PROTEIN REQUIREMENTS FOR THE
YOUNG GROWING BOAR

By

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CHAPTER I

INTRODUCTION

Both verbal and written communication with individual breeders across the United States has revealed a range of crude protein levels of 12 to 18% being fed to boars, with indecision by each as to which level would allow boars to develop their maximum growth rate, feed efficiency, longissimus muscle area and minimum backfat.

Although a number of studies have been conducted to determine the protein requirements of gilts and barrows, few studies have been conducted with the growing boar. The assumption is often made that the protein requirements of growing boars will be higher than that of barrows or gilts because of the leaner carcass produced by the boars. However the level of protein to feed growing boars has not been sufficiently documented.

With the cost of dietary crude protein, the major source of amino acids for pigs, increasing more than 100% from 1971 through 1975 (Cockrane and Kastens, 1976), of prime importance to the producer is the determination of the least amount of protein that can be fed while maintaining performance.

The objectives of this study were:

(1) to determine the effect of dietary crude protein levels on growth responses average daily gain, fed efficiency, average daily

feed intake, backfat thickness and longissimus muscle area in growing boars.

(2) to determine the effect of replacing a portion of the crude protein with the first-limiting amino acid, lysine, on boar performance and carcass characteristics.

CHAPTER II

LITERATURE REVIEW

This review will survey the literature relating to the following:

(1) the current crude protein levels being fed to growing boars and the levels currently recommended.

(2) the differences in growth and carcass characteristics and possible dietary protein requirement differences due to sex.

Current Levels of Crude Protein Being Fed and Recommended Levels for Growing Boars

Based upon research utilizing barrows and gilts, N.R.C. (1973), has published protein recommendations for growing-finishing swine. However, no specific recommendations are made for the growing boar.

A recent study of boar test stations throughout the nation by Bereskin et al. (1973) shows the levels of crude protein fed to growing boars varies from 12% to 18%. The level of crude protein fed at the Oklahoma Boar Test Station has ranged from 15% to 18%, while producers in Oklahoma normally feed protein levels ranging from 14% to 18% of the diet (Luce, 1976).

Spear et al. (1957) reported that a 19% crude protein diet, from an initial starting weight of 13.6 kg, for a fifty-six day feeding period supported maximum gains for young boars. Further, protein levels ranging from 16% to 25% had little effect upon growth rate and feed efficiency from 13.6 kg to 88.4 kg. In more recent studies Creswell et al. (1975) reported that a 17% to 13% crude protein ration from 25 kg to 55.8 kg and 55.8 kg to 94.8 kg live weight, respectively, supported higher rates of gain and feed efficiency for young boars than lower levels of protein. When boars, barrows, and gilts were fed various levels of crude protein, 18% vs 16% or 132, (Newell and Bowland, 1972) boars responded more to higher protein levels, with higher feed conversions ($P < .05$) and more carcass muscle with less fat ($P < .01$) than did barrows or gilts.

Moser and Gilster (1976) suggest that for optimum performance, boars from weaning to 31.8 kg should be fed 18% protein and a level of 16% protein from 31.8 kg to 99.8 kg. Hines et al. (1975) reported that a 12% crude protein ration is adequate for boars from 45 kg to 110 kg.

Luce et al. (1976) reported that for boars on a growing-finishing two-phase system, average daily gain over the entire period (23.8 kg to 99.6 kg) increased linearly ($P < .01$) and feed required per unit gain decreased quadratically ($P < .05$) as the percent protein in the diet increased from 16 to 20% in Period 1 (23.8 to 54.4 kg live weight) and 14 to 18% in Period 2 (54.4 to 99.8 kg live weight). Backfat decreased in a linear fashion ($P < .01$) and longissimus muscle area increased linearly ($P < .05$) as protein in the diet increased.

It appears that the lack of consistency from experimental trials and the trial and error method of feeding by the producer has not sufficiently determined the level or levels of crude protein that will allow maximum development in the growing boar.

Sex Differences in Growth and Carcass Characteristics and Possible Differences in Dietary Protein Requirements

In years past emphasis has been almost totally on the proper nutrition of the barrow and gilt, with little or no interest in the requirements of the young growing boar. Since information concerning boar nutrient requirements is very limited, it is essential that the performance of gilts and barrows be compared to determine if perhaps a sex x nutrient interaction exists, or if the same level of nutrients in the ration will suffice for all boars, barrows and gilts.

Lucas et al. (1971) found that barrows ate more feed and gained faster than gilts, but that gilts had leaner carcasses, when ration protein content ranged from 10% to 16%, increasing the 2% increments. Pigs of both sexes were leaner when fed higher protein levels than those fed lower protein diets.

Tjong-A-Hung et al. (1972) observed that barrows gained faster than gilts ($P < .01$). When barrows and gilts were fed either a 19% to 16% or a 16% to 13% ration, in a two phase growing-finishing system, both sexes gained faster and had superior feed efficiency as compared to the gains and feed efficiency of barrows and gilts fed a 13% to 10% protein sequence. Other workers (Irvin et al., 1975; Kornegay et al., 1973; and Pierce et al., 1972) also noted that gilts averaged higher in percent lean cuts, but grew slower than barrows.

Hale et al. (1967), feeding barrows and gilts, reported feed required per unit of weight gain decreased ($P < .05$) when the protein content of the diet was increased from 14% to 11% to either 16% to 13% or 18% to 15% protein in a two-phase feeding system. Carcasses of pigs fed the 18% to 15% protein diets contained less backfat and had a larger loin-eye muscle ($P < .05$) than carcasses of pigs fed either the 14% to 11% or 16% to 13% protein diets. Barrows gained faster ($P < .01$), but gilts yielded carcasses which were longer, had less backfat, had a larger loin-eye area, and had a higher yield of lean cuts ($P < .01$).

Bereskin et al. (1975), feeding barrows and gilts from high and low fat lines of Durocs and Yorkshires, found barrows to gain 7% faster ($P < .01$) than gilts. Gain or feed consumption was not found to be greatly affected by dietary protein level (20% to 14%). However, both gain and feed consumption were significantly affected by line x sex and breed x line x sex interaction. The Duroc breed outgained Yorkshires with the high-fat lines eating more than the low-fat lines. Low-fat Durocs outgained high-fat Durocs, but the reverse was true for Yorkshires, resulting in the breed x line interaction. Also, feed conversion was not significantly affected by sex, breed x sex, line x sex, protein or protein x energy during this trial but was affected by line and breed x line. In a later reporting of this experiment it was concluded that the need to consider sex effects in swine testing should be re-emphasized since breed x line and/or line x sex interactions were significant for all carcass traits except percent bone of ham (Bereskin et al., 1976).

Five hundred and five gene pool boars, barrows, and gilts and 126 Hampshire boars and gilts were fed two diets by Cunningham et al. (1973). One diet consisted of high lysin corn, minerals, and vitamins with a crude protein level of 10% and the other diet was a straight corn-soy-bean meal diet containing 14% c.p. A significant sex x diet interaction for daily gain was found for boars and gilts, with boars growing faster on the 14% c.p. corn-soybean diet and the gilts having faster gains on the 10% c.p. high lysine corn ration. From the observed results it was concluded that boars required a higher level of dietary crude protein than gilts.

Newell and Bowland (1972) found boars to have superior feed conversions ($P < .05$) and carcasses with more muscle and less fat ($P < .01$) than barrows and gilts. The boars were found to respond more to a high protein level (18% c.p. vs. 16-13% c.p.) fed throughout the trial than to lower levels fed in a two period feeding system. A significant interaction was found to exist between sex and protein as a result of this increased response. They ranked the sexes in order of carcass superiority with boars, gilts, and barrows as 1, 2, and 3 respectively. Many others have also found boars to have leaner carcasses than barrows (Charette, 1961; Christain, 1971; Omtvedt and Jesse, 1971).

Siers (1975), upon feeding 114 Yorkshire boars, barrows and gilts, found that boars and gilts had significantly larger loin-eye areas and higher ham-loin percentages than barrows. Boars also had the highest average daily gains, with gilts and barrows ranking second and third, respectively.

Davey et al (1976) found no major differences in rate of gain between boars and gilts, within a level of dietary protein, but did find that both sexes gained at a faster rate ($P < .01$) when fed a level of 20% protein, compared to those receiving 12% protein rations. Pigs fed the 20% level also had heavier carcasses and significantly ($P < .01$) less carcass fat than the groups fed the lower protein level.

Davey and Morgan (1969) found that pigs fed 20% protein diets gained faster ($P < .01$) than those receiving diets with 12% protein. There was nonsignificant differences in rate of gain between boars and gilts. Gain for gilts tended to plateau, while those for boars increased in a linear fashion up to 196 days of age. The carcasses of pigs fed the 20% protein diet were significantly heavier at 160-day slaughter weight than carcasses of pigs on a 12% level of protein, reflecting the more rapid gain. The percent of carcass fat was also less in pigs on the higher levels of protein.

Martin (1969), in a review, concluded that there is an advantage for boars in efficiency of feed utilization; however, most of this research failed to consider the composition of the gain.

Kornegay et al. (1973), evaluating gilt and barrow carcasses, determined that gilts had leaner carcasses than barrows. These workers further stated that if gilts produced leaner carcasses, then, theoretically, gilts may require a higher dietary protein level. This has been shown to be the case by Tanksley (1970) and Wallace and Lucas (1969).

If gilts do in fact require a higher level of dietary protein than barrows because of leaner carcasses, then boars may require a higher level of protein than either gilts or barrows because of the leaner carcass produced by the boar.

Relationship of Percent Lysine to Percent Crude Protein in Rations for Growing Swine

Evaluation of levels of protein considered inadequate for normal growth in swine requires supplementation of the first known limiting factor, other than protein, in an attempt to obtain a better estimate of the true response in growth to low protein levels.

Sharda et al. (1976) has shown that lysine is the first limiting amino acid in a low protein corn-soybean meal diet. Accepting lysine as the limiting factor in the diet to be supplemented, this review will survey the current literature concerning the general relationship of percent lysine to percent protein in the rations of growing swine.

