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The Effects of Protein Level and Age on Performance, Carcass Characteristics and Nutrient Digestibility of Growing-finishing Swine

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THE EFFECTS OF PROTEIN LEVEL AND AGE ON PERFORMANCE, CARCASS CHARACTERISTICS AND NUTRIENT DIGESTIBILITY OF GROWING-FINISHING SWINE

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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INTRODUCTION

The present trends toward the meat type hog and the consumer's demand for lean cuts have resulted in the investigation of methods to produce leaner pigs. During recent years there has been considerable interest in the effect of dietary protein levels on growth rate, feed efficiency and carcass characteristics of swine. Several reports have indicated that increased dietary protein levels may improve growth performance and/or carcass leanness without adversely affecting the quality of the pork produced.

However, little research has been conducted to show if this decrease in carcass quality of pigs fed a low protein diet could be at least partially due to differences in age, not protein per se. Pigs fed low protein diets have been shown to reach market weight at an older age due to a decreased rate of gain. Carcass development of swine is characterized by a period of rapid muscle growth from birth to approximately eighty days of age; a transition period from 80 to approximately 120 days of age where the rate of muscle development stabilizes and then a stage of increased fat deposition from 120 days of age to slaughter. Thus, this increased fat to lean ratio in carcasses of pigs fed the low protein diets could be due to the longer period of time that these animals are in the stage of relatively high fat deposition compared to pigs fed high protein levels.

The objectives of this study were to determine the effect of dietary protein level and age on the following characteristics of growing-finishing swine:

1. Growth rate

2. Feed efficiency

3. Carcass composition

4. Consumer acceptability and cooking characteristics of the *longissimus dorsi* muscle

5. Apparent ration digestibility

REVIEW OF LITERATURE

Effect of Protein Level on Growth Performance

Research conducted prior to the early 1950's by Keith and Miller (1939), (1941), Carroll and Burroughs (1939) and Mitchell (1939) as cited by Catron et al. (1952) showed that 22, 17 to 20 and 15% protein diets were the required levels for maximal growth performance of pigs from 13 to 34, 34 to 57 and 57 to 91 kg liveweight, respectively.

With the application of newly acquired knowledge concerning the nutrition of growing-finishing swine, especially the use of vitamin B_{12} and antibiotics, it was found that the crude protein content of the diet could be reduced without adversely affecting rate of growth or feed efficiency.

Catron et al. (1952) reported satisfactory growth and feed efficiency of swine fed a corn-soybean meal diet fortified with minerals and vitamins that was lower in protein than previously recommended. In the presence of antibiotics, a 14 - 11 - 8% protein level combination fed from weaning to 34, 34 to 68 and 68 to 91 kg liveweight supplied the pig's need for protein. Becker et al. (1954), feeding a 14 - 12% protein sequence, corn-soybean meal diet, observed normal gains and feed conversion from 18 to 45 and 45 to 91 kg, respectively. Results by Hoefer et al. (1952) showed that a 15 - 12% dietary protein level had an equivalent effect on performance of the pig from 11 to 45 and 45 to 91 kg liveweight, respectively, as did a 18 - 15% protein level. Jensen *et al*. (1955), feeding diets of 10, 12, 14, 16, 18 and 20% protein to pigs from 16 to 91 kg, reported the fastest rate of growth on the 14 and 16% protein diets in the absence and presence of antibiotics, respectively. Feed efficiency was not significantly affected by dietary protein level. In a subsequent trial, both rate of gain and feed efficiency were maximized at the 14% protein level. Work by Hanson, Ferrin and Singh (1955) and Meade (1956) also demonstrated that dietary protein levels lower than that previously recommended could be fed to swine without affecting average daily gain or feed efficiency.

During the last decade, there has been an increased consumer demand for meat of a high lean and reduced fat content. Therefore, the effect of increased dietary protein levels on performance and carcass characteristics of swine has been extensively reevaluated.

In three trials involving 176 pigs, Aunan, Hanson and Meade (1961) observed no significant difference in rate of gain or feed efficiency when pigs were fed diets of 17 - 15 or 15 - 11% protein. In a fourth trial, Aunan *et al*. (1961) evaluated 16 - 11, 14 - 11 and 12 - 11% dietary protein combinations. A significant increase in rate of gain of pigs fed the high protein level was noted during the period from 20 to 57 kg liveweight. The effect of initial protein level on gain decreased as the animals grew older and heavier. However, further analysis showed that the protein effect for the entire trial was significant even though the three treatment groups gained at nearly the same rate from 57 to 91 kg. No significant difference was observed in feed efficiency due to protein level.

In a study by Hale and Southwell (1967), rate of gain was not significantly affected by increasing the dietary protein content from 14 - 11 to 18 - 15 percent. Feed required per unit of gain was significantly reduced when the protein content of the diets was increased from 14 - 11 to either 16 - 13 or 18 - 15 percent. Boenker, Tribble and Pfander (1960), feeding 13 - 10, 16 - 13 and 19 - 16% protein level combinations, showed little effect of protein level on gain or feed efficiency. Only pigs fed the 10% protein diet gained significantly slower and were less efficient than those fed 13 or 16% protein diets from 57 to 91 kg liveweight. In three trials, Stevenson, Davey and Hiner (1960) compared diets of 18 - 15 and 14 - 11% protein. Rate of gain and daily feed consumption were not significantly affected by dietary protein level. However, a slightly faster rate of gain and an improved feed efficiency were consistently produced by the higher protein diet.

