EFFECTS OF VARYING SORGHUM GRAIN-SOYBEAN MEAL RATIOS, ADDED METHIONINE AND SEX UPON SWINE GROWTH RATE, FEED EFFICIENCY, CARCASS COMPOSITION AND QUALITY.

by

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Introduction

Consumer and processor demand for leaner pork plus economic pressure for more efficient production in the past 15 years has resulted in remarkable improvement in gaining ability, efficiency of feed conversion and carcass composition of swine. Swine nutrition has progressed so individual amino acid needs are considered in ration formulation. Most amino acid recommendations have been based on feedlot performance. Bearing in mind the continued breeding improvements, animal scientists have questioned whether these recommendations will produce maximum muscle development in swine. Therefore, the effect of feeding higher than recommended protein levels plus added methionine on muscle development and growth in swine was studied. Due to reported differences in feedlot and carcass performance of barrows and gilts, the effect of sex was studied.

Meat processors and scientists have demonstrated important differences in product desirability due to variations in muscle quality characteristics. This, along with the fact that there has been a quality deterioration associated with the production of lean pork, prompted a detailed study on these carcasses with respect to muscle color, firmness, marbling and related quality factors.

Review of Literature

The bulk of literature reviewed involves work using corn rations, simply because little research has been completed using milo (grain sorghum) rations. Results of trials using corn may give an indication of results expected when grain sorghum is used since Becker et al. (1966) states that milo can serve as a complete substitute for corn in growing, finishing swine rations and that it has a relative replacement value for corn of 98 percent. Jensen et al. (1965) reported no difference for average daily gain and "gain-feed ratio" when comparing a pelleted 12 percent crude protein milo-soybean meal ration with a "meal form" 12 percent crude protein corn-soybean meal ration fed to pigs weighing 57 kilograms initially. Aubel (1956) reported that pigs fed shelled corn gained only slightly faster than those fed whole or dry-rolled milo, but they required 0.4 to 0.7 pounds less feed per pound of gain. Peo and Hudman (1958) in one experiment involving 224 pigs fed from an initial weight of 56.5 pounds to a final weight of 128.8 pounds, found no difference in average daily gain when 14 percent crude protein corn-soybean meal rations were compared with 14 percent milo-soybean meal rations. However, it took from 0.2 to 0.7 pounds more feed to produce a pound of gain with the grain sorghums. In a second experiment using 75 cross-bred hogs that were fed from an average of 47.7 pounds to 170 pounds, pigs on a 14 percent crude protein corn-soybean meal ration gained more rapidly ($P < .05$) and were more efficient ($P < .05$) than those fed a 14 percent milo-soybean meal ration. However, pigs fed a 16 percent milo-soybean meal ration gained as fast as those fed the 14 percent corn-soybean meal ration, but they required 0.2 pounds more feed per pound of gain, although this was not statistically significant. These researchers explained that the poorer performance of pigs fed milo may be due to the higher protein content of milo grain as compared to corn. When formulating a ration containing milo less supplemental protein is required to meet recommended levels creating a greater possibility of producing an amino acid imbalance.

Protein Requirement of Growing, Finishing
Meat-Type Swine.

Before one can realistically evaluate the effects of varying protein levels in swine rations on feedlot performance and carcass characteristics, a basic knowledge of the minimum protein requirement for growth is necessary. According to the National Research Council (1964), 50 to 125 pound pigs require between 14-16 percent crude protein and pigs weighing from 125 to 225 pounds require 12-13 percent total crude protein in the ration. Becker and co-workers (1954) reported a 14 percent crude protein requirement for pigs weighing 40 to 100 pounds, and a 12 percent crude protein level for 100 to 200 pound pigs fed a corn-soybean meal ration. Becker and associates (1966) later revised their estimates of swine protein needs to 16 percent crude protein for 30 to 100 pound growing swine and 12 percent crude protein for finishing swine weighing 100 pounds or more. A corn-soybean meal ration containing 14-16 percent crude protein produced maximum gains in weanling to 100 pound pigs in a study conducted by Lassiter et al. (1955). They also discovered that a 12-14 percent crude protein ration was satisfactory for pigs fed from weaning to 200 pounds.

The question might be raised whether the above protein requirements will support maximum muscle development or nitrogen retention. Lassiter et al. (1956) determined that maximum nitrogen retention was reached below an 18 percent crude protein level for 37-50 pound pigs and at the 18 percent crude protein level for 114-162 pound pigs.

Methionine Requirement of Growing, Finishing Swine.

As the methionine content of soybean oil meal is relatively low in comparison to other swine feeds, researchers have been concerned with the adequacy of soybean oil meal in supplying this essential amino acid. Both Kroening et al. (1965) and Berry et al. (1966) have found methionine to be the first limiting amino acid in isolated soybean protein, with threonine and/or combinations of threonine and lysine to be the second most limiting.

National Research Council (1964), Kroening et al. (1965) and Becker et al. (1966) all state that individual amino acid needs for growing swine, expressed as a percentage of the diet, increase as the percent protein in the diet increases.

Becker et al. (1966) state the methionine requirements (percent of diet) for 30 to 100 pounds growing swine fed 14, 16 and 18 percent protein corn-soybean meal rations as 0.45 percent, 0.50 percent and 0.53 percent, respectively. Similar values are reported by Shelton et al. (1951), Curtin et al. (1952), National Research Council (1964) and Kroening et al. (1965). Finishing pigs, weighing 100 pounds or more, fed a 12 percent protein corn-soybean meal ration, required 0.30 percent methionine in the diet (Becker et al., 1966). These researchers all state that cystine could supply 40-50 percent of the methionine requirement.

Effects of Varying Ration Protein Levels of Growth, Feed Efficiency and Carcass Composition.

Similar Amino Acid Ratio Maintained at Various Protein Levels.

Kropf et al. (1959) feeding 12 and 16 percent protein corn-soybean meal rations of similar quality, Clawson et al. (1962) feeding corn-soybean meal rations varying in protein content from 10 to 18 percent and Greely et al. (1964 a, b) with 13-19 percent protein in corn-soybean meal rations all found no differences in average daily gain and feed conversion between groups fed high and low protein levels for the entire growth period. Kropf et al. (1959) did find that pigs fed a 16 percent protein ration based on a corn-gluten meal-peanut oil meal protein supplement gained significantly slower, consumed less feed per day and required more feed per pound of gain than pigs fed 12 and 16 percent protein rations with "good amino acid balance". Clawson et al. (1962) and Greely et al. (1964) both found no treatment effect on carcass measurements, but Kropf et al. (1959) reported that high protein levels significantly increased carcass specific gravity and carcass protein content and decreased carcass backfat. Kropf et al. (1959) also reported lower longissimus dorsi ether extract values and higher carcass composite moisture values for pigs fed higher protein levels, which is in contrast to the study of Clawson et al. (1962), where no differences were found in ether extract and moisture values for the longissimus dorsi.

Clawson (1967) feeding corn-soybean meal rations at two protein levels, 9.0 and 14.8 percent, found that the high protein level significantly increased average daily gain and feed efficiency. Wagner and co-workers (1963) who fed all possible combinations of three levels of protein (13, 19 and 25 percent) and two energy levels, reported that as protein level increased above 13 percent, average daily gain decreased, although feed efficiency tended to improve. Increasing the ration protein level resulted in significantly larger loin eyes (Clawson, 1967). Likewise, Wagner et al. (1963) reported decreases in carcass backfat, dressing percent and intramuscular fat of the longissimus dorsi and increases in proportion of carcass lean cuts and tissue nitrogen of the longissimus dorsi when the protein level was increased above 13 percent. Wagner et al. (1963) hypothesized that the reduction in carcass backfat may be partially due to decreased feed consumption resulting in a decrease in total energy intake and consequently less fat deposition.

Smith and associates (1967) reported some very significant work when feeding three corn-soybean meal rations that differed in the ration of protein supplied by soybean meal and corn (60:40, 50:50 and 40:60) at crude protein levels of 11.3, 12.8, 14.3 and 17.2 percent. Pigs fed the 60:40 soybean meal-corn ratio gained faster and were more efficient feed converters than those fed the 40:60 soybean meal-corn ratio. No significant differences were found, however, for average daily gain and feed efficiency between groups fed different protein levels (above 12.8 percent protein) from the same source. They also established that each increase in protein was accompanied by an increase in percent lean cuts, and that percent lean cuts also increased significantly as the percent protein from soybean meal increased, but neither protein source or level had any effect on carcass backfat thickness.

Non-Similar Amino Acid Ratios at Various Protein Levels.

Hudman et al. (1960), Dukelow et al. (1963) and Mead et al. (1960) feeding corn-soybean meal rations containing 12, 14 and 16 percent protein and Noland et al. (1960) with 12, 16 and 20 percent protein levels all reported no differences in gain and feed efficiency among the three levels. While Noland et al. (1960) reported that pigs fed either the 16 or 20 percent protein ration produced longer carcasses with a greater primal cut yield than those fed the 12 percent level, the other three studies concluded that carcass leanness was not significantly affected by ration protein level.

In agreement with the above work, Abernathy and co-workers (1958) found no difference in growth rate and feed conversion between pigs fed 14 and 18 percent protein rations containing corn, soybean meal, peanut oil meal and alfalfa meal. Robinson (1965) fed pigs from 60 kilograms to a final weight of 120 kilograms with a barley, maize and "soya bean meal" ration at three levels of protein (12, 15 and 18 percent) and observed that pigs fed the 12 percent protein ration gained faster and tended to be more efficient than those fed higher protein levels. He also noted that increasing the protein content increased loin eye area and pigs fed the 18 percent protein level had the greatest "percent lean of side".

Other work involving corn-soybean meal rations fed at protein levels of 8, 10, 12, 14, 16, 18 and 20 percent completed by Jensen et al. (1955) and Speer et al. (1956) showed that the 14 percent protein level produced maximum gains (with the addition of antibiotic) with growth rate leveling off or declining at higher levels. Feed efficiency was also improved up to the 14 percent protein level in the study of Speer et al. (1956). The carcass data for the study conducted by Jensen et al. (1955) was presented by Ashton et al. (1955). In general, the results were inconsistent, but carcass specific gravity increased significantly with increasing levels of ration protein up to 16 percent in one experiment and 20 percent in another. While increases in loin eye area and percent lean cuts and a decrease in carcass backfat were observed with increasing levels of protein in one experiment, they were not affected by treatment in the other experiment.

Baker and co-workers (1967), feeding fortified corn-soybean meal diets containing 10, 12, 14 and 16 percent protein in two experiments to a total of 62 pigs averaging 55 kilograms initially, reported rate and efficiency of gain were maximised at the 12 percent protein level for barrows and the 14 percent protein level for gilts. Maximal carcass leanness was reached at 14 and 16 percent protein levels for barrows and gilts, respectively. These researchers concluded that "gilts require a higher level (or a different pattern) of dietary amino acids than barrows". In general, increasing the protein level increased loin eye area and carcass lean cut yield, but had no effect on carcass backfat thickness or carcass length.

Jurgens and co-workers (1967), feeding ground milo-soybean meal rations at 12 and 16 percent protein, discovered that the group on the 16 percent protein level gained significantly faster with improved feed efficiency than the group fed the 12 percent level, but dressing percent, percent ham and loin, backfat, length and longissimus dorsi area were not affected by treatment.

Riley and co-workers (1965), feeding corn-soybean meal rations containing 12, 14 and 16 percent protein, found significant increases in percent ham plus loin and carcass length and a decrease in dressing percent as the level of protein was increased.