Baker et al. (1975) found the dietary requirement of lysine for growing pigs to decrease .02% for each 1.0% decrease in level of dietary crude protein. Also reported was that a 14% protein diet containing additional lysine to provide a total level of .73%, allowed performance similar to that obtained with a 16% protein ration containing .77% lysine.

Baker (1973) reported that for growing pigs from approximately 18 to 54 kg, the reduction in crude protein from 19 to 16%, with supplemental lysine added to equalize levels, supported optimal rate of gain. Rate of gain and feed efficiency has also been reported to be similar for pigs fed either 17 or 14% protein diets when .1% lysine was added to the lower level (Wahlstrom et al., 1974).

However, Meade (1965) using protein levels of 12, 14 and 16% found no significant differences in growth when additional lysine, lysine plus methionine, or no supplement was added to a corn-soybean meal diet.

Hines et al. (1975) suggests that a 12% protein ration containing 55% lysine is adequate for growing boars, while Brown et al. (1973)

reports that for various carcass characteristics of barrows and gilts, a range of .51 to .60% dietary lysine is adequate.

However, Luce et al. (1976) feeding diets containing 16 to 14% protein on a two-phase feeding system, reported that these levels of protein were inadequate for growing boars from approximately 55 to 99 kg. The lysine content of the 16 and 14% rations were .76 and .62% respectively.

The various references cited have reported different levels of lysine required at different levels of dietary protein, but none with respect to supplementing lysine in diets of growing boars when level of protein was low.

CHAPTER III

PROTEIN REQUIREMENT OF THE YOUNG GROWING BOAR

Summary

Five separate trials, with 425 growing Duroc, Hampshire and Yorkshire boars, were conducted to evaluate the effects of six levels of crude protein on average daily gain, feed intake, feed required per unit of gain, backfat thickness and longissimus muscle area. Upon completion of these trials, the results were combined in a regression model to give a response change of each variable to increasing protein levels.

Experimental levels of crude protein ranged from 14% to 24%, increasing in 2% increments, from approximately 22 to 54.4 kg live weight. From approximately 54.4 to 100 kg., levels of dietary protein was reduced 2% in each treatment.

Results indicate that from approximately 22 to 54.4 kg feed efficiency and rate of gain for growing boars responded quadratically ($P < .01$, $P < .0005$, respectively) to increasing levels of protein while feed intake was not significantly affected. In Period 2, average daily feed intake feed efficiency and average daily gain tended to show a linear response to increasing protein in the diet but differences due to treatment were non-significant (54.4 to 99.8 kg, live weight).

Increasing level of protein during the total trial period, approximately 22 to 99.8 kg live weight, produced no significant differences in average daily feed intake. Average daily gain ($P < .003$) and longissimus muscle area ($P < .0001$) responded quadratically to protein level. This would suggest that the level of protein for maximum response of these variables in growing boars had been reached. However, the linear response of feed efficiency ($P < .001$) and backfat thickness ($P < .001$) to increasing levels of protein indicate that the level needed for maximum efficiency or minimum backfat had not been reached.

Materials and Methods

The boars used in this study were obtained from the purebred Duroc, Yorkshire, and Hampshire lines maintained as a part of the swine breeding project at Stillwater.

A total of 425 boars were utilized in five separate trials. Within trials, the boars were randomly allotted by breed and litter to one of three dietary treatments. Dietary treatments were increasing levels of crude protein, at 2% increments, in a standard corn-soybean meal-based ration.

Methods of data collection, evaluation and facilities were the same for each individual trial, with animals, time of year, and dietary treatments varying between trials.

Individual trials, treatment within that trial, and number of boars per treatment and per pen are shown in Tables I through IV. Replications of the experimental unit (pen of boars) on the individual treatments are also shown. Since trial 2 is a complete replication of Trial 1, the combined results are reported.

TABLE I

TRIALS 1 AND 2

Dietary Crude Protein (%)	Treatments[a]		
	16 to 14	18 to 16	20 to 18
Boars, No.	72	72	72
Boars per pen, No.	9	9	9
Replicates, No.	8	8	8

[a]The higher protein level was fed until boars reached approximately 54.4 kg. Protein was then reduced 2% until the trial was completed.

TABLE II

TRIAL 3

Dietary Crude Protein (%)	Treatments[a]		
	14 to 12	16 to 14	18 to 16
Boars, No.	36	36	36
Boars per pen, No.	9	9	9
Replicates, No.	4	4	4

[a]The higher protein level was fed until boars reached approximately 54.4 kg. Protein was then reduced 2% until the trial was completed.

TABLE III

TRIAL 4

Dietary Crude Protein (%)	Treatments[a] 18 to 16	20 to 18	22 to 20
Boars, No.	18	18	18
Boars per pen, No.	9	9	9
Replicates, No.	2	2	2

[a]The higher protein level was fed until boars reached approximately 54.4 kg. Protein was then reduced 2% until the trial was completed.

TABLE IV

TRIAL 5

Dietary Crude Protein (%)	Treatments[a] 20 to 18	22 to 20	24 to 22
Boars, No.	18	18	18
Boars per pen, No.	9	9	9
Replicates, No.	2	2	2

[a]The higher protein level was fed until boars reached approximately 54.4 kg. Protein was then reduced 2% until the trial was completed.

Boars, in each separate trial, were housed and grouped in open-front concrete finishing floors containing individual 2.1 x 5.2 m pens equipped with self-feeders and automatic waterers.

When ambient temperatures were in the 29° to 35°C range, water mist-foggers were used to aid in cooling the boars. No means of environmental control was provided at temperatures below this range.

After the boars were allowed a one week adjustment period, they were individually weighed and placed on test. Average pen weight was approximately 22 kg for all boars when the experiments started. Boars were removed from the experiment when they reached approximately 100 kg. The total treatment period, within each trial, was also subdivided into Period 1 (approximately 22 to 54.4 kg) and Period 2 (approximately 54.4 to 99.8 kg).

Period 1

Period 1, for each trial, was the period of time from the start of the experiment until the average pen weight was approximately 54.4 kg. Levels of crude protein fed during this period were: 16, 18 and 20% in Trials 1 and 2; 14, 16, and 18% in Trial 3; 18, 20 and 22% in Trial 4; and 20, 22 and 24% in Trial 5 (Table V).

Individual boar weights were taken weekly throughout the trial. At the end of Period 1 average daily gain, average daily feed intake, average feed per kilogram of gain, and total pen feed consumption was calculated on a pen basis.

Period 2

The boars, within each trial, started Period 2 immediately upon

TABLE V

COMPOSITION OF EXPERIMENTAL RATIONS

	Level of Protein						
	Treatments						
	1		3		5		
		2		4		6	
Ingredient (%)	12% CP	14% CP	16% CP	18% CP	20% CP	22% CP	24% CP
Yellow Corn	83.14	75.0	69.5	64.0	58.3	52.8	47.25
Soybean meal (44%)	8.31	16.5	22.1	27.75	33.5	39.1	44.75
Wet molasses	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Dicalcium phosphate	1.8	1.75	1.65	1.5	1.4	1.3	1.2
Calcium carbonate	0.7	0.7	0.7	0.7	0.75	0.75	0.75
Vitamins-trace mineral mix[1]	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Aurcomycin 50	0.05	0.05	0.05	0.05	0.05	0.05	0.05
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00
% crude protein, calculated	12.0	14.03	15.99	17.99	20.02	22.00	24.00
% calcium, calculated	0.71	0.71	0.71	0.69	0.69	0.71	0.70
% phosphorus, calculated	0.61	0.61	0.61	0.61	0.61	0.61	0.61
% lysine, calculated	0.37	0.59	0.73	0.92	1.07	1.15	1.29

[1]Supplied 3,000,000 I.U. vitamin A, 3000,000 I.U. vitamin D, 4 gm. riboflavin, 20 gm. pantothenic acid, 30 gm. niacin, 1000 gm. choline chloride, 15 mg. vitamin B_{12}, 6,000 I.U. vitamin E, 20 gm. menadione, 0.2 gm. iodine, 90 gm. iron, 20 gm. manganese, 10 gm. copper and 90 gm. zinc per ton of feed.

[A]Two rations under treatment number indicate protein levels fed during Period 1 and 2. The higher protein level was fed from 22 to 54.4 kg (Period 1) followed by a 2% reduction in protein from 54.4 to 100 kg (Period 2).

completion of Period 1. Dietary treatment change for the various trials was a 2% reduction in crude protein. The levels of protein fed during this period were: 14, 16 and 18% in Trials 1 and 2; 12, 14 and 16% in Trial 3; 16, 18 and 20% in Trial 4; and 18, 20 and 22% in Trial 5 (Table V).

All boars were weighed weekly throughout the trial and individually removed from test as they reached approximately 99.8 kg. In instances where all but one or two boars in a pen reached the minimum final weight, the remaining boars were weighed and removed.

Average daily gain, feed per kilogram of gain, and average daily feed intake was calculated for each boar removed from test and for the entire pen when all boars had been removed. In addition, ultrasonic estimates of backfat thickness and longissimus muscle area were made by use of the Ithaco Scanogram Model 721 instrument.

Scanogram readings for estimated backfat thickness were taken at the middle over the first rib, last rib, and last lumbar vertebra for each animal. The longissimus muscle area estimates were taken over the tenth rib starting at the midline. All scanogram estimates were adjusted to a 99.8 kg basis for each boar using the conversions issued by the National Association of Swine Records (1970).

Each trial was conducted independently and was analyzed separately. Since treatments were applied to pens, pens were the experimental unit. Therefore, a pen means analysis was conducted on each trait. With pens as the experimental unit, the design of each trial was a randomized block, utilizing a model to include the effects of blocks, treatments and blocks x treatments, as the error term. Differences among treatments within the same trial were evaluated using Duncan's New Multiple

Range Test (Steele and Torrie, 1960), for Trials 3, 4, and 5.

To determine the average growth change of growing boars as the level of crude protein increased (14 to 24%) in two percent increments, a regression analysis was performed on the combined data. The five individual trials were combined to form an incomplete block design (Figure 1) and analysis of the response, i.e., average daily gain for Periods 1, 2 and total, adjusted backfat thickness, etc., was performed by the Oklahoma State University computer using the S.A.S. 1972 program (Barr and Goodnight, 1972).