Wagner et al. (1963) fed pigs diets of 13, 19 and 25% protein and showed that as the dietary level increased over 13% protein the average daily gain and feed efficiency decreased. Dukelow et al. (1963) fed 12, 14 and 16% dietary protein levels to 72 pigs from 25 to 90 kg liveweight. Rate of gain and feed efficiency were not significantly affected by protein level. Pigs fed dietary protein levels of 19 - 13, 17 - 13, 15 - 13 and 13 - 13% showed no difference in growth rate or feed efficiency in work by Greeley et al. (1964b). Wong, Boyland and Strothers (1968), feeding a 17 or 13% protein diet to pigs during the finishing period, from 50 to 100 kg, obtained similar results. Cole and Luscombe (1969) also reported nonsignificant differences in rate of gain and feed conversion in swine fed 17.1 - 13.7, 13.8 - 12.0 or 11.2 - 10.3% dietary protein sequences from 23 to 54 and 54 to 91 kg. Blair _et al_. (1969) found no significant increase in growth rate by increasing the protein level above 16, 14, 12 and 12% for pigs fed from 23 to 45, 45 to 68, 68 to 91 and 91 to 114 kg liveweight, respectively. However, the feed required per unit of gain was significantly reduced during the 23 to 45 kg weight period by increasing the protein level to 18 percent.

Seerley, Poley and Wahlstrom (1964) found a significant increase in average daily gain of pigs fed a 14.4% protein, corn-soybean meal diet compared to a 12.5% protein diet. The higher dietary protein level decreased feed required per unit of gain by 6 percent. The protein content of the diet did not influence feed intake. Clawson (1967), in comparing diets of 14.8 and 9.0% protein, observed that the higher protein level significantly increased average daily gain of pigs fed a corn-soybean meal diet. Significantly less feed per unit of gain was required when the 14.8% protein diet was fed. However, in a later trial Clawson (1967) found no significant difference in average daily gain or feed efficiency of pigs fed a 14 or 10% protein diet from 17 to 97 kg liveweight. Daily feed intake was not significantly influenced by protein level. Work by Stevenson _et al_. (1960) showed that pigs fed a 18 - 15% protein level from 20 to 45 and 45 to 95 kg did not gain significantly faster than those fed a 14 - 11% protein diet, however, feed efficiency was improved by 5 percent.

Lee, McBee and Horvath (1967) studied three protein level combinations, 21 - 18 - 15, 18 - 15 - 12 and 15 - 12 - 9%, fed to pigs from 25 to 34, 34 to 57 and 57 to 95 kg liveweight, respectively. Increasing the dietary protein level resulted in significantly improved growth rate and feed efficiency. Young et al. (1968) fed three protein sequences of 19.2 - 17.4, 17.4 - 15.5 and 15.5 - 14.2% to pigs from 20 to 50 and 50 to 95 kg. A linear increase in growth rate and curvilinear reduction in feed required per kg of gain were produced by increasing the dietary protein level fed to pigs from 20 to 50 kg. During the 50 to 95 kg weight period, the three protein levels fed did not significantly influence rate of gain, but feed required per unit of gain increased linearly as the protein level decreased. Crum et al. (1964) studying 17 - 17, 17 - 15, 13 - 13 and 13 - 11% protein sequences fed to pigs from 20 to 45 kg and 45 to 95 kg liveweight, respectively, noted significantly improved growth rate and feed utilization by pigs fed either of the high protein diets. Seymour et al. (1964) reported a similar advantage in pigs fed a 20 - 17 - 14% protein level combination from 3 to 7 weeks, 7 weeks to 57 kg and 57 to 91 kg compared to animals fed a 16 - 13 - 10% dietary protein sequence. In a study by Jurgens et al. (1967), it was observed that 120 pigs fed a 16% protein, milo-soybean meal diet from 57 to 98 kg had significantly higher average daily gains and improved feed efficiency compared to those fed a 12% protein diet.

Effect of Protein Level on Quantitative Carcass Traits

Ashton et al. (1955) fed a fortified corn-soybean meal diet of 10, 12, 14, 16, 18 and 20% protein content to swine from 15 to 91 kg liveweight. In the first trial, the only significant effect of increasing the dietary protein level from 10 - 20% was a linear increase in specific gravity. This increased specific gravity indicated a significantly greater proportion of lean to fat content in the carcass. In a second trial, backfat thickness, specific gravity, percent lean cuts and longissimus dorsi (l. dorsi) area were all significantly affected by dietary protein level. The l. dorsi area reached a maximum at 18% dietary protein. For the other criteria, each increase in protein level from 10 - 20% resulted in a decreased backfat thickness and an increased percent lean cuts and specific gravity. However, there were no significant differences in these carcass characteristics between any two adjacent levels of protein.

Noland and Scott (1960), comparing 12, 16 and 20% protein diets fed to pigs from 20 to 91 kg, reported longer carcasses and decreased dressing percent in pigs fed the two higher protein diets, however, backfat thickness was not significantly affected. Wilson et al. (1953) obtained similar results due to increased dietary protein when feeding 20 - 17 - 14, 16 - 13 - 11 and 12 - 10 - 9.5% protein sequences to pigs from 18 to 34, 34 to 68 and 68 to 98 kg liveweight.

