions		
	Exp. * week	Exp. * trt	Week * trt
Gain	.1302	.7617	.8177
Average Daily Gain	.1302	.7617	.8177
Average Daily Feed Intake	.0001	.8511	.9083
Feed Efficiency (gain:feed)	.0830	.9312	.8890

Table 3.4. Effect of dietary protein level during phase 2 of the nursery period on performance (kg)[a]

	Treatments				
	1	2	3	4	SEM
AverageDG, kg[b]	.506 [e]	.520 [ef]	.539 [ef]	.568 [f]	±.0448
ADFI, kg	.914	.871	.880	.861	±.0538
Feed Efficiency (G:F) [cd]	.562 [e]	.599 [e]	.614 [ef]	.663 [f]	±.0221

[a] LS means
[b] Linear increase in gain with increasing levels of lysine ($P < .02$)
[c] Linear increase in feed efficiency with increasing levels of lysine ($P < .002$)
[d] Treatment 1 differs from Treatment 3 ($p < .10$)
[ef] means in the same row with different superscripts differ ($P < .05$)

Table 3.5. Performance response for each week (kg) [a]

	Week			
	1	2	3	SEM
ADG, kg	.476 [b]	526 [c]	.598 [d]	±.0388
Feed Efficiency (G:F)	.638 [b]	.574 [c]	.617 [bc]	±.0191

[a] LS means
[bcd] means in the same row with different superscripts differ ($p<.05$)

Table 3.6. Effect of protein level on phase 2 average daily feed intake for each experiment (kg) [a]

	Experiment 1	Experiment 2	SEM
Week 1**	.82[b]	.66[e]	±.0659
Week 2***	1.03[c]	.83f	±.0659
Week 3	.94[d]	1.01[g]	±.0659
Overall 21-d Trial***	.93	.83	±.0381

[a] LS means
[bcd] means within a column lacking a common superscript letter differ (P < .01)
** means within a row differ (P < .01)
*** means within a row differ (P < .001)

CHAPTER IV

Effect of diet formulation based on ideal protein composition on performance during phase 2 of the nursery period

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ABSTRACT

The effect of diet formulation based upon ideal protein calculated requirements was studied utilizing 71 early weaned pigs averaging 22.5 d of age (ranging from 19 to 25 d). All pigs were fed a common phase 1 diet containing 1.50% lysine and 19.66 crude protein for the first 10 d following weaning. During phase 2 (average initial weight of 9.06 kg) pigs were fed one of the following diets. (1) The control diet (Treatment 1), which produced optimum performance in an earlier trial and contained 1.40% lysine from natural protein sources. (2) As Treatment 1 but corrected for by the addition of .13% synthetic methionine to meet the calculated methionine requirement based upon the Illinois ideal protein (IIP) ratio of indispensable amino acids (Treatment 2). (3) A reduced protein diet (1.29% lysine from natural protein sources) plus .14% added L-lysine HCL (making it equivalent to 1.40% total lysine) with .04% threonine added to meet the ideal protein requirement based upon the IIP ratio of indispensable amino acids (Treatment 3). This ration is adequate in all indispensable amino acids when compared to the IIP ratios except for a .16 deficiency in methionine. (4) As Treatment 3 but with synthetic methionine added to meet the calculated ideal amino acid requirements. Average daily gain (ADG) was similar ($P > .21$) among treatments. No differences ($p > .92$) were observed among dietary treatments for average daily feed intake (ADFI). Treatment 4 had a 10% greater gain:feed (G:F) ($p<.05$) than Treatment 1 in the total 4-wk experiment. During wk 2 both treatments that were deficient in methionine (Treatments 1 and 3) had poorer ($P < .05$) G:F than Treatment 4 which met the IIP indispensable amino acid requirements. During wk 3, the two diets in which natural lysine composed all of the 1.40% total lysine requirement (Treatments 1 and 2) had lower ($p<.05$) G:F than the 1.29% natural lysine diets with added lysine-HCL (Treatments 3 and 4). In wk 4, Treatment 1 had a lower G:F than Treatment 4 ($P < .05$). The results of this study indicate that formulating diets to meet ideal protein calculated ratios will result in a small nonsignificant improvement in gain and a significant improvement in feed efficiency in the 10 to 20-kg pig.