The initial model partitioned the variation into sources shown in Table VI. Trial x treatment interaction was not significant for any of the growth responses and allowed further modification of the model. The final model formed considered those sources of variation due to trial, replications with trial, and treatment. The final model is shown in Table VII. It should be noted that treatment effects were partitioned into linear and quadratic components.

Next, two regression analysis were computed, one showing the linear treatment response, and the other, linear plus quadratic treatment effects. When a quadratic response was probable ($P < .25$), the analysis that included the quadratic effect was used. The opposite was true when the quadratic response had a probability value greater than .25. The quadratic response was, therefore, the determining factor in deciding which model best described the data.

The analysis of variance for each variable is presented in Tables XVII to XIX in the Appendix.

All growth responses were plotted using $\hat{Y} = \alpha + \beta\ (x)$ or $\hat{Y} = \alpha + \beta_1\ (x) + \beta_2\ (x^2)$ as prediction equations when effects due to the level

	Highest Percent Crude Protein Fed in the Two Phase Sequence					
	14	16	18	20	22	24
Trial 1		4 pens 9 boars/pen	4 pens 9 boars/pen	4 pens 9 boars/pen		
Trial 2		4 pens 9 boars/pen	4 pens 9 boars/pen	4 pens 9 boars/pen		
Trial 3	4 pens 9 boars/pen	4 pens 9 boars/pen	4 pens 9 boars/pen			
Trial 4			2 pens 9 boars/pen	2 pens 9 boars/pen	2 pens 9 boars/pen	
Trial 5				2 pens 9 boars/pen	2 pens 9 boars/pen	2 pens 9 boars/pen
Trial 6	4 pens 9 boars/pen	12 pens 9 boars/pen	14 pens 9 boars/pen	12 pens 9 boars/pen	4 pens 9 boars/pen	2 pens 9 boars/pen

	Treatments		
Trial 1	16 to 14% c.p.	18 to 16% c.p.	20 to 18% c.p.
Trial 2	16 to 14% c.p.	18 to 16% c.p.	20 to 18% c.p.
Trial 3	14 to 12% c.p.	16 to 14% c.p.	18 to 16% c.p.
Trial 4	18 to 15% c.p.	20 to 18% c.p.	22 to 20% c.p.
Trial 5	20 to 18% c.p.	22 to 20% c.p.	24 to 22% c.p.

Figure 1. Combination of Trials 1 Through 5

TABLE VI

PRIMARY A.O.V. (ANALYSIS OF VARIANCE)

A.O.V. Source	df
Regression	25
Trial	4
Rep (Trial)	11
Treatment	5
Linear	1
Quadratic	1
Residual	3
Trial x Treatment	5
Linear x Trial	4
Quadratic x Trial	1
Error	22
Corrected Total	47

TABLE VII

FINAL MODELS USED - DEPENDING ON QUADRATIC OR LINEAR EFFECTS

A.O.V. Source	df	A.O.V. Source	df
Regression	16	Regression	17
Trial	4	Trial	4
Rep (Trial)	11	Rep (Trial)	11
Linear	1	Linear	1
		Quadratic	1
Error	31	Error	30
Corrected Total	47	Corrected Total	47

of protein was significantly linear or quadratic, respectively.

$\hat{Y}$ = the estimate of the dependent variable at a given level of the independent variable.

α = Y intercept.

β = the measure of slope of the line when only linear effects are considered.

β_1 = the partial regression coefficient attributed to linear effects.

β_2 = the partial regression coefficient attributed to curvilinear effects.

X = independent variable (a specific level of protein).

$(X)^2$ = independent variable squared.

Therefore, each graph shows the average change in the dependent variable for each unit (2%) change in level of protein. Actual mean values for treatment response for each individual trial has also been plotted on each graph.

Results and Discussion

Evaluation of the growth responses will be discussed separately within each period and for the total trial. Graphic representations of responses are additionally illustrated with individual trial and treatment with that trial in each case where a significant response was observed. Tabular results, within the various periods for the individual trials and treatments, may be found in Tables XIII through XVI of the Appendix.

Period 1

Average daily feed intake during Period 1 was not significantly affected by protein level when data from all five trials were combined.

Increasing the level of protein from 14% to 24% caused a significant ($P < .01$) quadratic response in kilograms of feed required per kilogram of gain (Figure 2). The combined response of all trials closely followed the changes found in Trials 2, 3 and 4. However, a level of 24% protein in Trial 5 resulted in a reduction in feed efficiency when compared with either the 20 or 22% protein levels.

Boars in Trials 1, 2, 3 and 4 had increasing average daily gains as level of protein in the ration increased from 14% to 20% (Figure 3). With a further increase in protein level (22% and 24%) no significant changes were found in average daily gain for boars in Trials 4 and 5. When data from all trials were combined, average daily gain increased quadratically ($P < .0005$) as percent of protein in the diet went from 14 to 24%. The increase in average daily gain from 14% to the 20% would suggest that ration levels of protein less than 20% would not allow growing boars in this weight range (22 kg to 54.4 kg) to gain at their maximum rate.

Period 2

No significant differences in average daily feed intake. Average daily gain or feed efficiency were noted from approximately 54.5 kg to 99.8 kg.

Combining the individual trial data and regressing kilogram of feed per kilogram of gain on protein level produced no significant difference, but individual analysis of trials 1 and 2 (Luce et al., 1976) indicated a significant quadratic effect ($P < .05$) on efficiency of gain during Period 2.

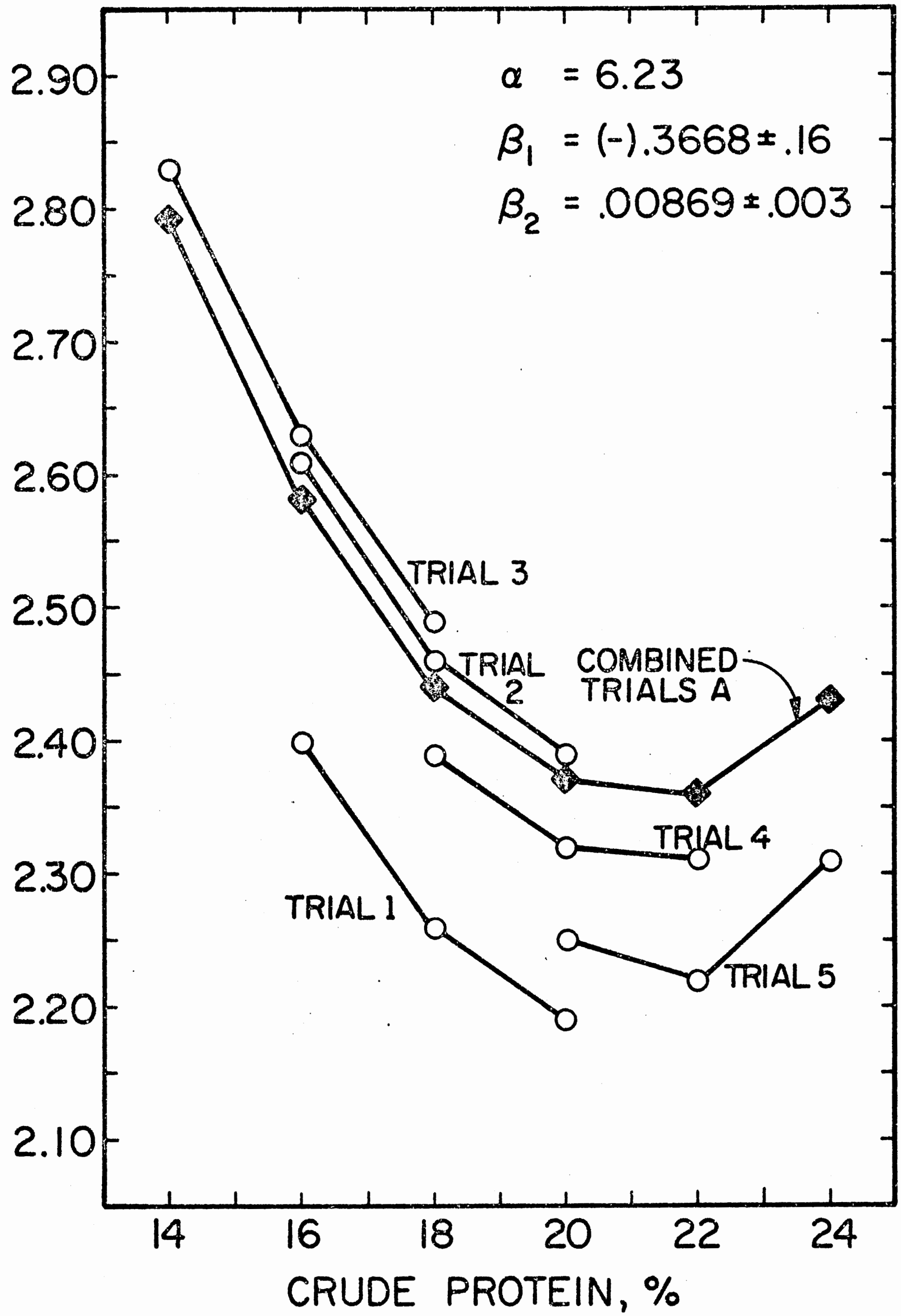

Figure 2. Kilogram Feed Per Kilogram Gain - Period 1; A Significant Quadratic Effect ($P < .01$)