Hale and Southwell (1967) compared 18 - 15, 16 - 13 and 14 - 11% protein, corn-soybean meal diets and observed significantly decreased backfat thickness and larger _l_. _dorsi_ area of carcasses from pigs fed the 18 - 15% protein diet. The lean cuts yield was significantly increased when the protein level of the diets was increased above the 14 - 11% protein sequence. Seerley _et al_. (1964) reported similar results of increased _l_. _dorsi_ area, percent lean cuts and reduced backfat thickness in pigs fed a 14.4 versus a 12.5% protein level. Wong _et al_. (1968) noted a significant reduction in backfat thickness of pigs fed a 17% protein level compared to those fed a 12% protein diet. In work by Seymour _et al_. (1964), a 20 - 17 - 14 protein sequence significantly increased percent lean cuts and decreased backfat thickness in pigs compared to a 16 - 13 - 10% dietary protein sequence.

Wagner _et al_. (1963), feeding 13, 19 and 25% protein diets, showed that increased dietary protein levels significantly decreased carcass backfat thickness, dressing percent and intramuscular fat content but increased the yield of percent lean cuts. However, these authors suggest that a significant decrease in feed consumption by pigs fed the two high protein diets may have caused the reduced backfat thickness. Two studies by Stevenson _et al_. (1960), comparing a 18 - 15 and 14 - 11% protein sequence, showed that backfat thickness and percent fat of the carcass was reduced by 6 and 10%, respectively, and percent lean cuts increased in pigs fed the high protein dietary sequence.

Crum _et al_. (1964) fed 17 - 17, 17 - 15, 13 - 13 and 13 - 11% protein level combinations to swine from 20 to 92 kg liveweight. Increased protein levels significantly increased the percentages of ham, loin and lean cuts but decreased carcass firmness and marbling.

In contrast to previous results, Aunan et al. (1961) observed no influence of dietary protein level on carcass characteristics when combinations of 17 - 15, 15 - 11, 16 - 11, 14 - 11 and 12 - 12% protein were fed. Catron et al. (1952), feeding 20 - 17 - 14, 18 - 15 - 11, 16 - 13 - 9 and 14 - 11 - 7% protein level combinations to pigs, also found no significant difference in backfat thickness, length and percent lean cuts due to dietary protein level. Bowland and Berg (1959) reported no significant difference in dressing percent, length, backfat thickness, percent ham and loin and carcass grade of pigs fed 20, 16 or 13% protein diets although increased protein levels tended to improve carcass leanness.

Dukelow et al. (1963), feeding a corn-soybean meal diet, showed no significant difference in backfat thickness, l. dorsi area or percent trimmed ham-loin in pigs fed 12, 14 or 16% protein diets. Clawson (1967) reported similar results except for a significantly increased l. dorsi area in pigs fed a 14.5 versus 9.0% protein diet.

Smith, Clawson and Barrick (1967) showed no increase in carcass leanness in pigs fed diets containing more than 14.3% protein.

Effect of Protein Level on Qualitative Carcass Traits

Jurgens et al. (1967) and Kroff et al. (1959) reported that the percent protein was significantly increased and the percent fat significantly decreased in the l. dorsi muscle of pigs fed a

16% protein diet compared to those fed a 12% protein diet. Similar results were reported by Ashton et al. (1955), who found that as the dietary protein level increased from 10 to 20% in increments of 2%, the proportion of lean to fat in the carcass increased linearly. However, no significant differences between any two adjacent protein levels were obtained.

Lee et al. (1967) reported increased fat and decreased protein and moisture content in carcasses of pigs fed either a 21 - 18 - 15 or 18 - 15 - 12% protein sequence compared to those fed a 15 - 12 - 9% protein level. These authors suggest that the changes in protein, fat and moisture content of the carcass due to dietary protein level is largely caused by the alterations of the fat content. Ether extract values of the l. dorsi muscle were shown to vary inversely with the protein content. The difference in crude protein content was not significant if converted to a fat-free basis. Vipperman et al. (1963) showed that an increase in moisture and ash content of the muscle is accompanied by a decrease in fat. Lee's et al. (1967) taste panel and shear test values showed that only the tenderness of the meat was significantly different between dietary protein levels. The meat from the low protein diets was favored. Kauffman et al. (1964) and Henry, Bratzler and Luecke (1963) found that an increase in intramuscular fat in pork improved the tenderness, juiciness and flavor of cooked meat. These results suggest that the taste panel preferred the meat from pigs fed low protein diets due to the increased fat content of the meat.

In contrast to previous results, Crampton and Ashton (1946) reported no significant difference in carcass quality of pigs fed either a 13 or 15% protein diet. Blair et al. (1969b) found that neither the chemical composition nor the pH of the l. dorsi muscle was significantly affected by dietary protein levels above 16 and 14% fed to pigs from 23 to 68 and 68 to 91 kg liveweight, respectively. However, the percent dry matter and intramuscular fat content rose with increased weight. The color and firmness scores and shear values were also significantly increased by increased weight but neither were influenced by dietary protein level or sex.

Assuming that dietary protein levels do significantly affect the fat content of the pig, O'hea and Leveille (1969) studied possible modes of action of the protein level on fat deposition. They showed that a high protein diet fed to pigs reduced the activity of certain key enzymes in adipose tissue that are associated with fatty acid synthesis. Thus it was suggested that the dietary protein level may influence the amount and type of fatty acid synthesis in the body.

Using results from previous work, Clawson et al. (1962) concluded that once a pig's growth requirement for protein and amino acids is met, no further improvement in carcass leanness will result. They also stated that excess protein in the diet decreased feed intake and daily gains. Using these assumptions, Greeley et al. (1964b) suggested that this depression in feed intake with resultant decrease in gain may result in an increase in the age of the pig at slaughter, which in itself may contribute to more apparent leanness and muscling in the pig.