Key Words: Pig, Ideal Protein, Amino Acids, Methionine,

Introduction

In typical feed formulations that utilize natural feed ingredients there is usually an excess of many dispensable and indispensable amino acids. This oversupply of amino acids is not only wasteful, because the animal does not have the potential to convert the extra amino acids into body proteins, but has been suggested to depress performance (Kerr, 1988). Properly balanced diets have been shown to have a large impact on feed intake, growth, and carcass composition. Similarly, excesses of amino acids have been shown to be detrimental to animal performance (Edmonds et al., 1987). In 1981 the ARC (1981) proposed an ideal protein for growing swine in which indispensable amino acids were listed as ratio's to (percentage of) lysine. The concept suggests that once requirements are determined for lysine, other amino acids would be required in proportions dictated by ratios in the ideal protein. Chung and Baker (1992a) developed an ideal protein amino acid pattern for the 10 to 20-kg pig and compared performance of pigs fed the ideal protein pattern with performance of pigs fed several suggested patterns. Patterns tested were the Illinois final amino acid pattern (IFP, Chung and Baker, 1991) , the Wang and Fuller ideal amino acid pattern (WFIP, Wang and Fuller, 1989), the Illinois ideal amino acid pattern (IIP, Chung and Baker, 1992a), or the 1988 National Research Council (NRCP, NRC, 1988) amino acid requirement pattern for 10-kg pigs. Although the ideal protein concept suggests that performance should be enhanced in pigs fed diets based upon the ideal amino acid composition, this has not been demonstrated in practical swine diets. This study was conducted to determine the effect of diet formulation of practical swine diets based on the Chung and Baker (1992a) ideal protein composition. The 1.40% total lysine diet from natural protein sources that optimized gain, feed intake, and feed efficiency during phase 2 of the nursery period (10 to 20 kg) in chapter 3 was used as the lysine requirement. Calculations, based upon the Chung and Baker (1992a) IIP pattern of indispensable amino acids, indicate that methionine was deficient in this diet, therefor methionine was added to the 1.40% lysine diet to determine if performance was enhanced by methionine addition. In addition protein level was then reduced in the control diet by changing the ratio of corn to soybean meal (to the point where the fourth limiting amino acid requirement, isoleucine was met) and lysine and threonine or lysine, threonine and methionine was supplemented. Therefor specific objectives of this study was to (1) determine if methionine is limiting in a 1.40% lysine diet which produced the optimum performance in section one of this study; and (2) determine if reduced protein diets formulated to meet the Chung and Baker (1992a) ideal indispensable amino acid pattern utilizing crystalline amino acids will improve performance in phase 2 nursery diets.

Materials and Methods

A total of 71 Yorkshire, Hampshire and Crossbred (Yorkshire X Hampshire) pigs were used in this 28-d study to determine the effect of ideal protein diet formulation on performance. The pigs were weaned at an average of 22.5 d of age (ranging from 19 to 25 d) and averaged 6.07 kg body weight. Pigs were stratified by litter, weight and sex (boars and gilts) into 12 pens with 6 pigs in a pen. Pens were randomly allotted to one of four treatments (3 pens/treatment). The experiment was conducted as a completely randomized design. All pigs were fed a common phase 1 diet (Table 3.1 and 3.2) containing 1.50% lysine and 19.66% crude protein for the first ten d following weaning. During phase 2 (average initial weight of 9.06 kg) pigs were fed one of the following diets. (1) The control diet (Treatment 1, Table 3.1 and 3.2) which produced optimum performance in studies reported in Chapter 3 and contained 1.40% lysine from natural protein sources. (2) As Treatment 1 plus .13% synthetic methionine was added to meet the methionine requirement based upon the Illinois ideal protein (IIP) ratio of indispensable amino acids by Chung and Baker (1992a, Treatment 2). (3) A reduced protein diet (1.29% lysine from natural protein sources) plus .14% added L-lysine HCL (making it equivalent to 1.40% total lysine) with .04% threonine added to meet the ideal protein requirement based upon the IIP ratio of indispensable amino acids (Treatment 3). This ration is adequate in all indispensable amino acids when compared to the IIP ratios except for a .16% deficiency in methionine. (4) As Treatment 3 plus .16% methionine added to meet the calculated ideal amino acid requirements (IIP) for all amino acids. All four diets contained .90% calcium and .75% phosphorus which exceeds current NRC (1988) requirements. Pigs were allowed ad libitum access to diets and water.