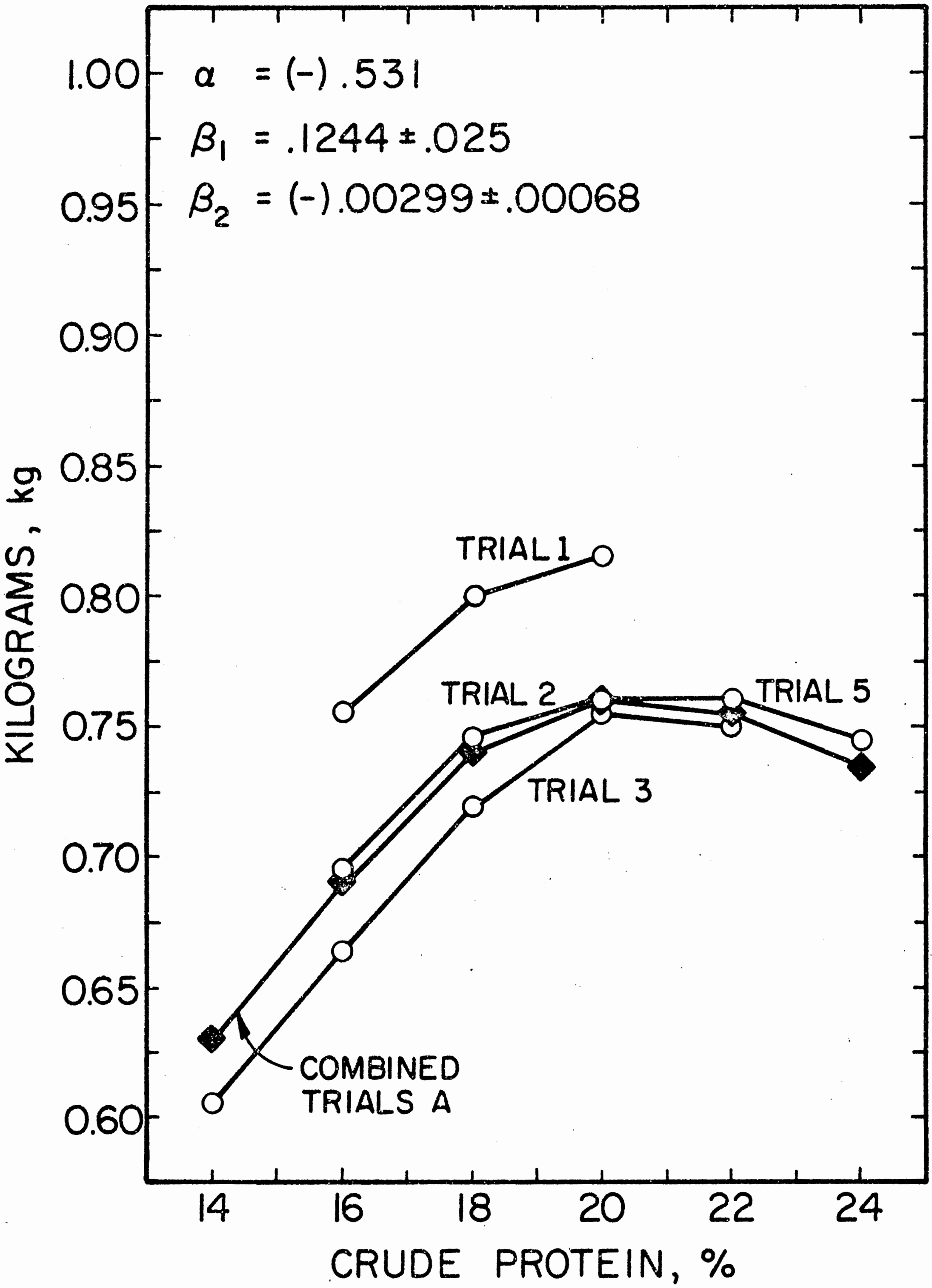

Figure 3. Average Daily Gain - Period 1; A Significant Quadratic ($P < .0005$)

Average daily gain increased linearly (P < .01) with protein during Trials 1 and 2 (Luce et al., 1976), but increases in daily gain during Trials 3, 4, and 5 were not greatly different across treatments.

Total Trial Period

Average daily feed intake tended to increase as growing boars approximately 22 kg to 100 kg) were fed increasing levels of crude protein, from 14% to 20% and decreased as protein level increased to 22 and 24%. This trend was not significant (quadratic effect, P < .23) but the tendency for an increasing average daily feed intake, through the 20% protein level, is in agreement with results published by other workers (Bereskin et al., 1975 and Luce et al., 1976). The cause of decreased intakes, by boars, as protein advanced from 20% to 24%, is unknown, but may be due to an amino acid imbalance. The likelihood of an amino acid imbalance as a causitive agent for decreased intakes will be discussed in conjunction with decreased average daily gains later.

Kilograms of feed required per kilogram of gain decreased in every trial (Trials 1, 2, 3, 4 and 5) as percentage of dietary protein increased, producing a linear (P < .0001) response to increasing protein when these trials were combined (Figure 4). These findings are not in total agreement with Luce et al. (1976) who reported a quadratic (P < .05) response or Spear et al. (1957), and Bereskin et al. (1975), who stated protein levels from 15% to 24% and 14% to 20%, respectively, to have little effect on feed efficiency. However, Hale (1967), reported reduced feed required per unit weight gain as protein was increased (from 14% - 11% to 18% - 15%). Average daily gain increased quadratically (P < .003) with increasing dietary protein levels.

The quadratic response of average daily gain to increasing protein is shown by the increasing change in gain as protein advances from 14% to 20% followed by a decline in average daily gain as protein percentage increased to 22% or 24% (Figure 5). Individual trial data shows that as level of protein advanced to the 20% level, average daily gain increased; but higher levels resulted in a reduction in gains. Reinhard et al. (1976) also found boars to have increased gains as protein advanced in 2% increments, from 14% to 18%, but to decrease as protein levels were increased to 20% or 22%. Other workers (Davey, 1976; Davey and Morgan, 1969 and Luce et al., 1976), reported similar findings, but not all researchers are in agreement. Several workers (Spear et al., 1957; Creswell et al., 1975; Moser and Gilster, 1976; Hines, et al., 1975 and Bereskin et al., 1976) reported that gain for growing boars reached a maximum at protein levels lower than 20%. No explanation of the differences found by other workers can be given here, but with the levels of protein and numbers of animals used in this experiment, there is very strong evidence that for maximum average daily gain for young boars, a two-phase sequence of 20% to 18% protein is required.

The decreased average daily gains at the higher protein levels (22 and 24% c.p.) and the tendency for a decrease in average daily feed intakes could possibly be the result of an amino acid imbalance or antagonism. Munro (1970) defines an amino acid imbalance as "a change in the proportions of amino acids in a diet which results in a depression in food intake or growth rate that can be completely prevented by a supplement of the indispensable amino acid present in least amount in the diet in relation to the amount required for optimal performance".

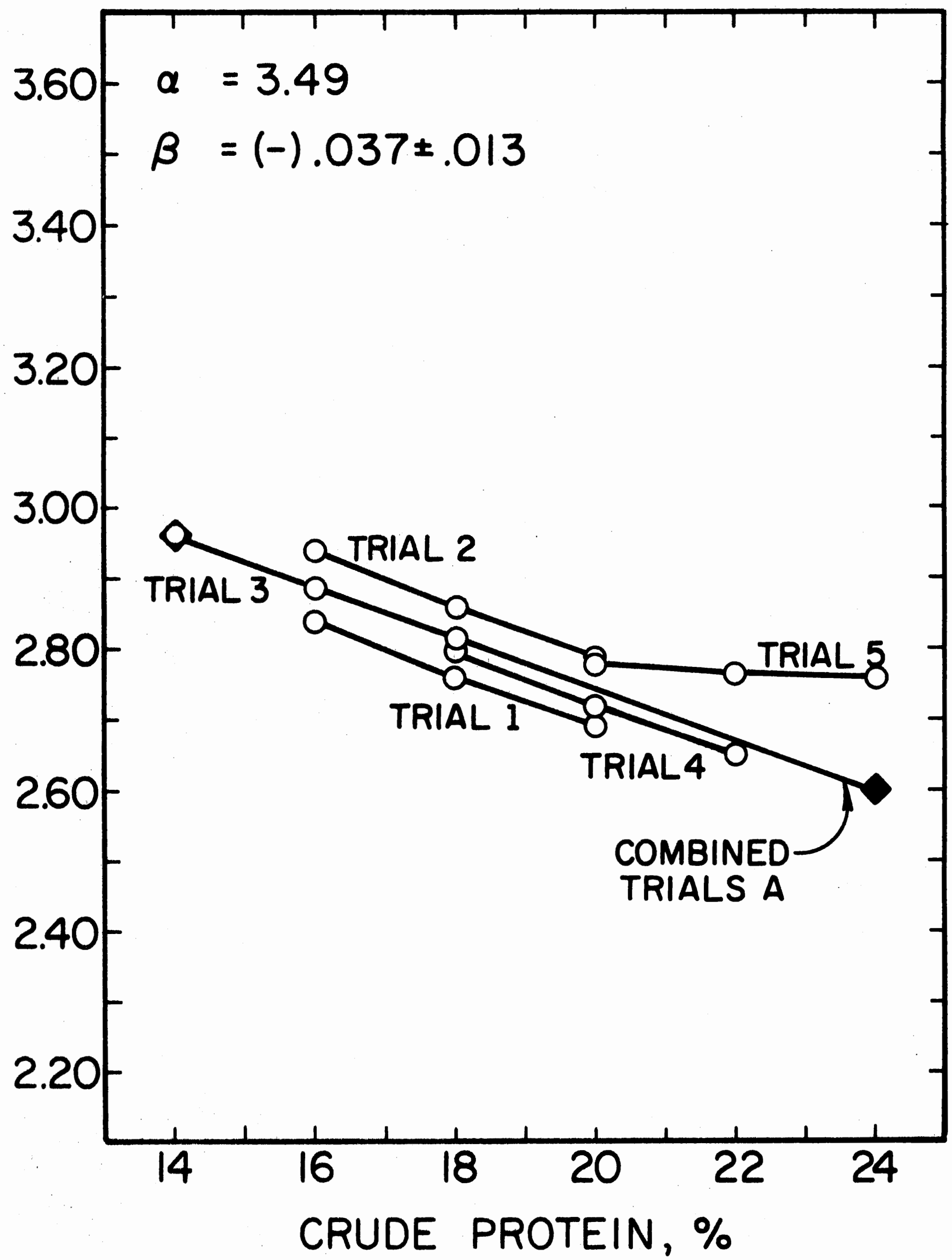

Figure 4. Kilograms Feed Per Kilogram Gain - Total Trial Period; A Significant Linear Effect ($P < .001$)