Effect of Feed Restriction on Growth Performance

Vanschoubroch, DeWilde and Lampo (1967) studied the effects of feed restriction in steps of 5% reduction from a 95% level of ad libitum intake to a 55% level of intake. Weight gain and backfat thickness decreased as feed intake decreased. As the degree of feed restriction increased, the decrease in daily gain became relatively greater while the decrease in backfat thickness became relatively smaller. Feed efficiency improved up to the 25% restriction level of ad libitum intake and then decreased as feed intake was further restricted. These authors suggested that the decrease in feed required per unit of gain followed by an increase is the result of two opposite effects. Owing to the restriction of feed, gains contain less fat with more protein and water, hence are of lower energy content. However, the feed requirement for maintenance increases because the growth period is of greater duration. By averaging several experiments, these authors noted that a 15.8% feed restriction decreased daily gain by 12.5%, improved feed efficiency by 3.96% and decreased backfat thickness by 7.63 percent.

Blair *et al*. (1969a) showed that gains were significantly decreased when feed intake was lower than ad libitum. Feed required per unit of gain was significantly decreased by feed restriction only in the live weight range of 23 to 45 kg. However, during the 45 to 113 kg weight period, a limited feed intake resulted in greater quantities of feed required per unit of gain. Becker et al. (1963) reported that limit feeding 1.82 kg of feed twice daily significantly reduced rate of gain but did not influence feed utilization compared to a full feed regime. Crampton, Ashton and Lloyd (1954); Braude et al. (1959) and Baker et al. (1968) all noted that a restricted energy intake consistently reduced rate of gain, but its effect on feed efficiency was highly variable.

Effect of Feed Restriction on Quantitative and Qualitative Carcass Traits

Keese et al. (1964) compared ad libitum fed pigs to pigs full fed to 45 kg and then restricted to 2.27 kg of feed daily until slaughter. The full fed pigs had significantly increased daily gains, backfat thickness and percent belly but had significantly lower percent ham and percent lean cuts than the limited fed pigs. The restricted fed pigs tended to be longer with larger l. dorsi area and specific gravity values of the carcass. Reduced feed intake also resulted in more tender, juicier muscles with higher color and firmness scores than those from full fed pigs.

Braude and Townshend (1958) studied the effects of ad libitum feeding versus three degrees of feed restriction on growth performance and carcass traits. These authors observed that restricted fed pigs grew more slowly, were less efficient, had slightly longer carcasses, less backfat and larger l. dorsi areas than ad libitum fed pigs. Similar effects of feed intake on backfat thickness and l. dorsi area were noted by Passbach et al. (1968). However, these workers showed no effect of feed intake on percent ham-loin, percent lean cuts, specific gravity of the carcass or the U.S.D.A. carcass grade. Restricted feeding tended to increase the occurrence of pale, soft, exudative pork and percent cooking loss of loin roasts, but did not affect the marbling, percent moisture, percent ether extract or the pH of the l. dorsi muscle. Neither did restricted feeding influence the shear force or palatability value of cooked roasts. Keese et al. (1964), comparing an ad libitum intake to 2.27 kg of feed/day in pigs from 45 to 91 kg, observed a similar lack of effect of feed restriction on pork palatability scores.

In three trials involving 127 pigs, Klay, Smith and Weller (1969) also noted increased l. dorsi area and percent lean cuts and decreased backfat due to restricted feed intakes of 2.25, 2.00 and 1.80 kg of feed per day. In contrast to previous work, these studies tended to show a lower flavor score, a higher shear test and greater cooking loss from carcasses of pigs fed a limited intake. Decreased tenderness and palatability of the l. dorsi muscle of pigs restricted to three-fourths the gross energy of pigs fed ad libitum was also noted by Thorton, Alsmeyer and Davey (1968). These workers suggested that the fat content of the carcass may be linked with, or responsible for, good palatability of the meat. In this study, all limited fed pigs with decreased backfat thickness had lower tenderness and palatability scores than full fed pigs.

Greer et al. (1965) fed pigs 85% of full feed and observed an increased degree of unsaturation of the backfat, especially in linoleic acid concentration. However, a further restriction to 75% of full feed caused a decreased linoleic acid level from that found in the 85% restricted fed pigs. These same authors reported that palmitic acid decreased as the feed level was restricted to 85%, but that it increased as the feed level was further restricted to 75 percent. Dahl and Persson (1964), Lucas, McDonald and Calder (1960) and Merkel et al. (1958) noted a slower rate of fat deposition, but an increased concentration of unsaturated fatty acids, especially linoleic, in pigs restricted fed 70% of ad libitum.

In contrast to previous results, two trials by Koch, Parr and Merkel (1968a) showed that with feed intakes below 80% of the ad libitum level, pigs had significantly less saturated fats whereas less restricted diets produced no change in fatty acid composition.

Effect of Protein Level and Feed Restriction on Nutrient Digestibility

Lowrey, Pond and Manner (1958) reported dry matter digestibility was not significantly influenced by dietary protein level when pigs were fed diets of 13, 16 or 19% protein. However, protein and fat digestibility were significantly increased by increasing the protein content of the diet.

Greeley, Meade and Hanson (1964a) fed 13, 15, 17 and 19% protein diets to pigs twice a day to appetite. Although protein levels did not significantly affect daily dry matter consumption or efficiency of conversion of the dry matter to gain, there was a significant linear decrease in dry matter consumption and in dry matter consumed per unit of gain with increasing protein levels. A significant increase in apparent digestible protein and apparent digestible energy resulted from increased protein in the diet.

Dietary protein levels significantly affected the efficiency of conversion of digestible protein to gain with a linear trend toward decreased efficiency of utilization of digestible protein with increasing levels of protein. Ether extract digestibility was not significantly influenced by dietary protein level.