Pigs were housed in an environmentally controlled nursery in elevated pens with woven wire floors, nipple waterers and open front self-feeders. The environmental temperature was initially 30°C, with a 1°C reduction in temperature each week until the temperature reached 26°C. Interim gain and efficiency of gain estimates were obtained weekly.

Statistics. Pen was considered the experimental unit and data were analyzed by least squares analysis of variance procedures (Steel and Torrie, 1980) using the GLM procedure of SAS (1985). The statistical model for ADG, ADFI, G:F and weight gain (G) included treatment. The difference between the control and each treatment was determined by Dunnett's procedure.

Results

One pig was removed from the trial because his total weight gain for the 4-wk trial was less than three standard deviations from the mean. This pig was removed from the gain calculations but was included when determining pen feed efficiency.

Initial pig weights averaged 8.88, 9.15, 9.03 and 9.12 kg for Treatments 1 through 4, respectively, after the 10-day phase 1 period in which all pigs received a common phase 1 diet (Tables 4.1 and 4.2). Performance was similar ($P > .10$) among pigs assigned to the four treatments during phase 1.

The effect of diet formulation to more closely simulate ideal protein composition on ADG, ADFI and G:F is presented in Table 4.3. The addition of .13% methionine (Treatment 2) to meet the IIP indispensable amino acid requirement (Chung and Baker, 1992a) to the 1.40% natural lysine control diet (Treatment 1) improved ADG in all weeks except wk 3 (Table 4.3), which resulted in a nonsignificant ($P > .43$) 5.01% greater ADG over the entire 4-wk trial. The improvement in ADG for wk 1, 2, and 4 were 9.76, 6.69, and 8.76%, respectively. Average daily feed intake for the entire trial was similar ($P > .60$) in pigs fed the control diet (Treatment 1) or the diet formulated to meet the ideal protein requirement by the addition of .13% methionine (Treatment 2), even though pigs fed the control diet (Treatment1) had a higher actual ADFI than pigs fed the methionine corrected natural protein diet (Treatment 2) in all weeks except for wk 4 (Table 4.3). Pigs fed the methionine corrected natural protein diet (Treatment 2) had higher G:F in all weeks when compared to those fed the control diet (Treatment 1, Table 3.3). This resulted in an nonsignificant 7.38% improvement in G:F over the entire trial. The improvement in G:F for wk 1 through 4 was 15.72, 7.32, 3.06, and 14.18%, respectively.

Improving amino acid balance to more closely reflect estimated ideal amino acid composition by reducing crude protein and supplementing lysine and threonine (Treatment 3) improved ADG by 4.84% over the 4-wk trial when compared to pigs fed the control diet (Treatment 1) although differences were not significant. The greatest improvement in gain occurred in wk 1 and wk 4 (14.93 and 9.71%, respectively), although differences were not significant. Reducing crude protein and supplementing the diet with lysine and threonine had no effect on ADFI. The overall ADFI over the 28-d trial for pigs fed Treatments 1 and 3 was similar with values of .890 and .881 kg intake/day, respectively (Table 3.3). Pigs fed the reduced protein diet supplemented with lysine and threonine (Treatment 3) utilized feed 8.06% ($P < .05$) more efficiently than those fed the control diet (Treatment 1) in wk 3, which resulted in a nonsignificant 5.90% improvement in G:F over the entire trial.

The further addition of methionine to the reduced protein diet (Treatment 4) resulted in a nonsignificant improvement in ADG of 8.35% for the overall experiment and an improvement in G:F during wk 2 (20.4%, nonsignificant), 3 (9.5%, $P < .05$), 4 (17.0%, nonsignificant), which resulted in a 10.82% ($P < .05$) improvement in G:F for pigs fed Treatment 4 over the entire trial when compared to those fed the control diet (Treatment 1) with amino acids from nonsynthetic sources. Over the 4-wk study pigs fed the reduced protein diet with amino acids supplemented to provide an ideal amino acid pattern (Treatment 4) had similar ADFI when compared to those fed the control diet (Treatment 1).