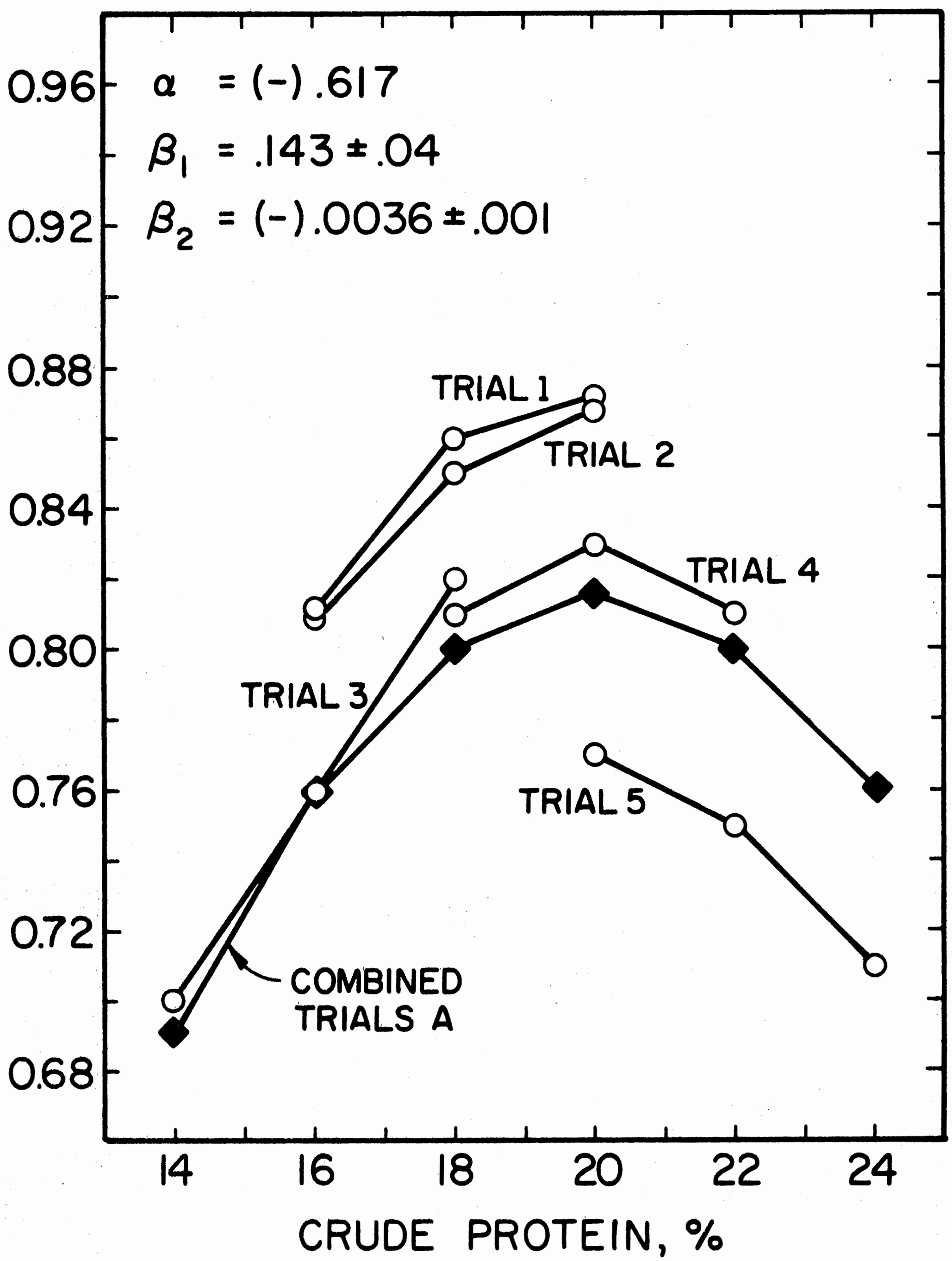

Figure 5. Average Daily Gain - Total Trial Period; A Significant Quadratic Effect ($P < .003$)

However, it is not known whether the observed effect on gain in these experiments can be corrected by an amino acid supplement.

Experiments dealing with amino acid imbalances (Shen et al., 1972; Kehchiro et al., 1974; Katz et al., 1975; Muller et al., 1944; Nakagawa et al., 1974; Boorman and Buttery, 1972) reported depressed intakes and daily gains, but all fed a low level of dietary protein and an excess individual amino acid, which was not done here. Muramatsu et al., 1971 found that these imbalances could be partially counteracted by increasing the protein content of the diet with the exception of the depressed growth caused by excess methionine (5% added L or D methionine). The conditions in the present experiments do not completely follow the guidelines usually followed to produce an amino acid imbalance, i.e., low protein, added individual amino acids, and the addition of an indispensable amino acid added to alleviate the lack of growth. Additional experimentation needs to be conducted to determine if this is truly an amino acid imbalance or some other growth depressing agent since level of protein was not lacking.

Backfat thickness, adjusted to a standard 99.8 kg boar equivalence for all animals, decreased linearly ($P < .001$) as level of protein increased (Figure 6). A one unit increase in protein level (2%) allowed a decrease of $.0454 \pm .01$ cm. of backfat thickness when individual trial data was combined for analysis. Boars in all trials responded in a similar fashion to increasing protein from the 14% to the 24% level. A decrease in backfat thickness as protein level was increased, has also been reported by many others (Bereskin et al., 1976; Davey, 1976; Davey and Morgan, 1969; Luce, 1975; Luce et al., 1976). Reinhard et al.

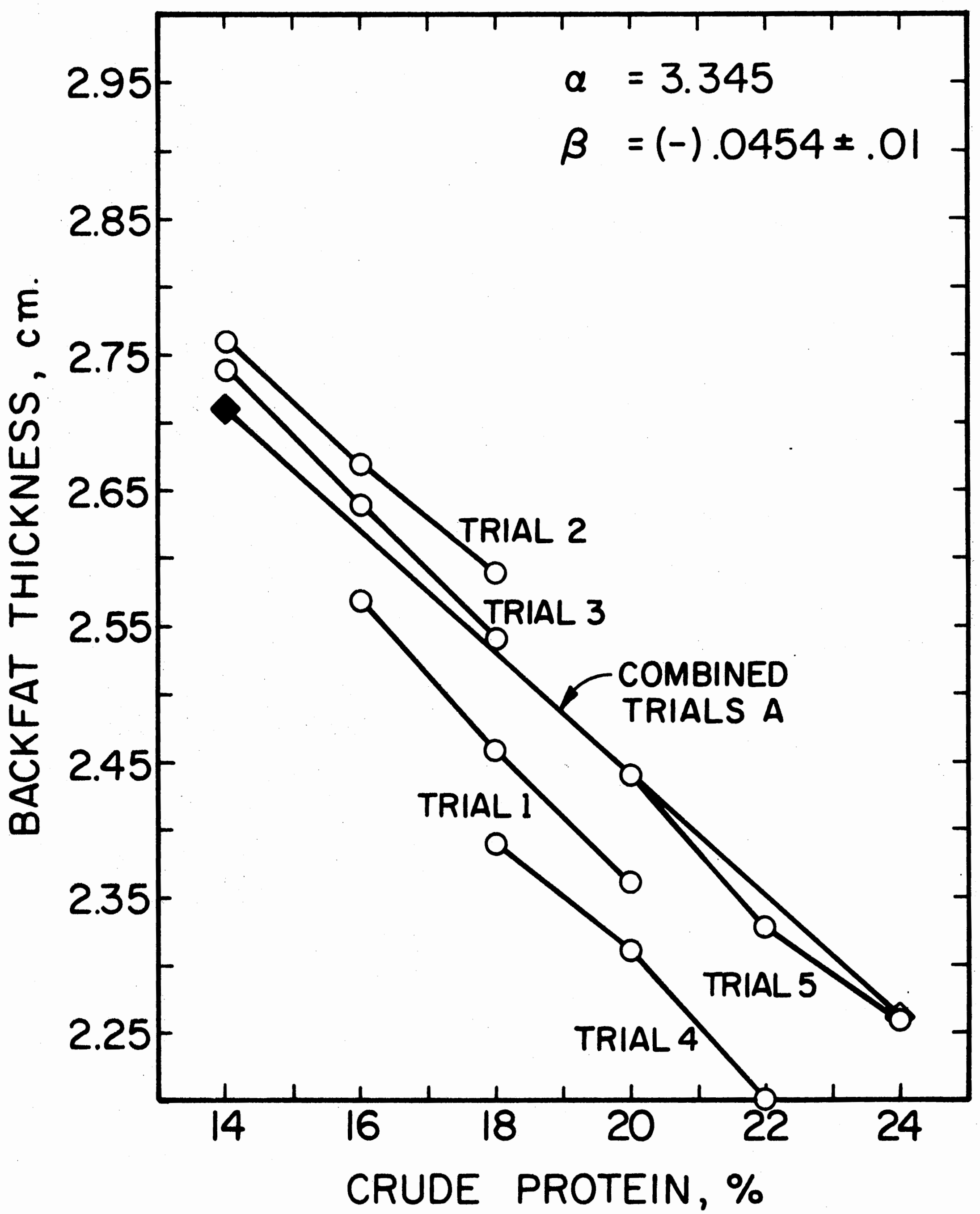

Figure 6. Backfat Thickness - Adjusted to 99.6 kg (220 lbs) Per Boar; A Significant Linear Effect ($P < .001$)

(1976) found backfat to decrease curvilinearly ($P < .01$) as protein level. However, the linear decrease in backfat found here would suggest that even higher levels of protein would cause a similar reduction; but the advantages of less backfat, if any, would probably not offset the disadvantages of such extreme protein levels, both from an economic standpoint or decreased growth rate of the boars.