Kuryvial and Bowland (1962) studied nutrient digestibilities of 7 and 45 kg pigs fed 22, 18 and 14% protein diets. Increased dietary protein levels significantly decreased energy digestibility in pigs of both weight groups. The two higher protein diets had significantly higher protein digestibilities in the 45 kg pigs. Increasing the protein content of the diet increased nitrogen retention in the 7 kg pig but reduced its retention in the 45 kg animal. Likuski, Bowland and Berg (1961) reported similar results of increased nitrogen retention in 8 kg pigs but significantly decreased retention in 20 and 50 kg pigs fed a 18 versus 14% protein diet.

In contrasting results, Lowrey _et al_. (1962) found no significant difference in apparent protein digestibility in pigs fed 19, 16 or 13% protein diets from 20 to 91 kg liveweight. Similar results were shown by Clawson _et al_. (1962) in pigs fed 19, 17, 15 or 13% protein diets from 17 to 91 kg.

Work by Greeley _et al_. (1964b) indicated that pigs fed 19 - 13, 17 - 13, 15 - 13 or 13 - 13% protein level combinations from birth to 42 days of age and 43 days to slaughter, respectively, did not differ significantly in apparent energy digestibility.

Kornegay and Graber (1968) studied the effects of feed restriction on digestibility of nutrients in two trials comparing 25 and 50% feed restriction to ad libitum feeding. In both trials, apparent digestibility of dry matter, protein and energy was not significantly affected by level of feed intake although the restricted fed pigs had a small, consistent advantage.

MATERIALS AND METHODS

The sixty pigs used in this study were Yorkshire-Hampshire-Chester White crossbred pigs from the South Dakota State University swine herd.

Twenty groups of three litter-mate pigs were each randomly allotted across treatments on the basis of weight and sex into 15 lots of four pigs each. Five replicated lots received each of the three dietary treatments. Each lot contained 2 barrows and 2 gilts averaging 20.4 kg initially. The experiment was initiated on May 1, 1971 when replicates one and two were allotted to the trial. Replicates 3, 4 and 5 were started on experiment one week later.

Experimental animals were housed in 2.4 by 3.0 meter indoor pens with access to automatic water fountains. The solid cement floored pens were bedded with straw at all times. Each of the pens was connected to individual 2.4 by 4.9 meter concrete surfaced, outdoor runways by means of a swinging door. A 225 kg capacity, three compartment self-feeder was supplied in each outside lot of pigs fed _ad libitum_. The restricted-fed pigs were fed in a .46 by 1.20 meter individual feeding stall twice daily at 8:00 A.M. and 5:00 P.M., respectively. The four stall, wooden structure with overhead roof is shown in figure 1.

Figure 1. Feeding stalls used for individual feeding of treatment 3.

All diets were mixed at the university feed unit in a twin spiral mixer. The vitamin, mineral and antibiotic premixes were preweighed and mixed with a diluent before being added to the mixer with the other ingredients. Composition of the fortified corn-soybean meal diet is shown in table 1.

Pigs in treatment 1 were fed the 16% protein diet *ad libitum* to an average lot weight of 50 kg and the 14% protein diet from 50 - 95 kilograms. Treatment 2 consisted of feeding the 12% protein diet *ad libitum* to 50 kg followed by the 10% protein diet for the finishing period. Pigs in treatment 3 received the 16 - 14% protein dietary sequence at a restricted level to produce the same average lot gain as in treatment 2. The pigs were weighed twice weekly to adjust the feeding level of treatment 3 in order to equalize the average daily gains of treatments 2 and 3. When each pig reached

TABLE 1. COMPOSITION OF DIETS (PERCENT)

Ingredient	% Protein (Calculated) 16	12	14	10
Ground yellow corn	76.41	87.71	81.94	93.44
Soybean meal (44.0%)	20.83	9.38	15.20	3.63
Dicalcium phosphate[a]	1.71	1.81	2.03	2.13
Ground limestone[b]	.53	.55	.26	.27
Trace mineralized salt[c]	.50	.50	.50	.50
Premix[d]	.08	.08	.08	.08
Calculated analyses, %				
Calcium	.65	.65	.60	.60
Phosphorus	.50	.50	.55	.55
Chemical analyses, %				
Dry matter	90.76	91.06	89.93	90.08
Protein	16.31	13.49	14.72	11.02
Ether extract	3.16	3.48	3.71	3.87

[a] Twenty-one to 24% calcium and 18.5% phosphorus.
[b] Thirty-eight % calcium.
[c] Contained NaCl, 97%; Zn, 0.8%; Co., 0.002%; Mn, 0.4%; Cu. 0.048%; Fe, 0.33%; I_2, 0.011%.
[d] Provided per kg of diet: 1,300 I.U. of vitamin A, 200 I.U. of vitamin D, 11 I.U. of vitamin E, 2.2 mg of riboflavin, 10 mg of niacin, 11 mg of pantothenic acid, 11 mcg of vitamin B_{12} and 22 mg of aureomycin.

a minimum weight of 93.2 kg on the weekly weigh date, it was removed from the experiment and transported to the university meat laboratory for slaughter following a 24 hour shrink.

Digestibility was determined by the chromic oxide indicator method. Chromic oxide [Cr_2O_3] was added as 0.16% and 0.50% of the feed in collection one and two, respectively. The low level of chromic oxide used in collection one was due to an undetected mistake in adding the necessary quantities of chromic oxide to the feed. The chromic oxide containing feeds were fed for three days. Fecal samples were collected from individual pigs at 6:00 A.M. on the fourth day. The pigs weighed an average of 40.8 and 77.5 kg at the time of the first and second collection, respectively. Most samples were collected without their touching the floor. However, if samples were removed from the floor, any straw or debris in the samples was removed before drying.