Non-Similar Amino Acid Ratios at a Protein Sequence within a Protein Level.

Stevenson et al. (1960), Aunan et al. (1961) and Hale et al. (1967) all worked with corn-soybean meal rations containing 14, 16 and 18 percent protein which were subsequently reduced 3 percent in protein when pigs reached 125 pounds. They found no great differnce in average daily gain between the three treatments, but Stevenson et al. (1960) and Hale et al. (1967) reported that increasing the ration protein level to 18 percent resulted in improved feed efficiency, less carcass backfat and a greater lean cut yield. Hale et al. (1967) also observed an increase in loin eye area with increasing protein levels. Chemical analysis of the ham revealed that pigs fed higher protein had a greater moisture and protein(dry matter basis) content and less fat (dry matter basis) than pigs on lower protein levels (Stevenson et al., 1960). Aunan et al. (1961) reported a slight increase in carcass leanness due to increasing dietary protein level. The 12 percent protein ration supported significantly slower gains from weaning to 125 pounds than did the higher levels.

Catron and associates (1952), when supplementing corn-soybean meal rations with an antibiotic, found no differences in average daily gain, feed efficiency, feed intake, carcass backfat, carcass length and percent lean for the following protein levels and sequences; 20-17-14 percent, 18-15-12 percent, 16-13-10 percent and 14-11-8 percent protein. Pond and co-workers (1960) found no performance differences between pigs fed a 20-18 and those fed a 16-12 percent protein sequence in corn-soybean meal-meat scraps rations, but when comparing a 20-18 percent with a 12-10 percent protein sequence, he noted a highly significant advantage in daily gains for those pigs on the high level sequence. They reported that pigs on the low protein diet were protein deficient, as evidenced by high serum cholesterol levels and low serum albumin and total serum protein levels. These pigs responded to high protein feeding after being removed from the test.

Lee et al. (1967), with corn-soybean meal rations containing the following protein level sequences; 21-18-15, 18-15-12 and 15-12-9 percent protein, Sewell et al. (1958) and Wilson et al. (1953) with similar ration composition and protein level sequences and Seymour et al. (1964) feeding corn-soybean meal rations with a 20-17-14 and 16-13-10 percent protein sequence, all found that pigs fed the higher protein levels gained significantly faster than those fed the lowest protein sequence level. Lee et al. (1967) and Seymour et al. (1964) also reported lower feed conversion ratios for pigs fed the highest protein level. Lee et al. (1967) also found that increasing the protein significantly decreased feed consumption and feed consumed per unit gain in lean cuts. It also significantly increased the protein consumed per unit gain in lean cuts. Pigs fed the high protein sequence yielded carcasses containing a greater percent of lean cuts (Sewell et al., 1958; Seymour et al., 1964; Lee et al., 1965, 1967). Seymour et al. (1964) reported that those pigs which were fed the high protein level had less carcass backfat. Lee et al. (1967) also observed that increasing the protein level increased the loin eye area and the specific gravity of the trimmed right ham. Chemical analysis of the fresh ham showed higher moisture, protein and ash and lower fat values for hams from pigs fed the highest protein level. Chemical analysis of the longissimus dorsi revealed that increasing the protein level increased the moisture and decreased the fat content on a dry matter basis.

Crum and co-workers (1964) compared a 17-15 percent protein sequence with a 13-11 percent protein sequence. They also compared the following sequences in another experiment; 17-17, 17-15, 13-13 and 13-11 percent protein. In both experiments high protein levels increased average daily gain, feed efficiency, percent lean cuts, percent ham, percent loin and loin eye area. The 13-13 percent protein sequence in comparison to the 13-11 percent showed increased gains, feed efficiency, percent lean cuts, percent ham, percent loin and loin eye area plus a reduction in carcass backfat.

Walstrom (1954) studied the effects of feeding the following protein sequences in corn-soybean meal-tankage rations; 18-16, 18-14, 16-12, 14-12, 14-10 and 12-8 percent protein. He observed that gain was drastically reduced only in pigs fed the 12-8 percent protein sequence, indicating that this level probably did not meet the pigs minimum protein requirement. He also noted in one experiment involving three protein sequences, that pigs fed the 18-14 and 16-12 percent protein sequence had significantly larger loin eyes than those fed the 14-10 percent protein sequence.

Effects of Supplementing Swine Rations with Methionine.

The majority of studies involving methionine supplementation in swine rations, especially for finishing swine, has been at the low or medium protein levels. Dukelow et al. (1963) and Meade et al. (1966) supplemented corn-soybean meal rations containing 12 and 14 percent crude protein with methionine and lysine to provide levels of these amino acids equivalent to rations containing 14 and 16 percent protein, respectively. They reported no response in gain, feed efficiency or carcass leanness.

Sewell and Keen (1958) supplemented corn-soybean meal-peanut oil meal rations (4 parts soybean oil meal to 1 part peanut oil meal) fed at three protein level sequences (20-17-11, 17-14-11 and 14-11-8.4 percent protein) with methionine so that the methionine content would equal 2.0 percent of the dietary protein. They found no significant growth response to methionine supplementation at any of the protein levels. Likewise, Curtin et al. (1952) found that supplementing D-L methionine to glucose-soybean meal rations containing 22 percent protein did not increase growth, feed efficiency or nitrogen retention. However, Dyer et al. (1949) found that pigs, weighing 27 pounds initially and fed to an average of 99 pounds, fed a corn-soybean meal mixture containing 20 percent crude protein gained faster when 0.2 percent D-L methionine was added to the ration.

Effects of Varying Protein Level on Muscle Color, Firmness and Marbling.

Crum and co-workers (1964) found that increasing the protein level decreased carcass firmness and marbling. Lee and co-workers (1967) reported no differences for color of the ham and loin, juiciness, flavor and Warner Bratzler shear values for the <u>longissimus dorsi</u> as affected by high, medium and low dietary protein levels. Taste panel results, however, showed that samples from the longissimus dorsi of pigs fed the high and medium protein levels were less tender than those fed the low levels of protein. Fat content of the longissimus dorsi also decreased significantly with increasing levels of protein, as it did in the studies of Kropf et al. (1959), Wagner et al. (1963) and Jurgens et al. (1967). Clawson (1962) reported that fat and moisture content of the longissimus dorsi were not affected by treatment. This information suggests that quality factors should be further examined in protein level studies.

Influence of Sex on Growth, Feed
Efficiency, Carcass Composition and Quality.

Barrows gained faster and were more efficient in feed utilization than gilts (Bruner et al., 1958; Crum et al., 1964; Jensen et al., 1965; Robinson, 1965; Hale et al., 1967; Smith et al., 1967). These researchers, plus Kropf et al. (1959, 1962) and Cahilly et al. (1963), all found that gilts yielded carcasses with a higher percent lean cuts and a larger longissimus dorsi cross sectional area. Bruner et al. (1958), Kropf (1962), Robinson (1965), Hale et al. (1967) and Smith et al. (1967) also reported that gilts had less carcass backfat and/or tended to be longer than barrows. Kropf et al. (1959), Cahilly et al. (1963) and Smith et al. (1967) concluded that gilts are more sensitive to changes in protein quantity and quality, and hence show greater response to treatment than barrows.

Judge et al. (1964) also found gilts to be heavier muscled than barrows, and that barrow carcasses are more variable in muscling at similar live weights than are gilts. Judge et al. (1959) found the longissimus dorsi of barrows to be firmer and contain significantly more fat than gilts. Weiner (1960) observed significantly lower cooking losses for the longissimus dorsi of gilts, with the longissimus dorsi of gilts having lower fat and higher moisture contents than that of barrows. This information points out the importance of controlling the distribution of barrow and gilt carcasses.

Specific Gravity and Depth of Chine as

Indexes of Carcass Muscling and Composition.

Brown et al. (1951) found carcass specific gravity to be highly correlated with the protein (r = 0.65) and ether extract (r = -.75) content of the carcass. Correlations between the percent lean cuts and percent protein (r = 0.66) and percent ether extract (r = -.67) of the carcass were high, as was the correlation between carcass specific gravity and percent lean cuts (r = 0.78).

Whiteman and co-workers (1953) using 323 carcasses, found correlations between carcass specific gravity and percent lean cuts ranging from 0.783 to 0.904. In a study involving 203 of the 323 carcasses, they found the following correlations with carcass specific gravity to be highly significant; percent lean cuts (r = 0.868), percent of ham and loin (r = 0.888) and loin eye area (r = 0.689). As backfat was not significantly correlated with any of these measurements there is good indication that it was not as closely associated with carcass leanness as was specific gravity. These workers also found strong correlations between specific gravity of the carcass and that of the ham (r = 0.894 to 0.949).

Pearson and associates (1956) found in all cases the specific gravity of the untrimmed left ham was much superior to carcass backfat or length as a measure of carcass leanness. Specific gravity of the left untrimmed ham was correlated with the following measurements; percent lean cuts of live shrunk weight (r = 0.70), percent primal cuts of live shrunk weight (r = 0.63), length (r = 0.42) and carcass backfat (r = -.34). The specific gravity of the ham was more highly correlated with carcass specific gravity (r = 0.93 to 0.94) than was either the specific gravity of the rough loin or shoulder.

Price et al. (1957) using 36 hogs concluded that specific gravity may be a more reliable indicator of muscling than carcass backfat. They found specific gravity and ham specific gravity to be highly correlated (r = 0.86).

Kropf (1962) using 85 pork carcasses found highly significant correlations between carcass specific gravity and ham specific gravity (r = 0.651), loin eye area at the 10th rib (r = 0.588), percent lean cuts of carcass (r = 0.646) and carcass backfat thickness (r = -.502). The correlations of ham specific gravity with loin eye area (r = 0.326) and percent lean cuts (r = 0.437) were not as strong as those of carcass specific gravity with these measurements. Percent lean cuts was significantly correlated with carcass backfat thickness (r = -.559) and loin eye area (r = 0.455).

Lee and co-workers (1965, 1967) found the following correlations of specific gravity of "trimmed" right ham and percent lean cuts; in 1965 study (r = 0.54) and in 1967 study (r = 0.59).

Pearson et al. (1959) found that the ratio of depth of lumbar lean at the last lumbar vertebra plus the fat thickness at the last lumbar to the depth of lumbar lean at the last lumbar was a better indication of loin eye area and carcass cut-out than were backfat and length.

Kauffman et al. (1959) and Kropf (1962) reported similar correlations between depth of lumbar lean at the last lumbar with loin eye area (r = 0.361, 0.396) and percent lean cuts, carcass (r = 0.544, 0.349), respectively. Kropf (1962) reported a correlation of 0.382 between carcass specific gravity and depth of lumbar lean.

Experimental Methods

Ration Treatments

Pelleted, fortified milo-soybean meal diets containing 13, 16, 20 and 20 percent protein plus methionine constituted the 4 treatments (table 1). Sorghum grain-soybean meal ratios were varied to arrive at the desired protein levels. The amounts of dicalcium-phosphate and limestone were adjusted to maintain similar levels of calcium and phosphorous at all of the protein levels. In an effort to stop chewing of teeth, salivation and scouring of pigs in the second trial, 5 percent alfalfa replaced sorghum grain in the ration beginning March 8, 1967, with good results. Rations were prepared and mixed by the Feed Control Laboratory of the Grain Science and Industry Department, Kansas State University. Outgoing feed was sampled for amino acid analysis (Appendix A) and protein determination. Average protein content of the four treatments was 13.30, 16.10, 19.65 and 19.65 percent, respectively. Calculated methionine and lysine ration levels and requirements for the four treatments are presented in table 2. As the percent protein in the ration is increased, the lysine-methionine ratio becomes larger, due to the relatively lower methionine content of the added soybean meal. Methionine was supplemented at the 20 percent protein level to narrow the lysine-methionine ratio.