In the overall response, longissimus muscle area increased quadratically ($P < .0001$) with increasing levels of crude protein from 14% to 24% (Figure 7). Longissimus muscle area increased linearly ($P < .05$) as protein increased during Trials 1 and 2 (Luce et al., 1976). Also, increasing protein percentage allowed an increase in muscle area for growing boars during Trials 3 and 4, until the level of 20% was surpassed (Figure 7). When the 22% to 24% level of crude protein was fed, a decrease in longissimus muscle was noted. Hale et al. (1967) also found larger longissmus muscle areas for pigs fed higher levels of protein; but Reinhard et al. (1976) found a decrease in longissimus muscle area when protein level above 18% protein were fed.

The data suggests that kilograms of feed per kilogram of gain consistently decreases with increasing level of protein. Average daily gain is highest at a level of 20%, and decreases as level of protein goes higher. The reduction in average daily gain may be partially due to the reduced average daily feed intake. Average daily feed intake tended to decrease when the level of protein was increased above 20%, producing a nonsignificant quadratic response to level of protein.

The response of longissimus muscle area and average daily gain to level of protein in the present experiment indicates the level of protein that allows the fastest lean muscle growth has been reached at

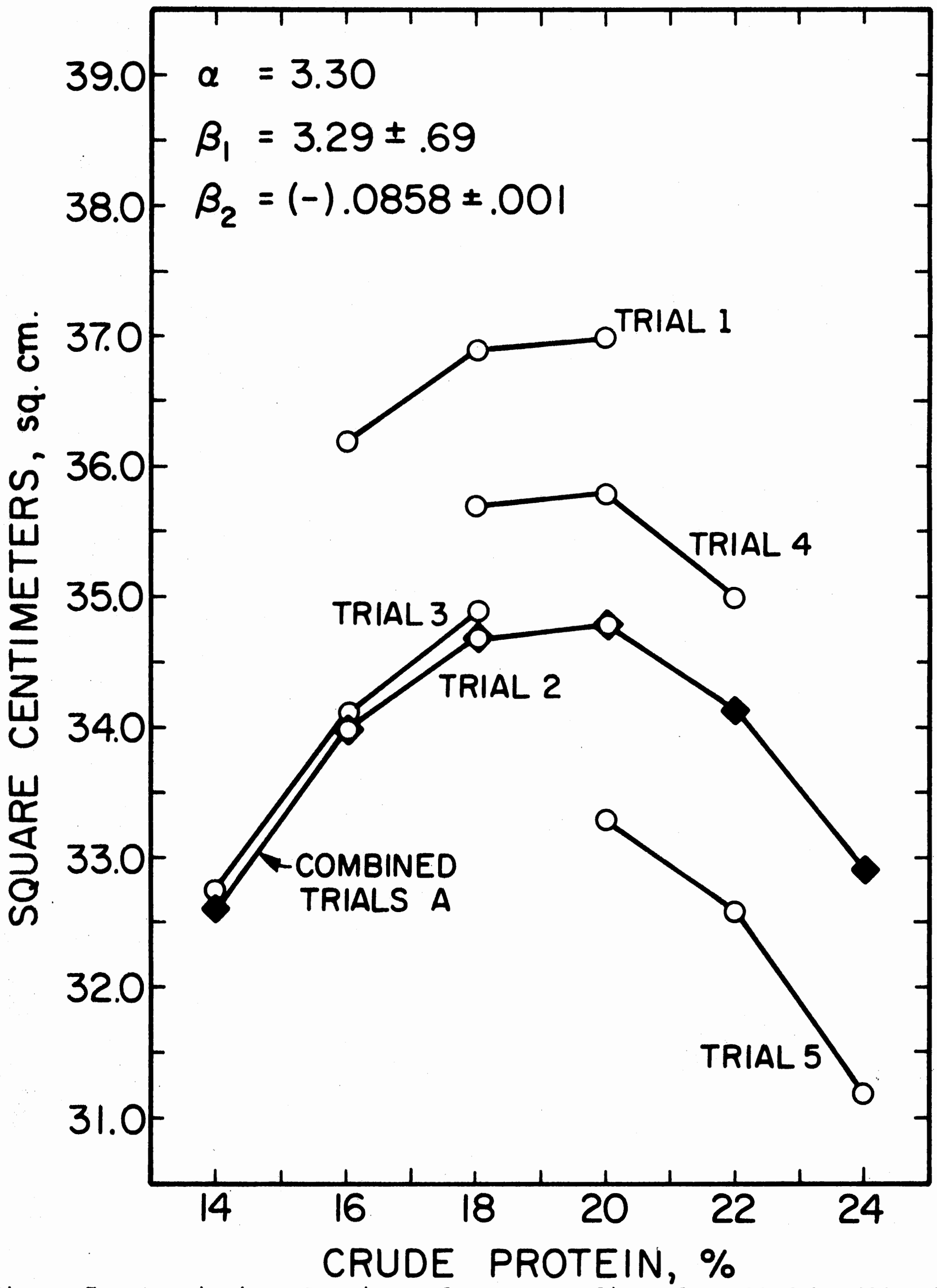

Figure 7. Longissimus Dorsi Muscle Area - Adjusted to 99.6 kg (200 lbs) Per Boar; A Significant Quadradic Effect ($P < .0001$).

the 20% level. However, the linear decrease in kilograms of feed required per kilogram of gain and the small linear decrease (approximately 0.09 cm per 2% change in dietary protein) in backfat thickness also indicates that the most efficient level of protein and the level that results in the least amount of backfat disposition has not been determined.

It would appear considering all of these variables, that a dietary level of crude protein of 20% from approximately 22 to 54.4 kg and 18% c.p. from 54.4 to 99.8 kg would be most advantageous to the young growing boar.

CHAPTER IV

RESPONSE OF GROWING BOARS TO DECREASING PROTEIN WHILE MAINTAINING EQUAL LYSINE LEVELS IN CORN-SOYBEAN MEAL DIETS

Summary

A trial was conducted involving one hundred and eight growing boars to measure the effect of lysine supplementation on rate of gain, feed conversion, daily feed intake, backfat thickness and longissimus dorsi area. The boars were fed either a 18% crude protein ration, a 16% crude protein plus 0.16% added lysine ration, or a 14% crude protein plus 0.32% added lysine ration from approximately 22 kg to 54.4 kg. The protein level was then reduced 2% for each treatment from approximately 54.4 kg to 100 kg. The added lysine resulted in equivalent lysine levels for all treatments during Period 1 (22 kg to 54.4 kg) and 2 (54.4 kg to 99.8 kg) as compared to the standard 18% to 16% crude protein rations for the same weight periods.

The results indicate that when lysine was added to the 16% crude protein ration in Period 1 and to the 14% crude protein ration in Period 2, growth performance for those boars was equal to that of boars receiving the standard 18% to 16% crude protein rations.

However, when the crude protein content was reduced 4% during Period 1 and 2 (14% to 12% crude protein plus additional lysine) there

was a significant reduction in average daily gains ($P < 0.05$) during Period 1, and an increase in feed required per unit of gain. There was also a significant decrease in feed intake ($P < 0.1$) and longissimus dorsi area ($P < 0.05$) for boars receiving this treatment.

Methods and Materials

One hundred and eight purebred Duroc, Hampshire and Yorkshire boars, produced from the swine herds maintained at the Oklahoma State University, were used in this study.

The boars, averaging 22 kg, were randomly allotted within breed and litter to three experimental treatments. Each experimental treatment consisted of four replicates. During the first period (22 kg to 54.4 kg average pen weight) the boars were fed a 18%, 16% plus 0.16% added lysine, or a 14% crude protein plus 0.16% added lysine ration. In the second period (54.4 kg to 96.8 kg average pen weight) the protein level of each diet was reduced 2% and additional lysine increased from 0.16% to 0.32%. Treatments 1, 2 and 3 consisted of 16%, 14% plus 0.32% added lysine and 12% crude protein plus 0.32% additional lysine. Composition of experimental rations are shown in Table VIII. Protein levels in the ration were reduced for each pen individually as the boars in the pen averaged 54 kg, and boars were individually removed from test weekly as they reached 99.8 kg.

The feeding floor was an open-front concrete finishing floor with 2.1 x 5.2 meter pens equipped with a self-feeder and automatic waterer. After assignment of 9 boars per pen, the boars were given a one-week adjustment period, after which on-test weights were recorded.

TABLE VIII

COMPOSITION OF EXPERIMENTAL RATIONS - TRIAL 6

	Ration Designation					
	Treatment 1		Treatment 2		Treatment 3	
Ingredients	18% c.p.	16% c.p.	16% c.p.	14% c.p.	14% c.p.	12% c.p.
Corn	64.00	69.50	69.20	74.70	74.50	80.30
Soy Meal, 44%	27.75	22.10	21.90	16.30	16.00	10.25
Molasses	5.00	5.00	5.00	5.00	5.00	5.00
Slat	0.50	0.50	0.50	0.50	0.50	0.50
Di Cal	1.50	1.65	1.65	1.75	1.75	1.80
Cal Carb	0.70	0.70	0.70	0.70	0.70	0.60
Vit.-TM Mix[1]	0.50	0.50	0.50	0.50	0.50	0.50
Aureo-50	0.05	0.05	0.05	0.05	0.05	0.05
Lys. Mix[2]	0.00	0.00	0.50	0.50	1.00	1.00
	100.00	100.00	100.00	100.00	100.00	100.00
% Crude protein, cal.	17.99	15.99	16.02	14.03	14.02	12.00
% Lysine, cal.	0.92	0.76	0.92	0.76	0.91	0.76

[1]Supplied 3,000,000 I.U. vitamin A; 300,000 I.U. vitamin D; 4 gm. riboflavin; 20 gm. pantothenic acid, 1000 gm choline chloride; 15 mg. vitamin B_{12}, 6000 I.U. vitamin E; 20 gm. menadione; 0.2 gm. iodine; 90 gm. iron; 20 gm. manganese; 10 gm. copper and 90 gm. zinc per ton of feed.

[2]Contained 62% soybean meal (44% c.p.) and 38% synthetic Lysine·HCl providing a 31.59% level of Lysine in the mix.

Ultrasonic estimates of backfat thickness and longissimus dorsi muscle area were obtained by the use of an Ithaco Scanogram Model 721 instrument. The measurements were adjusted to a 99.8 kg equivalent. Adjustments used were $\pm$ 0.022 centimeters for backfat thickness and $\pm$ 0.214 square centimeters for longissimus dorsi muscle area for each kilogram below or above 99.8 kg (National Association of Swine Records, 1970).