The two diets that met the IIP indispensable amino acid requirements (Treatments 2 and 4) were similar in ADG and identical in total trial ADFI (Table 4.3). In addition, Gain:Feed was similar ($P > .16$) for the two diets that met the IIP indispensable amino acid requirements (Treatments 2 and 4).

Discussion

In this study adding methionine to a high protein diet that recieve lysine only from dietary protein sources to more closely simulate ideal protein composition (Treatment 2) resulted in a slight but nonsignificant increase in ADG, no change in ADFI, and a nonsignificant 7.38% improvement in G:F over the entire trial. Altering the diet to more closely represent the IIP ideal protein pattern of indispensable amino acids by reducing protein and adding lysine and threonine (Treatment 3) resulted in nonsignificant improvements in ADG and G:F. Formulating a diet to more closely represent the IIP ideal protein pattern of indispensable amino acids by reducing protein and adding lysine, threonine and methionine (Treatment 4) resulted in a numerically higher ADG and a 10.82% improvement in G:F compared to the higher protein control diet (Treatment 1).

Similar pig performance in 10 to 20-kg pigs was reported by others feeding diets formulated to meet ideal protein patterns of indispensable amino acids. Chung and Baker (1992a) reported ADG of 597, 545, 573, and 570 g for pigs given ad libitum access to diets formulated to meet the Illinois final amino acid pattern (IFP), the Illinois ideal amino acid pattern (IIP), the Wang and Fuller ideal amino acid pattern (WFIP), and the 1988 National Research Council (NRC) amino acid requirement pattern for 10-kg pigs (NRCP). Average daily feed intake was 1007, 972, 994, and 994 g and G:F was 596, 563, 578, and 574 g/kg for pigs fed diets containing IFP, IIP, WFIP,and NRCP, respectively. The author's reported that when given ad libitum access to indispensable amino acids, pigs gained weight and converted feed to gain at a similar feed efficiency when fed diets containing IFP, IIP, WFIP, or NRCP. In a second experiment, all levels of indispensible and dispensible amino acids were reduced to 50% of levels present in Exp. 1. When pigs had ad libitum access to these diets, daily gains of pigs fed IIP were superior to those of pigs fed IFP or NRCP, but similar weight gains occurred in pigs fed IFP, WFIP and NRCP. In Exp. 3, the efficiency of nitrogen utilization of the four indispensable amino acid patterns was evaluated by a nitrogen balance experiment in pigs equally fed the same experimental diets fed in Exp. 2. Pigs fed NRCP utilized nitrogen less efficiently than pigs fed IFP, IIP and WFIP. In addition, grams of nitrogen retained per gram of nitogen intake from indispensible amino acids was greater for IIP than for either IFP or WFIP. The results of the second and third studies suggest that diets which meet ideal indispensable amino acid patterns more precisely may improve growth performance and efficiency of nitrogen utilization. Our study also showed a slight nonsignificant improvement in daily gain, as well as improved G:F.

Chung and Baker (1991) reported that pigs fed amino acid diets formulated to meet ideal protein calculated requirements of indispensable amino acids gained at the same rate and were as efficient as pigs fed the 20% protein C-SBM-10% DW positive control diet, with ADG, ADFI, and G:F of 511 g, 824 g, and 620 g/kg, respectively reported for the 10-kg pigs fed the purified amino acid diet. Furthermore, balance studies indicated that nitrogen and energy retention of pigs fed the amino acid diet was superior ($P < .05$) to values observed in pigs fed the intact-protein control diet. This study is similar to ours in reporting that pig growth and feed intake was equal if not better in diets formulated to meet the ideal protein requirements but does not report the improvement in G:F observed in our study.

This study reported ADG of 571 and 586 g for pigs fed diets formulated to meet ideal protein requirements which is very similar to those reported by Chung and Baker (1991, 1992a). Average daily feed intake reported here (872 and 872 g/d) was 48 g higher than that reported by Chung and Baker (1991) but about 125 g lower than that reported by Chung and Baker (1992a). Gain to feed reported here (655 and 676 g/kg) is higher than the 620 g/kg reported by Chung and Baker (1991a) and the 596, 563, 578 and 574 g/kg reported by Chung and Baker (1992a).