History of Animals

Eight Duroc pigs (4 barrows and 4 gilts) were selected from each of 8 litters and assigned in two replications to 16 groups, each containing either 4 barrows or 4 gilts. Groups were randomly allotted to 4 treatments, resulting in assignment of 1 barrow and 1 gilt from each litter to each treatment.

Pigs in the first trial were started on experiment October 25, 1966, at an average age of 77.7 days and a average body weight of 63.3 pounds. In the second trial, pigs were put on test February 7, 1967, at an average age of 92.5 days and a average body weight of 68.7 pounds.

Pigs were out of closely related dams. Two sires were represented equally in the first trial and one sire was used in the second trial.

The pigs were housed in 6x9 foot concrete-floored pens with free access to an additional 6x9 foot concrete-floored pen out-of-doors. Pens were equipped with two-hole self feeders and automatic waterers, although in cold weather they were watered by hand 3 times daily. Pens were scraped clean every day. Pigs were individually weighed every two weeks and when removed at slaughter weight. Feed intake was calculated on a pen (outcome group) basis.

The pigs had been kept in the farrowing house from birth to 5 weeks, after which the pigs in Trial I were put on green pasture, and those in Trial II were turned into dry pasture lots. They were weaned at 6 to eight weeks of age and placed on an 18 percent starter ration containing milo, soybean meal, dried whey, dried skim milk and meat meal. They were vaccinated for hog cholera and erysipelas and wormed with piperazine in the drinking water prior to being put on test and again 6 weeks after the test was started.

TABLE 1. COMPOSITION OF RATIONS(1000 LB.)

	Protein Content (%)							
	13		16		20		20 + methionine	
Ingredients	lb.	gm.	lb.	gm.	lb.	gm.	lb.	gm.
Sorghum grain[a]	870		770		670		670	
Soybean Meal (44%)	100		200		300		300	
Dicalcium Phosphate	10		8		6		6	
Limestone	10		10		11		11	
Salt	5		5		5		5	
Trace Mineral premix[b]	0.5		0.5		0.5		0.5	
Vitamin A[c]		150		150		150		150
Vitamin D[d]		10		10		10		10
Vitamin premix[e]		150		150		150		150
Vitamin B_{12}[f]		100		100		100		100
Aureomycin[g]		454		454		454		454
Methionine[h]		—		—		—		646
Sorghum grain		1180		2088		2542		1898

[a]In an effort to stop chewing of teeth, salivation and scouring, 5 percent alfalfa replaced sorghum grain in second trial on March 8, 1967 (about 4 weeks after start of Trial 2).

[b]Provides 22.7 mg. manganese, 22.7 mg. iron, 2.27 mg. copper, 11.35 mg. zinc, 6.81 mg. iodine and 227 ug. cobalt per lb. of diet.

[c]Provides 1500 I.U. vitamin A per lb. of diet.

[d]Provides 150 I.U. vitamin D per lb. of diet.

[e]Provides 24.6 mg. choline chloride, 7.9 mg. niacin, 2.6 mg. riboflavin and 5.3 mg. pantothenic acid per lb. of diet.

[f]Provides 4.4 ug. vitamin B_{12} per lb. of diet.

[g]Provides 10 mg. aureomycin HCl per lb. of diet.

[h]99% d-l methionine.

TABLE 2. CALCULATED METHIONINE AND LYSINE DIET LEVELS AND REQUIREMENTS FOR 13, 16 AND 20 PERCENT MILO-SOYBEAN RATIONS

	Requirement[a]						Ration Content[b]			
Amino acid	Weanling pig (30 lb.)			Finishing pig (100 lb.)						
Level of dietary protein (%)	13	16	20	13	16	20	13	16	20	20 plus methionine
				(percent of diet)			(percent of diet)			
Methionine	.43	.50	.57	.32	.37	.43	.213	.249	.286	.428
Methionine x .60[c]	.26	.30	.34	.19	.22	.26	—	—	—	—
Lysine	.64	.74	.87	.53	.62	.72	.554	.823	1.093	1.093

[a]Values are either those reported by Becker et al. (1966) or calculated on their assumption that "the need for each amino acid, expressed as a percent of the protein, decreases 1.75 percent (from value at 0 percent protein) per unit increase in percent protein".

[b]Calculated from the values reported for the methionine and lysine content of the grain sorghum and soybean meal used in this study. (Appendix 3)

[c]Based on the assumption that cystine can supply 40 percent of the total need for methionine.

Slaughter and Cutting Procedures

Pigs were individually removed from test when they weighed 210 ± 10 pounds. They were slaughtered at the Kansas State University Meat Laboratory after being held there overnight. Kidney and leaf fat weights were obtained. Carcasses were dressed packer style, weighed and then chilled for a minimum of 24 hours before the following data was obtained; chine depth at the last rib and last lumbar vertebral locations, carcass backfat thickness, carcass length and chilled carcass weight. Chine depth was measured from the dorsal portion of the vertebral foramen to the inner surface of the backfat. Backfat thickness (including skin) was an average of three measurements taken at the first rib, last rib and last lumbar vertebra. Length was measured from the anterior edge of the vertebral end of the first rib to the anterior segment of the aitch bone (pubis symphysis).

The right half of each carcass was cut by procedures outlined by the 1952 Reciprocal Meat Conference with the exception of the rough shoulder being removed between the third and fourth ribs. Wholesale cuts were trimmed to $\frac{1}{4}$ inch fat thickness, with the ham and picnic being partially skinned. Trimmed cuts were weighed to the nearest 0.1 of a pound. These weights were doubled and the percents of trimmed cuts were calculated on the basis of chilled carcass weight.

The lumbar lean and the cut surface of the ham were scored for color and firmness and the lumbar lean was also scored for marbling. Color and firmness were scored on a five point scale (Wisconsin Pork Standards, 1963). Subjective marbling scores were determined to one third of a degree using the U.S.D.A. beef marbling standards as a guide. (See appendixes B and C for color-firmness scores and marbling scores, respectively).

Specific gravity of the right untrimmed ham was determined by dividing the weight of the ham in air by the weight in air minus the weight in water. The ham was weighed in air to the nearest one hundreth of a pound. The submerged weight was obtained to the nearest whole gram with a Mettler top-loading balance. Cross-sectional longissimus dorsi area was obtained anterior to the 5th, 8th, 10th, 12th and last thoracic and the 1st, 3rd and 5th lumbar vertebrae. At each section, the longissimus dorsi muscle was scored for firmness, color and marbling. Loin eye tracings at the cross-sections were taken and the area was determined using a compensating planimeter. The longissimus dorsi muscle between the 8th and 10th thoracic vertebrae was trimmed free of external fat and stored at -20° C. for proximate analysis and water holding determinations. Two 3/4 inch chops were taken immediately posterior to the 10th vertebra and stored at -20° C. until used for cooking loss and tenderness determinations.

Water-Holding Capacity

The frozen samples were thawed and ground twice with a power grinder using a one eigth inch plate size. After removing enough sample for determination of expressible water, the remainder was refrozen for proximate analysis. Results were expressed as the "percent moisture lost" and determined in duplicate by the centrifuge method developed by Wierbicki et al. (1957), with two slight modifications. The fritted glass discs were cleaned after each determination by heating over a Bunsen burner for one half hour. They were stored in a saturated KCl solution for 12 hours before reuse.

Proximate Analysis

Ash, protein, dry matter and ether extract were determined in duplicate by modified methods of the procedures outlined by the A.O.A.C. (1960). In all cases, samples were weighed to the neasrest 0.1 milligram. Approximately 1.5 gram samples were weighed in glass crucibles and ashed in a muffle furnace for 16 hours at 600° C. Protein was determined by the Kjeldahl method using Kel-Paks for catalysts. Ammonia was collected in a boric acid solution which was titrated against a dilute sulfuric acid solution. The percent protein was calculated by multiplying the percent nitrogen by 6.25. One sample weighing approximately 2.5 grams was used for both the dry matter and ether extracts determinations. The fresh sample was weighed onto Whatman No. 41 filter paper that had been previously oven dried and stored in a dessicator. The paper was folded and stapled in such a manner that only one paper thickness surrounded the meat sample. Samples were dried in a vacuum oven at 95° C. under full vacuum for 25 hours, cooled in a dessicator and weighed. The weight lost in drying was expressed as percent moisture. Samples were then extracted with petroleum ether for 20 hours in Soxhlet extractors. The ether extracted samples were dried at full vacuum at 95° C. for 18 hours, and the additional weight lost was calculated as percent ether extract.

Cooking and Tenderness Determinations

Cooking losses were determined in duplicate by the method developed by Lind (1968). After thawing 12 hours, samples were trimmed free of excess fat. A hole was punctured through the center of the muscle for the insertion of a cooking thermometer. Samples were weighed to the nearest 0.1 milligram. The weighed samples, with inserted thermometers, were placed on wire screen cooking racks that were positioned over aluminum pans used to collect the drippings. The wire racks, aluminum pans, and cooking thermometers were all previously weighed. Samples were cooked in a pre-heated rotary oven at 400° F. to an internal temperature of 169° F. (76° C.). The samples did not need to be turned as heat was distributed on all sides of the chops, resulting in a uniform degree of doneness. After cooling to approximately 40° C., the cooked chops, wire screen racks, aluminum pans and thermometers were reweighed. Percent total cooking loss and percent drip loss were calculated and percent volatile loss was determined by difference.

The cooked samples were allowed to cool to room temperature and Warner-Bratzler shear values were obtained. One shear determination was made on each of two lateral and two medial ½ inch cores.

Statistical Analysis

Individual data for average daily gain and each of the carcass measurements from the 64 pigs were subjected to a three-way analysis of variance (Appendix D). Pen means (4 pigs per pen) were calculated for feed and crude protein consumption data and resolved by use of a three-way analysis of variance (Appendix E). When more than two means were compared, the Least Significant Difference method (5% level of probability) was used.

Results and Discussion

Effects of Ration and Sex on Feedlot Performance

Feedlot performance data is presented in table 3. Increasing the protein level or the addition of methionine had no significant effect on average daily gain at 70 days or for the entire feeding period, although there was a reduction in gain at the 20 percent protein level. This is in agreement with the findings of Jensen et al. (1955), Speer et al. (1956), Wagner et al. (1963) and Robinson (1965). They reported that pigs fed greater than 14 percent crude protein gained slower than pigs fed between 12 and 14 percent crude protein.

Feed conversion at 70 days was not significantly affected by ration or sex, but pigs fed the 16 percent protein diet had the smallest feed-gain ratio. For the entire feeding period, pigs fed the 16 percent dietary protein level were significantly more efficient feed converters than those fed either of the 20 percent protein diets ($P<.05$). Pigs fed the 13 percent protein diet had significantly lower feed-gain ratios than those fed the 20 percent protein diet without methionine ($P<.05$). Speer et al. (1956) and Robinson (1965) had previously reported maximum feed efficiency at crude protein levels of 15 and 12 percent, respectively, with any further increases in dietary protein resulting in poorer feed utilization. A significant interaction existed between trial and ration. Poorer feed conversions ratios were obtained for pigs fed the 16 percent crude protein in trial I than for those fed the ration in trial II. However, pigs on the 20 percent crude protein plus methionine diet in trial II were better feed converters than those fed that ration in trial I.