Since treatments were applied to pens, pens were the experimental unit for evaluating the effects of treatment. Therefore a pen means analysis was conducted on each trait. With pens as the experimental unit, the design of the trial was a randomized block utilizing a model to include the effects of blocks, treatments and blocks x treatment, as the error term. Treatment differences were tested for significance using Duncan's new multiple range test (Steele and Torrie, 1960).

Results and Discussion

Table IX shows the average boar weights per pen and dietary treatments for Periods 1 and 2. Results will be reported for each period and for a combination of the two for total trial results.

Period 1

The results are shown in Table X. Boars on treatment 3 (14% protein plus 0.16% added lysine) had significantly ($P < 0.05$) lower average daily gains of 0.60 kg compared to gains of 0.73 and 0.71 kg for boars on treatments 1 and 2 (18% protein and 16% protein plus 0.16%

TABLE IX

BOAR WEIGHTS AND TREATMENTS FOR PERIOD 1 AND 2

Weight	Treatments 1	2	3
		% c.p.	
22 to 54.4 kg (Phase 1)	18	16[a]	14[b]
54.4 to 96.6 kg (Phase 2)	16	14[a]	12[b]

[a]Treatments contained 0.16% additional Lys.

[b]Treatments contained 0.32% additional Lys.

TABLE X

EFFECTS OF DECREASING PROTEIN FOR GROWING BOARS WHILE MAINTAINING EQUAL LYSINE LEVELS - PERIOD 1

	Treatments 18%	16% + .16% Lys	14% + .32% Lys
Lysine, % - calculated	0.92	0.92	0.91
Tryptophane, % - Calculated	0.23	0.19	0.17
Threonine, % - calculated	0.47	0.37	0.27
Methione, % - calculated	0.33	0.31	0.27
No. boars	36	36	36
Avg. in. wt., kg	22.1	21.7	21.4
Avg. final wt., kg	55.7_A	56.0_A	57.9_A
Avg. daily gain, kg*	$0.73^a \pm .03$	$0.71^a \pm .03$	$0.60^b \pm .03$
Feed per kg gain, kg**	$2.48^c \pm .2$	$2.64^{c,d} \pm .2$	$2.83^d \pm .2$
Avg. daily feed intake, kg	$1.81 \pm .09$	$1.86 \pm .09$	$1.70 \pm .09$

A mean $\pm$ SE

*Means with different superscripts are different ($P < .05$).

**Means with different superscripts are different ($P < .10$).

added lysine respectively). The gains for boars receiving treatment 2 tended to be lower than those on treatment 1, but the difference was not significant. No large differences were noted in average daily feed intake, but boars on treatment 2 consumed slightly more feed per day.

The results from Phase 1 indicate that a 14% crude protein ration, based primarily on corn and soybean meal, with additional lysine added, is inadequate for growing boars from approximately 22 kg to 54.4 kg if optimum performance is to be obtained. However, the addition of 0.16% supplemental lysine to a ration containing 16% crude protein does allow growth similar to boars receiving a diet containing 18% protein.

Period 2

The results are shown in Table XI. Although not significant, boars on treatment 2 (14% protein plus lysine) had slightly higher daily gains, 0.98 kg per day, 3.29 kg per day, when compared to boars receiving treatments 1 and 3. Boars consuming the 16% crude protein diet tended to require less feed per pound of gain, but the difference was not significant.

The lower average final weight for boars receiving treatment 3 was attributed to the early removal of one whole pen of boars so that another experiment could be started.

The results from Period 2 indicate that growing boars from approximately 54.4 kg to 99.8 gk, when fed a 14% crude protein plus 0.32 additional lysine ration or a 12% crude protein plus 0.32% added lysine ration have similar growth performance to boars on a standard 16% crude protein yellow corn-soybean meal diet (Table XI).

TABLE XI

EFFECTS OF DECREASING PROTEIN FOR GROWING BOARS WHILE MAINTAINING EQUAL LYSINE LEVELS - PERIOD 2

	Treatments		
	18%	14% + .16% Lys	12% + .32% Lys
Lysine, % - calculated	0.76	0.76	0.76
Tryptophan, % - calculated	0.19	0.17	0.19
Threonine, % - calculated	0.38	0.28	0.17
Methionine, % - calculated	0.31	0.26	0.23
Avg. in. wt., kg	55.7	56.0	57.9
Avg. final wt., kg	99.9	99.3	90.9
Avg. Daily gain, kg	0.94 ±[A] .05	0.98 ±[A] .05	0.91 ±[A] .05
Feed per kg gain, kg	3.06 ± .31	3.35 ± .31	3.26 ± .31
Avg. daily feed intake, kg	2.88 ± .035	3.29 ± .035	2.96 ± .035

A mean ± SE

Total Period

Performance data was computed for the total feeding period (Table XII). Boars on treatment 3 had significantly ($P < .05$) lower average daily gains of 0.71 kg as compared to gains of 0.84 kg and 0.83 kg for boars receiving treatments 1 and 2, respectively. These findings do not support work reported by Baker et al. (1975) as to level of both protein and lysine, or to rates of gain found by others (Baker, 1973; Meade, 1965; Wahlstrom et al., 1974). While Luce et al. (1976) did not add supplemental lysine, results here are similar.

Feed required per kilogram of gain tended to increase as crude protein decreased and lysine was added. Again, results here are not in agreement with work previously reported (Meade, 1965 and Walstrom et al., 1974).

There were no significant differences in backfat thickness for boars receiving the three levels of crude protein, with or without added lysine. In agreement, is work done by Brown et al. (1973) and Meade (1965) and possibly suggests that after a specific level of protein is reached, further reduction has little effect upon backfat deposition.

Boars fed treatments 1 and 2 produced significantly ($P < .05$) larger longissimus muscle areas of 34.32 and 34.71 square centimeters as compared to 32.13 square centimeters for boars fed treatment 3. Brown et al. (1973) has reported that a level of approximately 0.60% dietary lysine was adequate; however, results from this trial are not supportive of that statement.

These results indicate that a 16% crude protein, plus added lysine, ration from approximately 22 kg to 54.4 kg and a 14% protein

TABLE XII

EFFECTS OF DECREASING PROTEIN FOR GROWING BOARS WHILE MAINTAINING EQUAL LYSINE LEVELS - TOTAL TRIAL

	Treatments		
	18%	16-14% + .16% Lys	14-12% + .32% Lys
Lysine, % - calculated	0.92-0.76	0.92-0.76	0.91-0.76
Tryphophan, % - calculated	0.23-0.19	0.19-0.17	0.17-0.13
Threonine, % - calculated	0.47-0.38	0.37-0.28	0.27-0.17
Methionine, % - calculated	0.33-0.31	0.31-0.26	0.27-0.23
No. Boars	36	36	36
Avg. in. wt., kg	22.1	21.7	21.4
Avg. final wt., kg	99.9_A	99.3_A	90.9_A
Avg. daily gain, kg*	$0.84^a \pm .035$	$0.83^a \pm .035$	$0.71^b \pm .035$
Feed per kg gain, kg	$2.81 \pm .18$	$2.92 \pm .18$	$3.00 \pm .18$
Avg. daily feed intake, kg**	$2.36^{c,d} \pm .3$	$2.48^c \pm .3$	$2.13^d \pm .3$
Adj. backfat thickness, cm.	$2.59 \pm .08$	$2.57 \pm .08$	$2.64 \pm .08$
Adj. loin-eye area, sq. cm.*	$34.32^a \pm 0.75$	$34.71^a \pm 0.075$	$32.13^b \pm 0.75$

A mean $\pm$ SE
* Means with different superscripts are different ($P < .05$).
** Means with different superscripts are different ($P < .10$).

plus lysine ration, from approximately 54.4 kg to 99.8 kg, will support growth equal to boars fed a standard 18% to 16% crude protein corn-soybean meal diet.

Based on the reduced average daily gains, increased amount of feed required to produce a unit of gain, and smaller longissimus muscle area, when compared to boars fed the 18% to 16% protein diet, the 14% to 12% crude protein, plus additional lysine, ration was considered to be inadequate for growing boars from approximately 22 kg to 99.8 kg.

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A P P E N D I X

TABULAR RESULTS OF INDIVIDUAL TRIALS

TABLE XIII

EFFECTS OF CRUDE PROTEIN ON BOAR GROWTH - TRIALS 1 AND 2[A]

	Treatments		
	1	2	3
	Protein Levels, %		
	20 to 18	18 to 16	16 to 14
Pens per treatment, no.	8	8	8
Boars per pen, no.	9	9	9
Period 1			
Avg. daily gain, kg[b]	.79±.01[a]	.78±.01[a]	.73±.01[a]
Feed per kg gain, kg[d]	2.30±.03	2.31±.03	2.51±.03
Avg. daily feed intake, kg	1.81±.03	1.79±.03	1.83±.03
Period 2			
Avg. daily gain, kg[c]	.93±.02	.91±.02	.87±.02
Feed per kg gain, kg[e]	3.06±.05	3.02±.05	3.21±.05
Avg. daily feed intake, kg	2.86±.06	2.75±.06	2.81±.06
Total Trial Period			
Avg. daily gain, kg[b]	.86±.01	.84±.01	.81±.01
Feed per kg gain, kg[d]	2.74±.04	2.72±.04	2.93±.04
Avg. daily feed intake, kg	2.36±.04	2.29±.04	2.36±.04
Adj. backfat thickness, cm[b]	2.45±.02	2.52±.02	2.63±.02
Adj. l. dorsi area, sq. cm[c]	35.77±.26	35.78±.26	34.73±.26

[A]Luce et al., 1976.

[a]Mean ± SE

[b]Linear effects significant ($P < .01$).

[c]Linear effects significant ($P < .05$).

[d]Quadratic effects significant ($P < .05$).

[e]Quadratic effects significant ($P < .01$).