All feed and fecal samples were dried in a forced-air drying oven at 78 C for 48 hours. Both feed and fecal samples were ground through a one millimeter screen in a Wiley mill. The ground sample was then put through a Gamate divider for a more random mixture of the sample particles. The pooled fecal samples used for chemical analysis were obtained by mixing together an equal amount of each of the four individual samples per pen and rerunning this combined sample through the Gamate divider for the final mixing.

A colorimetric procedure was used for chromic oxide analysis. The chromic oxide was precipitated during digestion with nitric acid and heat. Color development and chromic oxide solution were achieved by heating the digested material in the presence of 70% perchloric acid. Color intensity was read on an Evelyn colorimeter with a 440 mu filter. Samples were read against a perchloric acid and water blank. The chromic oxide content was calculated by first calculating an L value, which is equal to 2-log of the galvanometer reading, for each galvanometer reading. A value, K, was calculated from readings on solutions of known chromic oxide concentrations. The K value of a standard solution is equal to the milligrams of chromic oxide per flask divided by the L value of that solution. K values were calculated for several known chromic oxide solutions and then averaged. This average K value is used to calculate the percent chromic oxide in the feed and fecal samples.

$$\% \; Cr_2O_3 \text{ in sample} = \frac{K \times L}{(\text{sample wt. in g}) \quad (10)}$$

Duplicate samples of all feed and fecal collections were analyzed for moisture, crude protein and ether extract as described by the A.O.A.C. (1970). Chromic oxide, crude protein and ether extract were determined on a moisture free basis. Apparent digestibility coefficients were calculated according to the following equation.

$$\text{Dig.} = 100 - \left(100 \times \frac{\% \text{ indicator in feed}}{\% \text{ indicator in feces}} \times \frac{\% \text{ nutrient in feces}}{\% \text{ nutrient in feed}} \right)$$

Carcass data was collected after a 24 hour chill. Backfat measurements were taken at the first rib, last rib and last lumbar vertebra to calculate an average backfat thickness. Length of the carcass was determined by measuring the distance from the anterior edge of the first rib to the anterior edge of the aitch bone. The loin was cut between the 10th and 11th rib and an acetate tracing was taken of the area of the _longissimus dorsi_ (_l. dorsi_). The area was then determined using a compensating polar planimeter. The right side of the carcass was used to determine carcass composition. Percent ham, loin, ham-loin, shoulder, lean cuts and belly were determined. Ham and shoulder percentages were obtained two ways: bone-in, packing house trim and boneless, closely trimmed. The percent ham-loin and lean cuts values were determined on the basis of bone - in, packing house trimmed. The 10th through 14th rib chops were removed, bagged and frozen for future analysis.

Proximate analyses for moisture, crude protein and ether extract were determined as described by the A.O.A.C. (1970) on duplicate samples from the 11th chop. The remaining three chops were weighed to the nearest 0.1 g and cooked in an electric oven to an internal temperature of 74 C. The percentages of cooking loss, drip loss and volatile gas loss were determined on the chops by the following methods:

$$\text{Cooking loss \%} = \left(\frac{\text{wt. of fresh sample - wt. of cooked sample}}{\text{wt. of fresh sample}} \times 100 \right)$$

$$\text{Drip loss \%} = \left(\frac{\text{wt. of drip collected during cooking}}{\text{wt. of fresh sample}} \times 100 \right)$$

$$\text{Volatile gas loss \%} = \text{percent cooking loss - percent drip loss}$$

A twelve member taste panel evaluated the samples for tenderness, juiciness and flavor on the basis of a 8 point scale. Tenderness was also evaluated with a Warner-Bratzler shear using a 2.54 cm core from both medial and lateral positions of one cooked chop from each carcass. A visual estimate of marbling and color and firmness was made on the fresh chop using the procedures and illustrations of Topel and Rust (1969).

Backfat samples, containing both inner and outer layers of fat from the midline above the first and second rib, were analyzed by gas-liquid-chromatography for fatty acid concentrations. After fat samples were extracted with ether, duplicate 150 mg samples of each extract was saponified with .5 N methanolic sodium hydroxide and boiled with BF_3 methanol. The methyl esters were then floated out of the mixture, using a saturated salt solution, and extracted with heptane. A 5 microliter sample of the methyl ester was analyzed with a Varian Aerograph Model 1800 filtered by a hydrogen flame ionization detector. A stainless steel column (1.8 m diameter X 3.2 cm length) was packed with 10% EGSS - X on a 100/120 mesh chromosorb P. The carrier gas was nitrogen, the column and injector port temperatures were 170 and 210 C, respectively. Myristic, palmitic, stearic, palmitoleic, oleic and linoleic acid concentrations were measured by the triangulation method.

Data were analyzed statistically by the least squares analysis of variance method outlined by Steel and Torrie (1960). When significant differences were obtained from a given set of data, Tukey's "w" procedure was used to determine which treatments were significantly different.