The reduced rate and efficiency of gain of the pigs fed the 20 percent protein diets could have been directly related to the energy contents of the ration ingredients. Metabolizable and productive energy values for milo furnished by Merck and Co., Inc., are about 1½ times those for soybean meal. Net energy values reported in the 7th Annual California Feeders' Day (1967) bulletin for milo and soybean meal were 87 and 78 megcal per 100 lb., respectively, for maintenance and 58 and 52 megcal per 100 lb., respectively, for production. The importance of the higher heat increment for milo in maintaining body temperature in cool weather and the higher maintenance and net energy values for milo could have been reflected in the better performance of pigs fed the 13 and 16 percent protein diets.

Barrows gained faster ($P<.01$) and were more efficient in feed conversion ($P<.05$) than gilts.

Daily feed intake for the first 70 days on test was not significantly affected by ration, sex or trial. Barrows consumed more feed per day than gilts ($P<.05$) for the entire growth period, but there were no ration or trial differences.

Pigs fed the 13 percent protein diet consumed less total crude protein per day than those fed the other three diets ($P<.05$). The daily crude protein intake of pigs fed the 16 percent dietary protein level was less than those fed the 20 percent protein diets ($P<.05$). Barrows consumed more crude protein per day, but the difference was not quite statistically significant.

The amount of protein consumed per pound gain in weight was significantly affected by diet ($P<.01$). Pigs fed the 13 percent crude protein diet were considerably more efficient in protein utilization than those fed the other three rations ($P<.05$). Likewise, pigs fed the 16 percent dietary protein level required less protein per pound of gain than those fed the 20 percent protein rations ($P<.05$). This substantiates findings of Greely et al. (1964a) and Lee et al. (1967), who reported that the efficiency of conversion of protein to gain decreased with increasing levels of dietary protein.

While there was no difference in age at slaughter between pigs fed the 13 and 16 percent protein diets, those fed the 20 percent protein diets tended to be older at slaughter weight, but the difference was not statistically significant.

Effects of Ration and Sex on Carcass Characteristics

Carcass data are presented in table 4. Dressing percent, percent ham and loin, percent lean cuts, percent primal cuts, loin eye area, carcass length, carcass backfat, leaf fat, chine depth and ham specific gravity were not significantly affected by protein level or methionine addition. Smith et al. (1967), Baker et al. (1967), Hale et al. (1967) and Lee et al. (1967), along with numerous other earlier studies, reported significant increases in carcass lean cut yield with increasing levels of protein. It should be pointed out, however, that the higher values found in this study for ham specific gravity and percentages of ham plus loin and lean cuts for pigs fed greater than the 13 percent dietary protein level are of practical importance. The poorer response of the pigs in this study to increasing levels of dietary protein may be partially due to the overall trimness of all the pigs, resulting in less variation in total fat trim, between treatment groups.

Table 3. Effects of Protein Level, Added Methionine and Sex on Swine Feedlot Performance

(Ration and Sex Means - 2 trials combined)

Item	Protein Level (%) 13	16	20	20 + meth	F-Value	Sex: Barrows	Gilts	F-Value
No. of pigs	16	16	16	16		32	32	
Age at slaughter, days	176.6	176.7	184.7	188.4	1.72	176.6	186.6	4.82*
Total days on feed	91.3	91.6	100.2	103.3	1.84	91.5	101.8	5.22*
Live empty slaughter wt. lb.	198.5	201.0	197.6	198.4	0.82	199.4	198.3	0.48
70 day av. daily gain, lb.	1.46	1.49	1.36	1.39	0.99	1.47	1.38	2.05
Total av. daily gain, lb.	1.56	1.60	1.44	1.46	2.33	1.61	1.42	13.34**
70 day daily feed intake	4.97	4.66	4.61	4.53	0.67	4.78	4.60	0.55
Total daily feed intake	5.26	5.28	5.11	5.16	0.32	5.45	4.95	11.01*
70 day feed/gain ratio	3.41	3.13	3.39	3.26	2.13	3.27	3.33	0.51
Total feed/gain ratio	3.46[ab]	3.33[a]	3.63[c]	3.60[bc]	16.04*	3.45	3.56	10.77*
Total daily prot. intake	0.68[a]	0.85[b]	1.02[c]	1.03[c]	28.50*	0.94	0.85	7.68
Lb. crude protein/lb. of gain	0.45[a]	0.54[b]	0.72[c]	0.72[c]	256.00**	0.60	0.61	3.00

*P<.05

**P<.01

a,b,c Means on the same line with the same superscript are not significantly different (P<.05).

Hale et al. (1967) and Smith et al. (1967), plus many earlier studies, have shown that while the rate and efficiency of gain of gilts is lower than that of barrows, gilts are definitely heavier muscled and trimmer. This is in accordance with the results found in this study. Gilt carcasses were leaner as evidenced by larger loin eyes ($P<.01$), less carcass backfat ($P<.05$), less leaf fat ($P<.05$) and greater percentages of ham and loin ($P<.01$), lean cuts ($P<.05$) and primal cuts ($P<.05$). They also had higher values for ham loin index ($P<.01$), ham specific gravity ($P<.05$), dressing percent ($P<.01$) and depth of chine ($P<.01$, $P<.05$) at the last rib and last lumbar, respectively. Since there was essentially no difference between barrows and gilts in crude protein intake per lb. of gain, and being that gilts consumed less crude protein per day, it appears that gilts have a greater capacity than barrows for the utilization of dietary protein for muscle development, in as much as gilts exhibited heavier muscled carcasses.

Kidney weights of pigs fed diets containing 16 and 20 percent protein were significantly greater than for those fed the 13 percent protein diet. It is probable that the higher protein content of rations 2, 3 and 4 exceeded the pigs threshold for utilization and assimilation of nitrogen, Subsequent increased secretion of nitrogenous waste products could have resulted in hypertrophy of the cellular mass of the kidney. These results disagree with data collected by Kropf et al. (1959), who reported no differences in kidney weights from pigs fed 12 or 16 percent levels of dietary protein, but agree with findings of Carrol et al. (1935-36) and Woodman et al. (1934, 1936, 1945).

Table 4. Effects of Protein Level, Added Methionine and Sex on Swine Carcass Characteristics (Ration and Sex means - 2 trials combined)

Item	Protein Level 13	16	20	20 + meth	F-value	Sex Barrows	Gilts	F-value
No. of pigs	16	16	16	16		32	32	
Chilled carcass wt., lb.	144.2	144.4	141.7	142.0	0.82	142.3	143.8	1.03
Dressing %	72.7	71.8	71.7	71.6	1.34	71.3	72.5	6.07**
Carcass length, in.	28.5	28.6	28.5	28.7	0.33	28.3	28.9	14.90**
Av. Car. backfat thickness, in.	1.34	1.26	1.22	1.19	1.62	1.32	1.18	6.92**
Chine depth, last rib, in.	1.52	1.56	1.56	1.52	0.69	1.48	1.60	20.77**
Lumbar lean depth, last lumbar, in.	2.91	2.81	2.91	2.77	0.90	2.76	2.94	6.29*
L. dorsi area, in.								
5th thor. vert.	2.49	2.77	2.81	2.68	0.93	2.48	2.90	7.70*
8th " "	3.29	3.45	3.65	3.47	2.72	3.23	3.70	26.19**
10th " "	3.84	3.93	4.02	4.02	0.45	3.71	4.19	13.98**
12th " "	4.27	4.42	4.57	4.42	1.32	4.08	4.77	42.36**
last " "	4.14	4.27	4.34	4.24	0.75	3.97	4.53	32.29**
1st lumb. vert.	4.25	4.45	4.58	4.39	1.43	4.12	4.71	27.66**
3rd " "	4.36	4.63	4.60	4.45	1.26	4.27	4.75	18.84**
5th " "	4.72	5.01	5.08	4.89	1.50	4.67	5.18	16.06**
% of carcass								
ham and loin	37.1	37.8	38.5	38.1	1.39	37.0	38.7	11.56**
4 lean cuts	55.7	56.3	57.5	57.1	1.47	55.7	57.5	7.34*
primal cuts	69.5	69.9	70.6	70.2	1.12	69.5	70.6	5.14*
Ham-loin index	93.6	96.9	97.8	98.9	0.55	89.4	104.2	23.29**
Ham specific grav.	1.051	1.055	1.055	1.054	2.67	1.052	1.055	8.02*
Leaf fat wt., gm.	3.55	3.45	3.18	3.26	0.76	3.58	3.14	4.85*
Kidney wt., gm.	299.4[a]	343.2[b]	359.5[b]	359.1[b]	9.26**	339.5	341.1	0.03

*P < .05

**P < .01

[a,b]Means on the same line with the same superscript are not significantly different (P<.05).

Ration-Sex Interactions for Feedlot Performance and Carcass Characteristics

The data presented in table 5 showed that rate and efficiency of gain were greatest at the 13 percent dietary protein level for barrows and the 16 percent dietary protein level for gilts. Maximal muscle development occurred at the 16 percent dietary protein level for barrows and the 20 percent dietary protein level for gilts. Baker and co-workers (1967) found maximum rate and efficiency of gain at 12 percent and 14 percent dietary protein levels for barrows and gilts, respectively. They found carcass leanness was maximized at the 14 percent dietary protein level for barrows and the 16 percent dietary protein level for gilts. The above data is good support for the idea that gilts require greater levels of high quality dietary protein for maximal growth and carcass development.

Effects of Ration and Sex on Muscle Composition

Proximate analysis data for the longissimus dorsi muscle is presented in table 6. If muscle mass and size can be increased by feeding higher levels of dietary protein, it is also possible that changes could occur in the chemical composition of the muscle. In this study, increasing the dietary protein level above 13 percent significantly increased the protein and moisture and decreased the fat content of the longissimus dorsi ($P<.05$). Kropf et al. (1959), Wagner et al. (1963) and Jurgens et al. (1967) reported lower ether extract and higher protein values for longissimus dorsi samples of pigs fed greater than 12 percent or 13 percent dietary protein. Lee et al.