Some studies have reported increased daily gains and feed intakes with the addition of synthetic methionine similar to those reported in this study. Lunchick et al.

(1978) conducted an experiment that used corn-soybean meal and corn-soybean meal and L-lysine HCL to formulate diets which contained .92 and 1.0% total lysine. Each of the four treatments were repeated with or without .13% added supplemental methionine. The addition of methionine to the diets tended to increase feed intake and daily gain when soybean meal was the major source of protein. Owen et al. (1993a) reported that increasing dietary methionine quadratically improved ADG ($P < .01$), ADFI ($P < .05$), and G:F ($P < .05$) when feeding a corn-soybean meal based diet with 10% dried whey and 3% spray dried blood meal from day 7 to14 postweaning to pigs weaned at 21 days of age. Also Owen et al. (1993b) reported that ADG and ADFI were improved quadratically ($P < .01$) and was maximized when between .40 and .44% dietary methionine was fed (0 to 21 d postweaning) during phase 1 followed by .30% methionine during phase 2 (21 to 35 d postweaning). In contrast, Katz et al. (1973) reported that the addition of .10% DL-methionine to a 16% crude protein basal corn-soybean meal diet with .25% L-lysine HCL was without effect. Ong and Allee (1985) also reported similar ADG, ADFI, and F:G in pigs fed a 17.4% crude protein, 20% whey corn-soybean based diet with or without .1% supplemented DL-methionine.

Chung and Baker (1992b) reported a higher ADG for 10 to 20-kg pigs fed a methionine supplemented diet with a value of 665g ADG. However, gains in our study of 570.6 and 588 g/day by pigs fed the methionine supplemented diets are somewhat more than those reported by other workers for this age pig (Katz et al., 1973; Fetuga et al., 1975; Lunchick et al., 1978; Reifsnyder et al., 1984; Owen et al., 1993a; Owen et al., 1993b) which range from 439 to 665 g/day. In addition their reported G:F ratios were lower (.50-.64) than the .655 and .676 reported here as was the work by Chung and Baker (1992b).

Feed intake values reported here (871.7 and 871.7g/day) for starter pig diets with supplemental methionine are less than those reported by other workers which range from

921 to 1241 g/day (Katz et al., 1973; Lunchick et al., 1978; Chung and Baker, 1992a; Chung and Baker 1992b).

In this study G:F was improved when supplemental methionine was fed to meet ideal protein calculated requirements. Other studies have also reported a similar improvement in G:F when pigs were fed additional methionine. Owen et al. (1993a) reported that increasing dietary methionine from day 7 to 28-postweaning had no effect on ADG or ADFI, but G:F was improved when a 1.30% lysine corn-soybean meal based diet with 10% dried whey and 3% spray dried blood meal was fed to pigs weaned at 21 days of age. Fetuga et al. (1975) reported that the addition of synthetic methionine resulted in significant improvement in the rate and efficiency of gain but only at the 16 and 18% protein levels.

The trial was also analyzed as a 2 x 2 factorial arrangement of treatments in a completely randomized design to evaluate the efficacy of added methionine to meet IIP suggested ratios of indispensable amino acids in 1) a 22% crude protein corn-soybean meal-dried whey diet and 2) a 21% crude protein corn-soy bean meal-dried whey diet. Average daily gain was not affected by adding synthetic methionine or reducing crude protein. Average daily feed intake was only affected in wk 3 when pigs fed the reduced protein diets consumed more ($P < .05$) than those fed the higher protein diet. In wk 2 ($P < .04$), 3 ($P < .11$), and 4 ($P < .06$) pigs fed the diets with added methionine utilized feed more efficiently than those fed diets calculated to be deficient in methionine. In the overall 28 d trial pigs fed diets with added methionine to meet the IIP designated ratios gained weight more efficiently ($P < .03$) compared to those fed diets calculated to be deficient in methionine. In addition, those fed the reduced protein diets with added synthetic amino acids utilized feed more efficiently ($P < .08$) than those fed the slightly higher protein diet.