RESULTS AND DISCUSSION

Growth Performance

A summary of the growth performance data is presented in table 2 and the analysis of variance for average daily gain, feed consumption and feed efficiency are shown in tables 3, 4 and 5, respectively. In period one, from an average of approximately 20 to 50 kg liveweight, pigs fed the 16% protein diet ad libitum gained significantly ($P < .01$) faster than pigs fed either the 12% protein diet ad libitum or the 16% protein diet at a restricted level of intake. In period two, from an average liveweight of about 50 to 95 kg, pigs gained significantly ($P < .05$) faster when fed the 14% protein diet ad libitum than when fed either of the other two dietary treatments. Average daily gains during period one were 0.70, 0.64 and 0.63 kg and during period two were 0.83, 0.64 and 0.70 kg for treatment 1, 2 and 3, respectively. The attempt to equalize the gains of pigs in treatment two and three by restricting the diet intake fed to pigs in treatment three was quite successful in the first period of growth. However in period two, although not significantly different, daily gains were 9.3% faster for pigs in treatment three than those in treatment two. This difference was due to removing individual pigs for slaughter as they reached a weight of approximately 95 kilograms. Pigs fed the low protein diet were much more variable in performance and adjusting lot weights became more difficult after the best gaining pigs had been removed from their lots.

TABLE 2. EFFECT OF PROTEIN LEVEL AND FEED RESTRICTION ON GROWTH PERFORMANCE OF GROWING-FINISHING SWINE

Treatment Protein Level, Percent Feeding Method	(1) 16 - 14 *ad libitum*	(2) 12 - 10 *ad libitum*	(3) 16 - 14 restricted
No. of pigs[a]	20	20	20
Avg. initial wt., kg	20.36	20.41	20.34
Avg. final wt., kg	96.72	93.16	95.16
Avg. daily gain, kg			
20 - 50 kg	.701[b]	.641[c]	.632[c]
50 - 95 kg	.833[b]	.645[c]	.699[b,c]
20 - 95 kg	.771[b]	.644[c]	.664[c]
Avg. daily feed, kg			
20 - 50 kg	1.82[b]	1.87[b]	1.49[c]
50 - 95 kg	2.62[b]	2.41[b,c]	2.15[c]
20 - 95 kg	2.27[b]	2.20[b]	1.86[c]
Avg. feed/gain			
20 - 50 kg	2.62[b,c]	2.95[b]	2.37[c]
50 - 95 kg	3.20[b]	4.35[c]	3.32[b]
20 - 95 kg	2.98[b]	3.77[c]	2.92[b]

[a] Five replicated lots of four pigs each.
[b,c] Means on the same line without a common superscript were significantly different ($P < .05$).

TABLE 3. ANALYSIS OF VARIANCE FOR AVERAGE DAILY GAIN

Source of Variation	df	Mean Squares		
		Period I	Period II	Total Trial
Treatment (T)	2	.02804**	.18321*	.10081**
Replication (R)	4	.00945	.09902**	.03944
Sex (S)	1	.01247	.13567*	.06607
T X R	8	.00057	.02620	.00734
T X S	2	.00048	.01286	.00560
R X S	4	.01433	.01757	.01597
T X R X S	8	.00361	.01495	.00705
Residual	30	.00842	.02423	.01485

* P<.05
** P<.01

TABLE 4. ANALYSIS OF VARIANCE FOR FEED CONSUMPTION

Source of Variation	df	Mean Squares		
		Period I	Period II	Total Trial
Treatment	2	.21421**	.27601*	.23891**
Replication	4	.02462	.07586	.01572
Residual	8	.01763	.04369	.02583

* P<.05
** P<.01

TABLE 5. ANALYSIS OF VARIANCE FOR FEED EFFICIENCY

Source of Variation	df	Mean Squares Period I	Period II	Total Trial
Treatment	2	.42128**	2.01885**	1.13802**
Replication	4	.07654	.35778*	.14117
Residual	8	.04652	.06439	.05523

* $P < .05$
** $P < .01$

Five pigs fed the low protein diet grew very slowly during the 50 to 95 kg growth period. Because of the starting of a new experiment and the need of pen space, three of the above five pigs were taken off test before they reached 95 kg, this resulted in an approximate 3% reduction in the average final weight of pigs in treatment two.

Feed consumption did not differ significantly between pigs fed the 16 - 14 or 12 - 10% protein diets ad libitum in either period of growth. Restricting the 16 - 14% protein diets to obtain gains equal to those of pigs fed the low protein diet ad libitum resulted in a significantly ($P < .01$) lower feed consumption than by pigs fed either of the ad libitum diets in period one. However in period two, only pigs fed the high protein diet ad libitum consumed significantly ($P < .05$) more daily feed. Over the entire experiment, both ad libitum fed diets were consumed at a significantly ($P < .05$) higher level than the limited fed diet.

Feed efficiency differed significantly between treatments during all growth periods. Pigs fed the low protein diet *ad libitum* were significantly ($P < .01$) less efficient in feed conversion during both weight periods than the high protein restricted fed pigs. In period two, the 10% low protein diet was also utilized significantly ($P < .01$) less efficiently than the 14% protein diet when both were fed *ad libitum*. The difference in feed required per unit of gain for the entire trial was also significantly affected by protein level. Pigs fed the 16 - 14% protein diets were significantly ($P < .01$) more efficient than those pigs fed the 12 - 10% protein diets. The level of feeding the high protein diet had no significant effect on feed efficiency.

The increased growth rate and feed efficiency produced by the high protein diets are in agreement with Jurgens *et al*. (1967), who observed that pigs fed a 16% protein, milo-soybean diet had significantly higher average daily gains and an improved feed efficiency compared to pigs fed a 12% protein diet. Seerley, Poley and Wahlstrom (1964), comparing a 14.4% and 12.5% protein diet, also found significantly increased average daily gain in pigs fed the higher protein diet. The 14.4% protein diet decreased feed required per unit of gain by 6%, however, feed intake was not significantly influenced. Clawson (1967) reported that average daily gain and feed efficiency were significantly improved when pigs were fed a 14.8% protein level compared to a 9.0% protein diet.