Table 5. Feedlot Performance and Carcass Characteristics of Barrows and Gilts Fed Varying Protein Levels and Added Methionine (Sex x Ration Interaction)

(Sex Means - 2 trials combined)

Item	Barrows	Gilts	F-value
No. of pigs	32	32	
Total av. daily gain, lb.			0.71
13% C. P. (crude protein)	1.70	1.42	
16% C. P.	1.65	1.54	
20% C. P.	1.55	1.33	
20% C. P. + methionine	1.52	1.40	
Total feed/gain ratio, lb.			5.19
13% C. P.	3.37	3.54	
16% C. P.	3.31	3.36	
20% C. P.	3.48	3.78	
20% C. P. + methionine	3.64	3.57	
Loin eye area, 10th thoracic vertebra, sq. in.			0.24
13% C. P.	3.63	4.04	
16% C. P.	3.74	4.12	
20% C. P.	3.78	4.25	
20% C. P. + methionine	3.69	4.36	
Loin eye area, 12th thoracic vertebra, sq. in.			0.44
13% C. P.	3.92	4.63	
16% C. P.	4.14	4.70	
20% C. P.	4.13	5.01	
20% C. P. + methionine	4.12	4.73	
Percent ham and loin of carcass			0.73
13% C. P.	35.8	38.4	
16% C. P.	37.6	38.1	
20% C. P.	37.6	39.3	
20% C. P. + methionine	37.1	39.1	
Percent four lean cuts of carcass			0.80
13% C. P.	54.1	57.2	
16% C. P.	56.2	56.4	
20% C. P.	56.6	58.4	
20% C. P.	56.1	58.1	
Ham-loin index			0.43
13% C. P.	86.6	100.6	
16% C. P.	91.4	102.4	
20% C. P.	87.5	108.0	
20% C. P. + methionine	92.0	105.9	

Table 6. Effects of Protein Level, Added Methionine and Sex on Swine Longissimus Dorsi Muscle Composition (Ration and Sex Means - 2 trials combined)

Item	Protein Level 13	Protein Level 16	Protein Level 20	Protein Level 20 + meth.	F-value	Sex Barrows	Sex Gilts	F-value
No. of pigs	16	16	16	16		32	32	
L. dorsi; fresh basis								
protein, %	20.84[a]	21.68[b]	21.64[b]	21.40[b]	6.60**	21.14	21.63	10.74**
moisture, %	72.98[a]	74.29[b]	74.45[b]	74.77[b]	8.57**	74.38	73.86	3.80
ether extract, %	5.90[a]	3.71[b]	3.67[b]	3.80[b]	15.11**	4.37	4.17	0.47
ash, %	1.10	1.11	1.13	1.09	1.15	1.09	1.12	4.91*
L. dorsi; fat free basis								
protein, %	22.14	22.51	22.46	22.24	2.33	22.10	22.57	16.14**
moisture, %	77.57	77.16	77.29	77.72	2.23	77.78	77.08	16.25**
ash, %	1.17	1.15	1.17	1.13	1.85	1.14	1.17	5.10*
L. dorsi; moisture free basis								
protein, %	77.57[a]	84.47[b]	84.47[b]	85.08[b]	11.44**	82.79	83.16	0.13
ether extract, %	21.48[a]	14.33[b]	14.32[b]	14.83[b]	16.76**	16.83	15.65	1.92
ash, %	4.10	4.33	4.41	4.32	2.36	4.27	4.32	0.33

*$P < .05$

**$P < .01$

[a,b]Means on the same line with the same superscript are not significantly different ($P < .05$).

(1967) reported similar findings with samples from ham muscles.

When the effect of moisture was removed, longissimus dorsi muscles from pigs fed greater than the 13 percent protein level were higher in protein ($P<.05$) and lower in fat content. In the study of Lee and co-workers (1967) an increase in dietary protein resulted in a linear decrease in fat content of the longissimus dorsi (dry matter basis).

No ration differences were observed for protein, moisture and ash content of the longissimus dorsi when expressed on a fat free basis. Lee et al. (1967) also observed that increasing the ration protein level had no effect on the protein and ash content of ham muscles when corrected to a fat free basis, but there was a linear decrease in the percent moisture.

The longissimus dorsi muscles of gilts were higher in percent protein ($P<.01$) and ash ($P<.01$) than those of barrows. No significant difference existed for moisture and ether extract values, which is in contrast to the work of Judge et al. (1957), who found that longissimus dorsi muscles from gilts contained significantly less fat, and Weiner (1964), who observed that longissimus dorsi muscles from gilts had lower ether extract and higher moisture values than those from barrows

On a fat free basis, gilt longissimus dorsi muscles had lower moisture ($P<.01$) and higher protein ($P<.01$) and ash ($P<.01$) values. No sex differences existed for ether extract, protein and ash contents of the longissimus dorsi when calculated on a moisture free basis.

Effects of Ration and Sex on Muscle Quality
and Related Factors

Cooking losses, expressible moisture, Warner-Bratzler shear values and subjective quality scores are found in table 7. The low values for drip losses obtained in this study are associated with the method in which the samples were cooked (modified broiling). There was a greater opportunity for the drippings to volatilize due to the increased exposure to heat since the samples were placed 6 inches above the collection pans.

Drip, volatile and total cooking losses were not significantly affected by protein level, added methionine or sex. Kauffman et al. (1964) had found lower cooking losses for loins containing greater quantities of intramuscular fat, which might lead one to expect lower cooking losses for the chops from pigs on the 13 percent protein diet. Weiner (1964) and Lind (1968) could find no significant relationship between cooking loss and marbling, but their samples did not have as great a range in intramuscular fat content as did the samples of Kauffman et al. (1964).

Increasing the protein level or the addition of methionine did not affect the moisture lost upon heating and centrifugation. Although not statistically significant, samples from gilts had greater expressible moisture values than those from barrows.

Lateral or medial Warner-Bratzler shear values of cooked loin chops were not significantly affected by protein level, which compares favorably with the findings of Lee and co-workers (1967). However, taste panel results in the study of Lee et al. (1967) showed that samples from pigs fed high and medium protein levels were less tender than those from pigs fed the low level of dietary protein. The slightly lower shear values for loin chops from pigs fed the 13 percent dietary protein level might be partially explained by the significantly higher marbling scores of these chops. The work of Weiner

(1964) and Harrington and Pearson (1962) showed that increases in marbling reduced Warner-Bratzler shear values.

Lateral shear values for gilts were significantly higher than those for barrows (P<.05), and there was a slight tendency for this to occur in the medial shears. The slightly higher marbling scores of the loins from barrows may also account for some of this difference.

There is some evidence indicating that decreases in carcass firmness and marbling occur with increasing levels of dietary protein (Crum et al., 1964). In this study, marbling scores of the longissimus dorsi were significantly increased in pigs fed the 13 percent protein level, but there were no marbling differences between loins from pigs fed the 16 percent protein level and of loins from either of the 20 percent protein diets. Firmness and color scores of the longissimus dorsi were not affected by protein level or methionine addition. Increasing the protein level or addition of methionine had no significant effect on color, firmness and marbling scores for either the lumbar lean or ham.

At the 5th thoracic and 1st lumbar vertebra locations, longissimus dorsi muscles from gilts had less marbling than those from barrows (P<.01, P<.05), respectively. At the other cross-sections of the longissimus dorsi the lower marbling scores of gilts were not statistically significant. This data is in partial agreement with results published by Judge et al. (1957), which showed the longissimus dorsi of barrows to be firmer and contain significantly more fat than the longissimus dorsi of gilts. In this study, however, no differences for firmness and color existed between sexes. The lumbar lean of gilts was darker (P<.05) and less firm (P<.01) than that of barrows. Ham muscles of gilts were also less firm (P<.05).

Table 7. Effects of Protein Level, Added Methionine and Sex on Muscle Quality and Related Factors (Ration and Sex Means - 2 trials combined)

Item	Protein Level				F-value	Sex		F-value
	13	16	20	20 + meth.		Barrows	Gilts	
Lateral shear, l. dorsi, lb.[x]	7.05	7.28	7.77	7.10	0.82	6.84	7.76	6.50*
Medial shear, l. dorsi, lb.[x]	5.31	5.64	6.04	6.02	2.44	5.58	5.93	2.42
Wierbicki, % expressible H_2O	34.65	34.63	34.37	33.61	0.52	33.66	34.97	3.66
Cooking loss								
drip, %	1.00	1.09	1.00	0.96	0.69	1.06	0.97	1.86
volatile, %	28.82	28.97	26.81	30.42	1.94	28.96	28.55	0.01
total, %	29.82	30.05	27.82	31.38	1.72	30.01	29.52	0.19
Lumbar lean subjective scores[y,z]								
color	2.98	3.06	3.16	3.06	1.31	2.99	3.14	5.80*
firmness	3.16	3.12	3.16	3.06	0.82	3.20	3.05	10.29**
marbling	19.94	18.81	20.12	19.31	0.94	19.66	19.44	0.12
Ham surface subjective scores[y]								
color	2.81	2.84	3.03	3.00	1.39	2.89	2.95	0.45
firmness	2.81	2.81	2.88	2.72	0.61	2.89	2.72	4.31*
L. dorsi, 10 T subjective scores[y]								
color	2.81	2.78	3.12	2.97	1.74	2.86	2.98	1.08
firmness	2.72	2.72	2.72	2.72	0.00	2.75	2.69	0.81
Marbling, l. dorsi[z]								
5th thoracic vertebra	21.12[a]	16.38[b]	16.50[b]	16.12[b]	6.81**	18.84	16.22	8.15**
8th thoracic vertebra	23.06[a]	17.38[b]	18.19[b]	18.69[b]	7.18**	20.25	18.41	3.76
10th thoracic vertebra	23.00[a]	17.75[b]	18.25[b]	19.06[b]	6.23**	20.16	18.88	1.80
12th thoracic vertebra	22.69[a]	18.19[b]	18.38[b]	18.94[b]	5.68**	20.19	18.91	2.08
last thoracic vertebra	20.62[a]	18.06[b]	17.19[b]	17.88[b]	3.64*	19.16	17.72	3.32
1st lumbar vertebra	21.12[a]	18.25[b]	17.31[b]	17.75[b]	5.81**	19.53	17.69	6.67*
3rd lumbar vertebra	21.62[a]	18.88[b]	18.50[b]	18.75[b]	3.34*	20.06	18.81	2.42
5th lumbar vertebra	22.25	19.94	20.19	20.88	1.54	21.22	20.41	0.95

x Warner-Bratzler.

y Color and firmness scores based on a 5 point scale; higher number indicates darker, firmer muscle.

z Marbling scores based on U.S.D.A. standards; 16 = modest minus and 24 = slightly abundant plus.

* $P < .05$

** $P < .01$

a,b Means on the same line with the same superscript are not significantly different (P<.05).

Effect of Season (Trial) on some Muscle Quality Characteristics

The data is presented in table 8. Judge (1959) observed that pigs fed during cool weather yielded darker more highly marbled loin eye muscles. The marbling values collected in this experiment substantiate his findings. Loin eyes from pigs in trial I had higher marbling scores than those from pigs in trial II ($P<.01$). Pigs in Trial I were grown and finished during the colder months of November, December and January while those in the second trial were on feed during February, March and April. Cool weather may trigger a physiological response in the animal that results in a build up of intramuscular fat stores which serve as a potential heat source for maintenance of body temperature under severe weather conditions.

In addition, samples from pigs in the first trial had higher total cooking losses ($P<.05$), drip losses ($P<.01$), expressible moisture values ($P<.01$), lateral shears ($P<.01$), medial shears ($P<.05$) and longissimus dorsi ether extract values ($P<.01$) and lower longissimus dorsi moisture content ($P<.01$). This partially corresponds to the findings of Weiner (1964), who reported lower cooking losses for longissimus dorsi samples from gilts that were high in percent fat and low in percent moisture. The greater shear values for samples from Trial I are probably directly related to the higher cooking losses and expressible moisture values, plus the original lower moisture content of these samples. The marbling values were also higher from the longissimus dorsi samples from Trial I, but it appears that high moisture losses produced a toughening in muscle that prevailed over the reported tenderizing effect of marbling.

Table 8. Effect of Season (Trial) on Some Muscle Quality Characteristics

Item	Trial I[a]	Trial II[b]	F-value
Cooking loss			
total %	31.02	28.51	4.97*
volatile, %	29.92	27.59	3.51
drip, %	1.10	0.92	8.30**
Wierbicki, % expressible H_2O	35.21	33.43	6.77*
Warner-Bratzler shear values, cooked ½ inch cores			
lateral, lb.	8.26	6.34	28.00**
medial, lb.	6.02	5.48	5.88*
Marbling			
10th thoracic vertebra	21.69	17.34	20.68**
12th thoracic vertebra	20.75	18.34	7.33*
L. dorsi, fresh basis			
% ether extract	5.13	3.41	37.89**
% moisture	73.51	74.73	20.73**

[a] Pigs were put on test October 25, 1966, and remained on feed for an average of 99 days. Slaughter dates ranged from January 4, 1967, through April 18, 1967.