Implications

The suggestion that excess amino acids contribute to pollution in the environment through the release of excess nitrogen in the form of nitrates and may depress animal performance has resulted in research to determine the efficacy of low-protein, amino acid-supplemented diets for swine. This has led to the conclusion that minimum levels of amino acids must be present for maximum growth and proper ratios of amino acids must be present for maximum feed efficiency. These results indicate that formulating diets to meet ideal protein calculated ratios will result in a small nonsignificant improvement in gain and a significant improvement in feed efficiency in the 10 to 20-kg pig.

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Table 4.1. Calculated analysis of experimental diets used to determine the effect of ideal protein formulations on pig performance[a]

	Phase 1 diet	Phase 2 diet			
		Treatment			
		1	2	3	4
Lysine	1.50	1.40	1.40	1.40	1.40
Crude Protein	19.66	22.16	22.28	20.85	20.99
Calcium	.90	.90	.90	.90	.90
Phosphorus	.79	.75	.75	.75	.75
M.E. (Kcal/lb)	1582.46	1474.66	1472.64	1476.19	1473.70
Tryptophan	.26	.30	.30	.28	.28
Threonine	.93	.92	.92	.91	.91
Met & Cyst	.76	.71	.84	.68	.84

[a] as fed basis

Table 4.2. Composition of experimental diets used to determine the effect of ideal protein formulation on pig performance[a]

	Phase 1 diet	Phase 2 diets			
		Treatments			
Ingredient		1	2	3	4
AP300		2.75	2.75	2.75	2.75
AP820	5.00				
Whey,Dehydrated	20.00	5.00	5.00	5.00	5.00
Dried Skim Milk	10.00				
SBM,44%		27.75	27.75	23.80	23.80
Corn,Ground	38.67	58.50	58.37	62.20	62.04
Oats, Steam Rolled	10.00				
Soybean oil	4.00				
Pro-88	5.00				
Fishmeal,Menhaden	5.00	3.00	3.00	3.00	3.00
Lysine, HCL	0.28			0.14	0.14
DL-Methionine	0.02		0.13		0.16
Threonine				0.04	0.04
Mecadox-10	0.25				
Tylan 40		0.125	0.125	0.125	0.125
Turbozyme-160	0.20				
Flavor, Berry	0.10				
Salt		0.40	0.40	0.40	0.40
Copper Sulfate	0.08	0.075	0.075	0.075	0.075
Calcium Carbonate		0.47	0.47	0.45	0.45
Dicalcium phosphate	0.90	1.55	1.55	1.64	1.64
Vitamin TM PMX [d]	0.38	0.38	0.38	0.38	0.38
Special Premix	0.12				
	100.00	100.00	100.00	100.00	100.00

a As fed basis.

d Premix supplied

Table 4.3. Effect of diet formulation based on ideal protein composition on average daily gain, average daily feed intake and feed efficiency[a]

	Treatments				
Item	**1**	**2**	**3**	**4**	**SEM**
No. of Pigs	17	18	18	18	—
Week 1 ADG	.325	.357	.373	.330	.0822
Week 2 ADG	.548	.585	.535	.650	.1069
Week 3 ADG	.680	.665	.689	.684	.0349
Week 4 ADG	.621	.675	.681	.692	.0686
Overall ADG	.543	.571	.570	.589	.0514
Week 1 ADFI	.568	.545	.577	.586	.0507
Week 2 ADFI	.772	.767	.763	.758	.0776
Week 3 ADFI	1.094	1.040	1.026	1.008	.0501
Week 4 ADFI	1.121	1.135	1.162	1.135	.0727
Overall ADFI	.890	.872	.881	.872	.0491
Week 1 G:F	.566	.655	.650	.560	.0550
Week 2 G:F	.710	.762	.700	.855	.0422
Week 3 G:F	.621	.640	.671[b]	.680[b]	.0075
Week 4 G:F	.522	.596	.586	.611	.0160
Overall G:F	.610	.655	.646	.676[b]	.0141

[a] LS means kg gain/kg feed
[b] Means with a superscript letter differ from Treatment 1 ($P < .05$)

VITA 2

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