TABLE XIV

EFFECTS OF CRUDE PROTEIN ON BOAR GROWTH - TRIAL 3

	Treatments		
	1	2	3
	Protein Levels, %		
	18 to 16	16 to 14	14 to 12
Pens per treatment, no.	4	4	4
Boars per pen, no.	9	9	9
Period 1			
Avg. daily gain, kg[1]	.73±.03[a,b]	.70±.03[a,b]	.60±.03[a,c]
Feed per kg gain, kg	2.48±.2	2.64±.2	2.83±.2
Avg. daily feed intake, kg	1.81±.09	1.86±.09	1.70±.09
Period 2			
Avg. daily gain, kg	.94±.05	.85±.05	.85±.05
Feed per kg gain, kg	3.06±.31	3.32±.31	3.27±.31
Avg. daily feed intake, kg	2.88±.35	3.29±.35	2.96±.35
Total Trial Period			
Avg. daily gain, kg[1]	.84±.035[b]	.76±.035[b]	.70±.035[c]
Feed per kg gain, kg	2.81±.18	2.86±.18	3.00±.18
Avg. daily feed intake, kg	2.36±.13	2.48±.13	2.13±.13
Adj. backfat thickness, cm	2.59±.08	2.57±.08	2.64±.08
Adj. l. dorsi area, sq. cm.[1]	34.34±.75[b]	34.71±.75[b]	32.13±.75[c]

[a]Mean ± SE.

[1]Means with different superscripts (b-c) are significantly different (P < .005).

TABLE XV

EFFECTS OF CRUDE PROTEIN ON BOAR GROWTH - TRIAL 4

	Treatments		
	1	2	3
	Protein Levels, %		
	22 to 20	20 to 18	18 to 16
Pens per treatment, no.	2	2	2
Boars per pen, no.	9	9	9
Period 1			
Avg. daily gain, kg	.75±.08[a]	.77±.08[a]	.73±.08[a]
Feed per kg gain, kg	2.36±.05	2.18±.05	2.49±.05
Avg. daily feed intake, kg	1.76±.09	1.67±.09	1.81±.09
Period 2			
Avg. daily gain, kg	.81±.04	.79±.04	.93±.04
Feed per kg gain, kg	2.87±.09	3.02±.09	2.93±.09
Avg. daily feed intake, kg[1]	2.41±.01[b]	2.39±.01[b]	2.73±.01[c]
Total Trial Period			
Avg. daily gain, kg	.80±.03	.78±.03	0.85±.03
Feed per kg gain, kg	2.76±.06	2.79±.06	2.78±.06
Avg. daily feed intake, kg	2.16±.07	2.10±.07	2.36±.07
Adj. backfat thickness, cm[1]	2.17±.03[b]	2.18±.03[b]	2.45±.03[c]
Adj. l. dorsi area, sq. cm.	34.97±.52	35.35±.52	35.61±.52

[a]Mean ± SE.

[1]Means with different superscripts are significantly different ($P < .05$).

TABLE XVI

EFFECTS OF CRUDE PROTEIN ON BOAR GROWTH - TRIAL 5

	Treatments		
	1	2	3
	Protein Levels, T		
	24 to 22	22 to 20	20 to 18
Pens per treatment, no.	2	2	2
Boars per pen, no.	9	9	9
Period 1			
Avg. daily gain, kg	.76±.015[a]	.78±.015[a]	.76±.015[a]
Feed per kg gain, kg	2.32±.04	2.23±.04	2.27±.04
Avg. daily feed intake, kg	1.71±.05	1.73±.05	1.71±.05
Period 2			
Avg. daily gain, kg	.74±.05	.67±.05	.79±.05
Feed per kg gain, kg	3.06±.12	3.43±.12	3.06±.12
Avg. daily feed intake, kg	2.25±.15	2.30±.15	2.42±.15
Total Trial Period			
Avg. daily gain, kg	.74±.03	.72±.03	.78±.03
Feed per kg gain, kg	2.76±.25	2.79±.25	2.78±.25
Avg. daily feed intake, kg	2.04±.08	2.09±.08	2.14±.08
Adj. backfat thickness, cm	2.29±.065	2.24±.065	2.39±.065
Adj. l. dorsi area, sq. cm.[1]	31.48±.32[b]	31.42±.32[b]	33.48±.32[c]

[a]Mean ± SE.

[1]Means with different superscripts (b-c) are significantly different ($P < .05$).

TABLE XVII

ANALYSIS OF VARIANCE (LINEAR PLUS QUADRATIC) - PERIOD 1 VARIABLES

Source	df	Mean Square ADFI	ADG	F/E
Trial	4	0.19799	0.40358	1.0744
Rep (Trial)	11	0.40469	0.33166	0.4819
Treatment	5	0.22903		
Linear	1	0.1755	0.1525	0.3140
Quadratic	1	0.04444	0.0833[a]	0.1459[b]
Residual	3	0.00909	0.0105	0.0033
Trial x Trt.	5	0.031373		
Trial 1 x Trt. Lin.	1	0.01824	0.00001	0.0999
Trial 2 x Trt. Lin.	1	0.006776	0.00574	0.0003
Trial 3 x Trt. Lin.	1	0.004504	0.00039	0.0347
Trial 4 x Trt. Lin.	1	0.010769	0.00015	0.0159
Trial 1 x Trt. Quad.	1	0.0075	0.00079	0.0015
Total	25	2.09368		
Error	22	0.04358	0.0049	0.0191

[a]Quadratic effects significant ($P < .0005$).

[b]Quadratic effects significant ($P < .01$).

TABLE XVIII

ANALYSIS OF VARIANCE (LINEAR PLUS QUADRATIC) - PERIOD 2 VARIABLES

Source	df	Mean Square		
		ADFI	ADG	F/E
Trial	4	11.387	0.9306	0.38228
Rep (Trial)	11	11.125	0.6229	0.89085
Treatment	5			
Linear	1	0.194	0.3214	0.1352
Quadratic	1	0.2424	0.05716	0.0093
Residual	3	2.7849	0.07536	0.1877
Trial x Treatment	5			
Trial 1 x Trt. Lin.	1	0.0059	0.0714	0.0112
Trial 2 x Trt. Lin.	1	0.5244	0.0191	0.0002
Trial 3 x Trt. Lin.	1	0.0198	0.0593	0.2533
Trial 4 x Trt. Lin.	1	2.4205	0.0573	0.3124
Trial 1 x Trt. Quad.	1	0.0319	0.00128	0.0243
Total	25			
Error	22	0.3267	0.03687	0.07282

TABLE XIX

ANALYSIS OF VARIANCE (LINEAR PLUS QUADRATIC) - TOTAL TRIAL VARIABLES

Source	df	Mean Square				
		ADFI	ADG	F/E	ALEA	A.B.F.
Trial	4	680.137	0.383	0.198	2.184	0.1513
Rep (Trial)	11	1076.625	0.2391	0.40469	0.81554	0.05006
Treatment	5					
Linear	1	63.825	0.10093	0.1755	0.07032	0.04111
Quadratic	1	86.16	0.1199[a]	0.0444	0.34323[b]	0.00063
Residual	3	734.744	0.02323	0.0091	0.01293	0.00534
Trial x Treatment	5					
Trial 1 x Trt. Lin.	1	0.663	0.0189	0.0018	0.01095	0.00007
Trial 2 x Trt. Lin.	1	22.203	0.00353	0.00678	0.0184	0.001334
Trial 3 x Trt. Lin.	1	0.3252	0.01759	0.0045	0.00706	0.002112
Trial 4 x Trt. Lin.	1	51.576	0.02812	0.01077	0.05025	0.00519
Trial 1 x Trt. Quad.	1	6.143	0.000052	0.0075	0.04343	0.00488
Total	25					
Error	22	57.282	0.01098	0.02626	0.01576	0.00254

[a]Quadratic effects significant ($P < .003$).

[b]Quadratic effects significant ($P < .0001$).

TABLE XX

ANALYSIS OF VARIANCE (LINEAR EFFECTS) - PERIOD 1 VARIABLES

Source	df	Mean Square ADFI	ADG	F/E
Trial	1	0.0119	0.060	0.240
Rep (Trial)	6	0.5912	0.2345	0.2343
Treatment				
Trt. Lin.	1	0.00526	0.133	0.166
Trt. Quad.	1	0.0218	0.030	0.0180
Trial x Treatment				
Trial x Trt. Lin.	1	0.228	0.0056	0.0856
Trial x Trt. Quad.	1	0.0015	0.0075	0.0015
Total	11	0.0781	0.0428	0.0678
Error	12	0.0339	0.0185	0.0093

TABLE XXI

ANALYSIS OF VARIANCE (LINEAR EFFECTS) - PERIOD 2 VARIABLES

Source	df	Mean Square		
		ADFI	ADG	F/E
Trial	1	3.7871	0.1291	0.0338
Rep (Trial)	6	3.014	0.1659	0.2884
Treatment				
Trt. Lin.	1	0.0501	0.0481	0.0784
Trt. Quad.	1	0.4219	0.00002	0.0300
Trial x Treatment				
Trial x Trt. Lin.	1	0.00834	0.0539	0.1225
Trial x Trt. Quad.	1	0.0319	0.0013	0.0243
Total	11	0.6649	0.0362	0.0525
Error	12	0.1524	0.0128	0.0307

TABLE XXII

ANALYSIS OF VARIANCE (LINEAR EFFECTS) - TOTAL TRIAL VARIABLES

Source	df	Mean Square ADFI	ADG	F/E	ALEA	ABF
Trial	1	184.056	0.0012	0.060	0.7082	0.0409
Rep (Trial)	6	241.825	0.0114	0.2345	0.0716	0.0344
Treatment						
Trt. Lin.	1	26.838	0.0520	0.1332[a]	0.0886	0.020[a]
Trt. Quad.	1	7.538	0.0008	0.030	0.0527	0.0001
Trial x Treatment						
Trial x Trt. Lin.	1	21.965	0.021	0.0056	0.0119	0.0008
Trial x Trt. Quad.	1	6.143	0.0001	0.0075	0.0434	0.0049
Total	11	44.397	0.0079	0.0428	0.0888	0.0092
Error	12	8.182	0.0047	0.0185	0.0127	0.0022

[a]Linear effects significant ($P < .001$)

2

VITA

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