[b] Pigs were put on test February 7, 1967, and remained on feed for an average of 94 days. Slaughter dates ranged from April 18, 1967 through June 12, 1967.

* $P < .05$

** $P < .01$

Summary

A total of 64 pigs averaging 66 pounds bodyweight and 85 days of age were utilized in two trials to study the effect of protein level, added methionine and sex on feedlot performance, carcass composition and quality. The four treatments consisted of milo-soybean meal rations containing: (1) 13 percent crude protein, (2) 16 percent crude protein, (3) 20 percent crude protein and (4) 20 percent crude protein plus 0.14 percent dl-methionine (percent of diet).

Daily feed intake, rate and efficiency of gain were not affected by ration or sex for the first 70 days on test. For the entire feeding period, pigs fed 20 percent protein gained slower and were less efficient than those fed 16 percent protein ($P<.05$). No significant differences were found for daily feed intake, growth rate and efficiency of gain between pigs fed rations 1 and 2 or between pigs fed rations 3 and 4. Increasing the level of protein resulted in a linear increase in daily crude protein intake and in the crude protein consumed per pound of gain ($P<.05$).

Barrows consumed more feed ($P<.05$), gained faster ($P<.01$), were more efficient in total feed conversion ($P<.05$) and consumed more crude protein per day than gilts.

Pigs were individually slaughtered when they reached a weight of 210 ± 10 pounds.

None of the carcass measurements were significantly affected by ration, but pigs fed ration 1 did not develop the muscling or trimness of pigs fed the other rations.

Gilt carcasses were leaner than barrows as evidenced by larger loin eyes

($P<.01$), less carcass backfat ($P<.05$), less leaf fat ($P<.05$) and greater percentages of ham and loin ($P<.01$), lean cuts ($P<.05$) and primal cuts ($P<.05$). They also had higher values for ham-loin index ($P<.01$), ham specific gravity ($P<.05$), dressing percent ($P<.01$) and chine depth ($P<.01$, $P<.05$) at the last rib and last lumbar, respectively.

Maximum gain and feed efficiency was reached at protein levels of 13 percent for barrows and 16 percent for gilts. Maximal carcass development for barrows and gilts was generally observed at 16 and 20 percent protein levels, respectively.

Kidney weights of pigs fed 13 percent protein were lighter than those from the other treatments ($P<.05$), with no difference between barrows and gilts.

Longissimus dorsi muscles from pigs fed ration 1 were lower ($P<.05$) in protein and moisture and higher ($P<.05$) in fat (fresh or dry matter basis). On a fat free basis, no significant differences existed for proximate analysis values.

Fresh longissimus dorsi samples from gilts were higher in protein and ash than those from barrows ($P<.01$). On a fat free basis, gilt longissimus dorsi muscles were lower in moisture ($P<.01$) and higher in protein ($P<.01$) and ash ($P<.05$). No sex differences were present when proximate analysis values were expressed on a moisture free basis.

Drip, volatile and total cooking losses plus expressible moisture values (Wierbicki) for longissimus dorsi samples were not significantly affected by ration or sex, although samples from barrows tended to have lower expressible moisture values.

Lateral or medial Warner-Bratzler shear values were not significantly affected by ration. Lateral shears for gilts were higher than those for barrows (P<.05).

Longissimus dorsi marbling scores at 8 locations were higher in pigs fed the 13 percent protein ration (P<.01), but firmness and color scores were not affected by diet. Marbling, color and firmness scores of the lumbar lean and ham were not significantly affected by ration.

Firmness and color scores of the longissimus dorsi did not differ between sexes, but gilts tended to have less marbling. The lumbar lean of gilts was darker (P<.05) and less firm (P<.01) than that of barrows. Ham muscles of gilts were also less firm (P<.05).

Pigs in the winter trial compared to those in the spring trial had higher total cooking losses (P<.05), drip losses (P<.01), expressible moisture values (P<.01), lateral shears (P<.01), medial shears (P<.05), longissimus dorsi ether extract values (P<.01) and marbling scores (P<.01) and lower longissimus dorsi moisture content (P<.01).

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Literature Cited

Abernathy, R. P., R. F. Sewell and R. L. Tarpley. 1958. Interrelationships of protein, lysine and energy in diets for growing swine. J. Animal Sci. 17:635.

Association of Official Agricultural Chemists. 1960. Official Methods of Analysis (9th ed.). Washington, D. C.

Ashton, G. C., J. Kastelic, D. C. Acker, A. H. Jensen, H. M. Maddock, E. A. Kline and D. V. Catron. 1955. Different protein levels with and without antibiotics for growing-finishing swine: Effect on carcass leanness. J. Animal Sci. 14:82.

Aubel, C. E. 1956. Comparative value of corn and whole ground milo as swine fattening feeds. Kan. Agr. Exp. Sta. Circular 335:84.

Aunan, W. J., L. E. Hanson and R. J. Meade. 1961. Influence of levels of dietary protein on live weight gains and carcass characteristics of swine. J. Animal Sci. 20:148.

Baker, D. H., C. E. Jordan, W. P. Waitt and D. W. Gouivens. 1967. Effect of a combination of diethylstilbestrol and methyltestosterone, sex and dietary protein level on performance and carcass characteristics of finishing swine. J. Animal Sci. 26:1059.

Becker, D. E., J. W. Lassiter, S. W. Terrill and H. W. Norton. 1954. Levels of protein in practical rations for the pig. J. Animal Sci. 13:611.

Berry, T. H., G. E. Combs, H. D. Wallace and R. C. Robbins. 1966. Responses of the growing pig to alterations in the amino acid pattern of isolated soybean protein. J. Animal Sci. 25:723.

Brown, C. J., J. C. Hillier and J. A. Whatley. 1951. Specific gravity as a measure of the fat content of the pork carcass. J. Animal Sci. 10:97.

Bruner, W. H., Vern R. Cahill, W. L. Robison and Richard F. Wilson. 1958. Performance of barrow and gilt littermate pairs at the Ohio Swine Evaluation Station. J. Animal Sci. 17:875.

Cahilly, G. M., Jr., R. F. Miller, R. F. Kelly and C. C. Brooks. 1963. Effect of various levels of dietary lysine on certain blood phenomena, muscle development, and muscle-protein biological value of growing swine. J. Animal Sci. 22:726.

California Feeders' Day. 1967. Net energy contents of feeds. University of California. Davis, California.

Carrol, W. E., W. P. Garrigus, H. H. Mitchell, T. S. Mitchell and W. T. Haines. 1935-36. Protein in ration influences composition of pork. Annual Report III. Agr. Exp. Sta. P. 93.

Catron, D. V., A. H. Jensen, P. G. Homeyer, H. M. Maddock and G. C. Ashton. 1952. Re-evaluation of protein requirements of growing-fattening swine as influenced by feeding an antibiotic. J. Animal Sci. 11:221.

Clawson, A. J. 1967. Influence of protein level, amino acid ratio, and caloric density of the diet on feed intake and performance of pigs. J. Animal Sci. 26:328.

Clawson, A. J., T. N. Blummer. W. W. G. Smart Jr. and E. R. Barrick. 1962. Influence of energy-protein ratio on performance and carcass characteristics of swine. J. Animal Sci. 2:62.

Crum, R. C. Jr., H. D. Wallace, A. Z. Palmer, J. W. Carpenter, G. H. Taki and G. E. Combs. 1964. Protein level effect on swine performance and carcasses. J. Animal Sci. 23:871.

Curtin, L. V., J. K. Loosli, J. P. Willman and H. H. Williams. 1952. Methionine as a supplement to soybean oil meal for weanling pigs. J. Animal Sci. 11:459.

Diggs, B. G., Bryan Baker, Jr. and R. W. Rogers. 1965. Influence of protein level and confined feeding on performance and carcass characteristics of swine. J. Animal Sci. 24:283.

Dukelow, W. R., R. S. Grant, R. J. Meade and J. H. Goihl. 1963. Influence of protein level, and of amino acid supplementation, on performance of growing swine, and on carcass characteristics. J. Animal Sci. 22:1119. (abstract).

Dyer, I. A., J. L. Krider and W. E. Carrol. 1949. Known and unidentified factors supplement a corn-soybean meal ration for weanling pigs in drylot. J. Animal Sci. 8:541.

Greeley, M. G., R. J. Meade and L. E. Hanson. 1964. Energy and protein intakes by growing swine. I. Effects on rate and efficiency of gain and on nutrient digestibility. J. Animal Sci. 23:808.

Greeley, M. G., R. J. Meade, L. E. Hanson and J. Nordstrom. 1964. Energy and protein intakes by growing swine. II. Effects on rate and efficiency of gain and on carcass characteristics. J. Animal Sci. 23:816.

Hale, O. M. and B. L. Southwell. 1967. Differences in swine performance and carcass characteristics because of dietary protein level, sex and breed. J. Animal Sci. 26:341.

Hudman, D. B. and E. R. Peo, Jr. 1960. Carcass characteristics of swine as influenced by levels of protein fed on pasture and in dry lot. J. Animal Sci. 19:943.

Jensen, A. H., D. C. Acker, H. M. Maddock, G. C. Ashton, P. G. Homeyer, E. O. Heady and D. V. Catron. 1955. Different protein levels with and without antibiotics for growing-finishing swine: Effect on growth rate and feed efficiency. J. Animal Sci. 14:69.

Jensen, A. H., D. E. Becker and B. G. Harmon. 1965. Nutritutional adequacy of milo for the finishing pig. J. Animal Sci. 24:398.

Judge, M. D. 1964. Comparisons of longissimus dorsi area of genetically similar barrows and gilts. J. Animal Sci. 23:118.

Judge, M. D., V. R. Cahill, L. E. Kunkle and W. H. Bruner. 1959. Pork Quality. I. Influences of some factors on pork muscle characteristics. J. Animal Sci. 18:448.

Jurgens, M. H., D. B. Hudman, C. H. Adams and E. R. Peo, Jr. 1967. Influence of a dietary supplement of lysine fed at two levels of protein on growth, feed efficiency and carcass characteristics of swine. J. Animal Sci. 26:323.

Kauffman, R. G., R. W. Bray and D. E. Goll. 1959. The relationship of lumbar lean measurements to pork carcass muscling. J. Animal Sci. 18:1481.

Kroening, G. H., W. G. Pond and J. K. Loosli. 1965. Dietary methionine-cystine requirement of the baby pig as affected by threonine and protein levels. J. Animal Sci. 24:519.

Kropf, D. H. 1962. The relationship between bone and muscle characteristics in pork carcasses. S. Carolina Agr. Exp. Sta. Tech. Bull. 1005.

Kropf, D. H., R. W. Bray, P. H. Phillips and R. H. Grummer. 1959. Effect of protein level and quality in swine rations upon growth and carcass development. J. Animal Sci. 18:755.

Lassiter, J. W., S. W. Terrill, D. E. Becker and H. W. Norton. 1955. Protein levels for pigs as studied by growth and self-selection. J. Animal Sci. 14:482.

Lee, C., C. W. Scherer, J. L. McBee, Jr. and D. J. Horvath. 1965. Influence of corn: soybean meal ratio on carcasses of swine. J. Animal Sci. 24:893. (abstract)

Lee, C., J. L. McBee, Jr. and D. J. Horvath. 1967. Dietary protein level and swine carcass traits. J. Animal Sci. 26:490.

Lind, K. D. 1968. Effect of the estrous cycle and pregnancy on the water holding capacity and related properties of porcine muscle. Masters Thesis, Kansas State University.

Meade, R. J., W. R. Dukelow and R. S. Grant. 1966. Lysine and methionine additions to corn-soybean meal diets for growing swine: Effects on rate and efficiency of gain and carcass characteristics. J. Animal Sci. 25:78.

Noland, P. R. and K. W. Scott. 1960. Effect of varying protein and energy intakes on growth and carcass quality of swine. J. Animal Sci. 19:67.

National Research Council. 1964. Nutrient requirement of domestic animals. No. 2. Nutrient requirements of swine. Washington, D. C.

Pearson, A. M., L. J. Bratzler, R. J. Deans, J. F. Price, J. A. Hoefer, E. P. Reineke and R. W. Luecke. 1956. The use of specific gravity of certain untrimmed pork cuts as a measure of carcass value. J. Animal Sci. 15:86.

Pearson, A. M., R. J. Deans and L. J. Bratzler. 1959. Some lumbar lean measures as related to swine carcass cut-outs and loin eye area. J. Animal Sci. 18:1087.

Peo, E. R. and D. B. Hudman. 1958. Grain sorghum for growing-finishing swine. J. Animal Sci. 17:813.

Pond, W. G., E. Kwong and J. K. Loosli. 1960. Effect of level of dietary fat, pantothenic acid and protein on performance of growing-fattening swine. J. Animal Sci. 19:1145.

Pork Carcass Evaluation Committee. 1952. Cutting procedure for pork carcasses. Proc. Reciprocal Meat Con. 5:120.

Price, J. F., A. M. Pearson and E. J. Benne. 1957. Specific gravity and chemical composition of the untrimmed ham as related to leaness of pork carcasses. J. Animal Sci. 16:85.

Riley, M. L., D. B. Hudman, C. H. Adams and E. R. Peo, Jr. 1965. The influence of supplemental lysine on finishing swine. J. Animal Sci. 24:596. (abstract)

Robinson, D. W. 1965. The protein and energy nutrition of the pig V. The effect of varying the protein and energy levels in the finishing diet of heavy pigs. J. Agric. Sci. 65:405.

Sewell, R. F. and B. C. Keen, Jr. 1958. Methionine and antibiotic supplementation for growing swine at three protein levels. J. Animal Sci. 17:353.

Seymour, E. W., V. C. Speer, V. W. Hays, D. W. Mangold and T. E. Hazen. 1964. Effects of dietary protein level and environmental temperature on performance and carcass quality of growing-finishing swine. J. Animal Sci. 23:375.

Shelton, D. C., W. M. Beeson and E. T. Mertz. 1951. The effect of methionine and cystine on the growth of weanling pigs. J. Animal Sci. 10:57.

Smith, Jack Jr., A. J. Clawson and E. R. Barrick. 1967. Effect of ratio of protein from corn and soybean meal in diets of varying total protein on performance, carcass desirability and diet digestibility in swine. J. Animal Sci. 26:752.

Speer, V. C., G. E. Combs, Jr., G. C. Ashton and D. V. Catron. 1956. Protein levels with and without an antibiotic for growing-finishing swine fed on legume pasture. J. Animal Sci. 15:1052.

Stevenson, J. W., R. J. Davey and R. L. Hiner. 1960. Some effects of dietary levels of protein and alfalfa meal and of antibiotic supplementation on growth, feed efficiency and carcass characteristics in swine. J. Animal Sci. 19:887.

Wagner, G. R., A. J. Clark, V. W. Hays and V. C. Speer. 1963. Effect of protein-energy relationships on the performance and carcass quality of growing swine. J. Animal Sci. 22:202.

Walhstrom, R. C. 1954. The effect of penicillin and B-Vitamins on the growth of pigs fed different levels of protein. J. Animal Sci. 18:918.

Weiner, P. D. 1964. The effect of processing pork carcasses prior to rigor mortis upon muscle and fat quality. Masters Thesis, Kansas State University.

Whiteman, Joe V., J. A. Whatley and J. C. Hillier. 1953. A further investigation of specific gravity as a measure of pork carcass value. J. Animal Sci. 12:859.

Wilson, G. D., J. E. Burnside, R. W. Bray, P. H. Phillips and R. H. Grummer. 1953. Pork Carcass value as effected by protein level and supplementation with aureomycin and vitamin B_{12}. J. Animal Sci. 12:291.

Wisconsin Pork Quality Standards. 1963. Special Bull. 9. Agr. Exp. Sta. University of Wisconsin. Madison, Wisconsin.

Woodman, H. E. and R. E. Evans. 1945. Nutrition of the bacon pig XI. The minimum level of protein intake consistent with quick growth and satisfactory carcass quality (part IV). J. Agr. Sci. 35:133.

Woodman, H. E., R. E. Evans, E. H. Callow and J. Wishart. 1936. The nutrition of the bacon pig I. The influence of high levels of protein intake on growth, conformation and quality in the bacon pig. J. Agr. Sci. 26:546.

Woodman, H. E., R. E. Evans and W. G. Turpitt. 1934. The nutrition of the bacon pig III. The minimum level of protein intake consistent with quick growth and satisfactory carcass quality (part I). J. Agr. Sci. 29:115.

Appendix A. Amino Acid Composition (percent of diet)[a]

	Concentrate		Rations			
Amino acid	Grain sorghum composite	Soybean meal	13% crude protein	16% crude protein	20% crude protein	20% crude protein + meth.
Lysine	0.29	2.99	0.60	0.90	1.09	1.05
Histidine	0.28	1.27	0.37	0.48	0.54	0.52
Ammonia	0.35	0.86	0.42	0.46	0.51	0.52
Arginine	0.49	3.26	0.78	1.13	1.28	1.25
Aspartic acid	0.77	5.64	1.44	2.02	2.34	2.11
Threonine	0.38	1.96	0.61	0.78	0.90	0.77
Serine	0.49	2.57	0.82	1.05	1.23	1.01
Glutamic acid	2.29	8.84	3.33	4.03	4.58	3.97
Proline	0.89	2.17	1.09	1.32	1.39	1.16
Glycine	0.38	2.06	0.57	0.79	0.91	0.78
Alanine	0.95	2.11	1.16	1.31	1.41	1.17
Cystine	0.21	0.74	0.25	0.31	0.37	0.36
Valine	0.29	1.98	0.22	0.80	1.02	——
Methionine	0.18	0.55*	0.19*	0.28*	0.29*	0.44
Isoleucine	0.45	1.98	0.62	0.83	0.95	0.88
Leucine	1.37	3.61	1.78	2.05	2.24	1.93
Tyrosine	0.44	1.70	0.62	0.78	0.87	0.77
Phenylalanine	0.56	2.30	0.82	1.04	1.19	1.03

[a] Furnished by the Feed Control Laboratory of the Grain Science and Industry Department, Kansas State University.

Appendix B. Color and Firmness Standards[a]

Key	Color	Firmness
(1)	Extremely pale	Soft and watery
(2)	Pale	Moderately soft and moderately pale
(3)	Uniformly grayish-pink	Moderately firm and moderately dry
(4)	Moderately dark	Firm and dry
(5)	Dark	Very firm and very dry

[a] Wisconsin Pork Standards (1963). Special Bulletin #9. Wisconsin Agricultural Experiment Station.

Appendix C. U.S.D.A. Marbling Standards (Numerical Coding)

Marbling	Minus	Average (Key)	Plus
Abundant	28	29	30
Moderately Abundant	25	26	27
Slightly Abundant	22	23	24
Moderate	19	20	21
Modest	16	17	18
Small	13	14	15
Slight	10	11	12
Traces	7	8	9
Practically Devoid	4	5	6
Devoid	1	2	3

Appendix D. Analysis of Variance

		Variable						
Source	Degrees of freedom	Age at slaugh.	Total days on feed	Live empty slaugh. wt.	70 day A.D.G.	Total A.D.G.	Chilled Car. Wt.	Dressing %
				(Mean squares)				
Litters	7	907.30	1086.27	36.70	0.16	0.04	33.09	4.70
Trials	1	1435.28	284.78	27.03	0.33	0.03	10.35	0.09
Remainder	6	819.31	1219.85	41.80	0.14	0.04	36.88	5.46
Rations	3	561.15	595.81	34.44	0.06	0.09	31.85	3.86
Sex	1	1570.91	1691.28	19.91	0.06	0.09	40.04	23.34
Litter x Ration	21	288.90	277.16	57.11	0.05	0.04	28.06	2.14
Ration x Trials	3	76.39	45.80	76.84	0.11	0.04	71.61	3.60
Remainder	18	324.32	215.72	53.82	0.04	0.03	20.80	1.90
Litters x Sex	7	329.25	306.33	98.78	0.07	0.04	34.64	1.43
Sex x Trials	1	1433.75	1198.88	171.50	0.07	0.05	77.47	- 0.02
Remainder	6	145.16	157.58	86.66	0.07	0.04	27.50	1.67
Ration x Sex	3	86.51	100.14	3.55	0.11	0.03	11.86	2.71
Error	21	325.78	324.07	41.74	0.06	0.04	38.73	2.89
Total	63							

Appendix D. continued

Source	Carcass length	Av. carcass backfat	Chine depth last rib	Lumbar lean depth last lumbar	5T	8T	10T	12T	Last T	1L	3L	5L
					Variable		L. dorsi area					
					(Mean squares)							
Litters	0.39	0.04	0.02	0.18	1.77	0.86	1.16	1.53	1.79	1.64	1.19	1.92
Trials	0.33	0.05	0.01	0.53	0.00	0.00	0.07	0.59	0.04	0.23	0.00	3.14
Remainder	0.40	0.04	0.02	0.12	2.07	1.00	1.34	1.69	2.09	1.87	1.39	1.72
Rations	0.14	0.08	0.01	0.08	0.33	0.36	0.12	0.24	0.12	0.29	0.25	0.39
Sex	6.38	0.32	0.23	0.56	2.73	3.43	3.78	7.60	5.02	5.67	3.77	4.20
Litter x Ration	0.46	0.02	0.01	0.04	0.39	0.15	0.13	0.21	0.17	0.22	0.19	0.52
Ration x Trials	1.46	0.02	0.01	0.05	0.49	0.07	0.12	0.36	0.11	0.24	0.55	1.04
Remainder	0.29	0.02	0.01	0.04	0.38	0.17	0.13	0.19	0.18	0.22	0.13	0.44
Litters x Sex	0.82	0.03	0.03	0.02	0.28	0.20	0.14	0.26	0.23	0.23	0.28	0.70
Sex x Trials	3.06	0.07	0.02	0.01	0.00	0.07	0.04	0.01	0.02	0.00	0.01	0.01
Remainder	0.44	0.02	0.03	0.03	0.32	0.23	0.15	0.30	0.26	0.27	0.32	0.82
Ration x Sex	0.22	0.01	0.01	0.04	0.12	0.05	0.06	0.08	0.10	0.03	0.09	0.04
Error	0.43	0.05	0.01	0.09	0.35	0.13	0.27	0.18	0.16	0.20	0.20	0.26

Appendix D. continued

Source	% of Carcass			Variable				L. dorsi fresh basis (%)			
	ham-loin	4 lean cuts	primal cuts	ham-loin index	ham specific gravity	leaf fat wt.	kidney wt.	protein	moisture	ether ext.	ash
				(Mean squares)							
Litters	7.39	12.00	13.35	343.08	0.00	1.40	3859.68	1.21	6.11	10.31	0.01
Trials	0.51	0.56	11.20	89.34	0.00	4.05	6561.25	2.47	23.84	47.63	0.00
Remainder	8.54	13.90	13.71	385.37	0.00	0.95	3409.42	1.00	3.16	4.09	0.01
Rations	5.58	10.36	3.67	83.87	0.00	0.48	12835.17	2.40	9.86	18.99	0.00
Sex	46.41	51.57	16.84	3543.65	0.00	3.02	42.50	3.90	4.37	0.59	0.02
Litter x Ration	3.74	6.76	6.99	64.80	0.00	0.54	1562.99	0.27	1.41	1.57	0.00
Ration x Trials	6.33	9.20	7.45	65.69	0.00	1.24	440.42	0.83	2.64	5.61	0.00
Remainder	3.31	6.36	6.91	64.65	0.00	0.43	1750.08	0.17	1.20	0.89	0.00
Litters x Sex	1.04	1.95	1.92	67.69	0.00	0.26	2421.82	0.20	0.72	0.62	0.00
Sex x Trials	1.56	6.99	2.30	2.07	0.00	0.79	2.00	0.99	0.57	0.93	0.00
Remainder	0.95	1.11	1.86	78.63	0.00	0.18	2825.13	0.06	0.74	0.57	0.00
Ration x Sex	2.94	5.62	1.32	64.93	0.00	0.28	870.67	0.25	1.38	1.35	0.00
Error	4.02	7.03	3.27	152.17	0.00	0.62	1385.94	0.36	1.15	1.26	0.00

Appendix D. continued

Source	*L. dorsi*; -fat free basis (%) protein	moisture	ash	*L. dorsi*; H_2O free basis (%) protein	ether ext.	ash	Warner-Bratzler shear values lateral	medial	*L. dorsi* % expressible H_2O
				(Mean squares)					
Litters	0.00	0.01	0.00	1.21	1.18	0.00	8.65	1.02	32.67
Trials	0.00	0.00	0.00	4.53	5.35	0.01	59.00	4.61	50.64
Remainder	0.01	0.01	0.00	0.66	0.49	0.00	0.25	0.42	29.67
Rations	0.01	0.01	0.00	2.08	1.96	0.00	1.73	1.91	3.87
Sex	0.04	0.08	0.00	0.02	0.22	0.00	13.70	1.90	27.40
Litter x Ration	0.00	0.00	0.00	0.21	0.15	0.00	3.72	2.66	28.17
Ration x Trials	0.00	0.00	0.00	0.54	0.53	0.00	1.50	0.43	8.64
Remainder	0.00	0.00	0.00	0.15	0.09	0.00	4.13	3.03	31.43
Litters x Sex	0.00	0.01	0.00	0.07	0.08	0.00	4.12	1.59	25.49
Sex x Trials	0.01	0.02	0.00	0.00	0.13	0.00	10.51	2.20	7.71
Remainder	0.00	0.00	0.00	0.08	0.07	0.00	3.06	1.49	28.45
Ration x Sex	0.00	0.00	0.00	0.24	0.10	0.00	1.06	1.40	17.35
Error	0.00	0.00	0.00	0.18	0.12	0.00	2.11	0.79	7.48

Appendix D. continued

Source	Cooking loss (%)			Lumbar lean subjective scores			Ham subjective scores		L.dorsi; 10T subjective scores	
	drip	volatile	total	color	firm-ness	marbling	color	firm-ness	color	firm-ness
				(Mean squares)						
Litters	0.12	48.56	48.86	0.25	0.27	7.03	0.52	0.41	0.83	0.33
Trials	0.54	66.46	100.28	0.42	0.56	5.64	0.00	0.00	0.77	0.02
Remainder	0.05	45.58	40.29	0.22	0.22	7.27	0.61	0.48	0.84	0.38
Rations	0.05	36.80	34.62	0.08	0.03	5.77	0.19	0.07	0.40	0.00
Sex	0.12	0.24	3.85	0.36	0.39	0.77	0.06	0.47	0.25	0.06
Litter x Ration	0.07	22.75	23.11	0.17	0.05	8.90	0.22	0.10	0.22	0.08
Ration x Trials	0.12	38.17	29.89	0.17	0.05	32.18	0.39	0.05	0.21	0.10
Remainder	0.06	20.17	21.99	0.17	0.05	5.02	0.19	0.11	0.22	0.07
Litters x Sex	0.07	12.61	11.06	0.06	0.30	6.94	0.30	0.14	0.38	0.17
Sex x Trials	0.01	14.61	6.83	0.00	0.77	9.77	0.39	0.19	0.06	0.14
Remainder	0.09	12.28	11.76	0.07	0.22	6.47	0.29	0.13	0.44	0.17
Ration x Sex	0.08	11.09	9.45	0.05	0.07	11.89	0.22	0.12	0.41	0.21
Error	0.07	18.95	20.17	0.06	0.04	6.16	0.14	0.11	0.23	0.08

Appendix D. continued

	Variable							
	L. dorsi; subjective marbling scores							
Source	5T	8T	10T	12T	Last T	1L	3L	5L
	(Mean squares)							
Litters	74.13	79.00	73.52	45.35	39.61	35.66	28.89	42.93
Trials	410.06	375.39	301.89	92.64	36.00	11.39	1.56	2.25
Remainder	18.15	29.60	35.45	37.47	40.21	39.70	33.45	49.71
Rations	92.23	103.85	91.02	71.77	36.29	47.35	34.42	17.21
Sex	110.25	54.39	26.27	26.27	33.06	54.39	25.00	10.56
Litter x Ration	10.01	16.19	14.90	11.12	11.79	12.96	8.96	12.27
Ration x Trials	36.90	38.10	35.47	40.27	40.29	44.22	19.56	18.04
Remainder	5.53	12.54	11.47	6.27	7.04	7.74	7.20	11.31
Litters x Sex	12.18	15.35	8.27	10.98	5.21	10.43	16.86	17.31
Sex x Trials	0.25	5.64	9.77	2.64	14.06	31.64	27.56	52.56
Remainder	14.17	16.97	8.02	12.37	3.73	6.89	15.07	11.44
Ration x Sex	13.54	15.27	26.93	15.64	12.14	14.31	14.17	15.27
Error	13.54	14.47	14.60	12.64	9.96	8.15	10.31	11.16

Appendix E. Analysis of Variance

		Variable					
	Degrees of	Daily feed intake		Feed/gain ratio		Total daily crude protein	Lb. crude protein per lb.
Source	freedom	70 days	total	70 days	total	intake	of gain
				(Mean Squares)			
Trial	1	0.22	0.00	0.10	0.00	0.00	0.00
Ration	3	0.15	0.03	0.07	0.08	0.11	0.08
Sex	1	0.12	1.00	0.02	0.05	0.08	0.00
Trial x Ration	3	0.36	0.43	0.08	0.09	0.02	0.00
Trial x Sex	1	0.17	0.17	0.00	0.00	0.01	0.00
Ration x Sex	3	0.23	0.04	0.01	0.02	0.00	0.00
Error	3	0.22	0.09	0.03	0.00	0.00	0.00
Total	15						

EFFECTS OF VARYING SORGHUM GRAIN-SOYBEAN MEAL RATIOS, ADDED METHIONINE AND SEX UPON SWINE GROWTH RATE, FEED EFFICIENCY, CARCASS COMPOSITION AND QUALITY.

by

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B.S., University of Minnesota, 1966

AN ABSTRACT OF A MASTER'S THESIS

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requirements for the degree

MASTER OF SCIENCE

Department of Animal Husbandry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

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A total of 64 pigs averaging 66 pounds bodyweight and 85 days of age were utilized in two trials to study the effect of protein level, added methionine and sex on feedlot performance, carcass composition and quality. The four treatments consisted of milo-soybean meal rations containing: (1) 13 percent crude protein, (2) 16 percent crude protein, (3) 20 percent crude protein and (4) 20 percent crude protein plus 0.14 percent dl-methionine (percent of diet).

Daily feed intake, rate and efficiency of gain were not affected by ration or sex for the first 70 days on test. For the entire feeding period, pigs fed 20 percent protein gained slower and were less efficient than those fed 16 percent protein ($P<.05$). No significant differences were found for daily feed intake, growth rate and efficiency of gain between pigs fed rations 1 and 2 or between pigs fed rations 3 and 4. Increasing the level of protein resulted in a linear increase in daily crude protein intake and in the same protein consumed per pound of gain ($P<.05$).

Barrows consumed more feed ($P<.05$), gained faster ($P<.01$), were more efficient in total feed conversion ($P<.05$) and consumed more crude protein per day than gilts.

Pigs were individually slaughtered when they reached a weight of 210 $\pm$ 10 pounds.

None of the carcass measurements were significantly affected by ration, but pigs fed ration 1 did not develop the muscling or trimness of pigs fed the other rations.

Gilt carcasses were leaner than barrows as evidenced by larger loin eye area ($P<.01$), less carcass backfat ($P<.05$), less leaf fat ($P<.05$) and greater percentages of ham and loin ($P<.01$), lean cuts ($P<.05$) and primal cuts ($P<.05$). They also had higher values for ham-loin index ($P<.01$), ham specific gravity

($P<.05$), dressing percent ($P<.01$) and chine depth ($P<.01$, $P<.05$) at the last rib and last lumbar, respectively.

Maximum gain and feed efficiency was reached at the protein levels of 13 percent for barrows and 16 percent for gilts. Maximal carcass development for barrows and gilts was observed at 16 and 20 percent protein levels, respectively.

Kidney weights of pigs fed 13 percent protein were lighter than those from the other treatments ($P<.05$), with no difference between barrows and gilts.

Longissimus dorsi muscles from pigs fed ration 1 were lower ($P<.01$) in protein and moisture and higher ($P<.01$) in fat (fresh or dry matter basis). On a fat free basis, no significant differences existed for proximate analysis values.

Fresh *longissimus dorsi* samples from gilts were higher in protein and ash than those from barrows ($P<.01$). On a fat free basis, gilt *longissimus dorsi* muscles were lower in moisture ($P<.01$) and higher in protein ($P<.01$) and ash ($P<.05$). No sex differences were present when proximate analysis values were expressed on a moisture free basis.

Drip, volatile and total cooking losses plus expressible moisture values (Wierbicki) for *longissimus dorsi* samples were not significantly affected by ration or sex, although samples from barrows tended to have lower expressible moisture values.

Lateral or medial Warner-Bratzler shear values were not significantly affected by ration. Lateral shears for gilts were higher than those for barrows ($P<.05$).

Longissimus dorsi marbling scores at 8 locations were higher in pigs fed the 13 percent protein ration ($P<.01$), but firmness and color scores were not affected by diet. Marbling, color and firmness scores of the lumbar lean and ham were not significantly affected by ration.

Firmness and color scores of the longissimus dorsi did not differ between sexes, but gilts tended to have less marbling. The lumbar lean of gilts was darker ($P<.05$) and less firm ($P<.01$) than that of barrows. Ham muscles of gilts were also less firm ($P<.05$).

Pigs in the winter trial compared to those in the spring trial had higher total cooking losses ($P<.05$), drip losses ($P<.01$), expressible moisture values ($P<.01$), lateral shears ($P<.01$), and marbling scores ($P<.01$) and lower longissimus dorsi moisture content ($P<.01$).