However in contrast to the results presented here, Clawson (1967) found no significant difference in growth rate, feed efficiency or daily feed consumption of pigs fed 14 or 10% protein diets from 17 to 97 kg liveweight. These authors suggest this lack of protein effect was due to the presence of a constant amino acid balance regardless of dietary protein level. This balance was obtained by supplying a constant ratio of corn to soybean meal in the diet. Dukelow et al. (1963) and Cole and Luscombe (1969) also reported no significant differences in growth rate or feed efficiency when pigs were fed diets differing in protein content.

Dietary protein levels, ranging from 16 to 12%, did not significantly influence rate of gain or feed efficiency in work by Hoefer et al. (1952), Wahlstrom (1954), Hanson, Ferrin and Singh (1955), Jensen et al. (1955) and Meade (1956).

In the study reported herein, an approximate 16.4% restriction in feed consumption of the high protein diet significantly decreased rate of gain but did not significantly influence feed efficiency. Similar results were shown by Becker et al. (1963). Braude et al. (1959) and Lucas, McDonald and Calder (1960) also reported that restricting feed intake to 75% of ad libitum did not significantly influence feed efficiency.

However, Merkel et al. (1958) found that pigs fed 70% of ad libitum required significantly less feed per unit of gain than those on a full feed regime. Vanschoubrach, DeWilde and Lampo (1967), studying feed intakes from 55 to 95% of ad libitum, reported feed efficiency was improved up to the 25% restriction level of ad libitum and then decreased as feed intake was further restricted. These authors suggest that this increase in feed efficiency followed by a decrease is the result of two opposite effects. Owing to the feed restriction, gains contain less fat with more protein and water, hence are of lower energy content. However, the feed requirements for maintenance increase because the growing period is of greater duration.

The 12 and 10% protein diets fed in this experiment were calculated to contain 0.40 and 0.27% lysine, respectively. These levels are considerably below the National Research Council's (NRC) (1968) requirements of 0.70% for 20 to 35 kg pigs and .50% for 35 to 95 kg pigs. Wahlstrom et al. (1971) reported that supplementation of 12 - 10% protein, corn-soybean meal diets with 0.15% lysine significantly increased average daily gain and l. dorsi area and decreased backfat thickness. Work by Blair et al. (1969b), Pick and Meade (1970) and Vipperman et al. (1963) also indicated that the levels of lysine in the low protein diets were below that required by the pig for maximum growth performance.

In period two (50 to 95 kg), barrows gained significantly ($P < .05$) faster than gilts. This is in agreement with work by Young et al. (1968), Hale and Southwell (1967), Crum et al. (1964) and Wagner et al. (1963).

Apparent Nutrient Digestibility

Individual fecal samples for determination of apparent digestion coefficients were collected once daily at 6:00 A.M. Luce, Peo and Hudman (1964), studying ration digestibility by the chromic oxide method, reported that one collection during the day was sufficient to compare treatments as no treatment by time interaction was found. German (1968) reported that pooled fecal samples showed essentially the same trends in digestibility as the individual fecal samples. Thus, a composite from the fecal samples of the four pigs per pen was used in the chemical analysis to determine digestibility coefficients.

Summarized data of the digestion study is shown in table 6 and the statistical analysis of the data in table 7. No significant differences in apparent dry matter digestibility was found between the dietary treatments. However, apparent ether extract digestibility was significantly ($P < .01$) increased and apparent protein digestibility was significantly ($P < .01$) depressed when pigs were fed the 12 - 10% protein diets compared to either of the 16 - 14% dietary protein treatments. Apparent protein digestibility was not significantly affected by level of feed intake of the 16 - 14% protein diets. However, apparent ether extract digestibility was significantly ($P < .01$) lower on the 16 - 14% protein, restricted fed diet. Although negative apparent ether extract digestibilities were obtained when the 16 - 14% protein diets were fed, the individual values in each treatment were very consistent. Two possible causes for these negative digestibilities are that a very small amount of dietary fat

TABLE 6. EFFECT OF PROTEIN LEVEL AND FEED RESTRICTION ON APPARENT DIGESTIBILITIES OF DRY MATTER, PROTEIN AND ETHER EXTRACT

Treatment	(1)	(2)	(3)
Protein Level, Percent	16 - 14	12 - 10	16 - 14
Feeding Method	ad libitum	ad libitum	restricted
No. of pigs	20	20	20
Avg. dry matter dig., %			
20 - 50 kg[a]	93.65	93.44	93.92
50 - 95 kg[b]	94.07	93.87	93.96
20 - 95 kg	93.86	93.65	93.94
Avg. protein dig., %			
20 - 50 kg[a]	76.10[c]	72.83[d]	77.47[c]
50 - 95 kg[b]	75.19[c]	67.11[d]	75.57[c]
20 - 95 kg	75.64[c]	69.97[d]	76.52[c]
Avg. ether extract dig., %			
20 - 50 kg[a]	-24.05[c]	21.13[d]	-38.64[c]
50 - 95 kg[b]	8.13	18.69	15.15
20 - 95 kg	-7.96[c]	19.91[d]	-11.74[e]

[a] Determined at an average pig age of 95.6 days.
[b] Determined at an average pig age of 143.4 days.
[c,d,e] Means on the same line without a common superscript were significantly different ($P < .05$).

TABLE 7. ANALYSIS OF VARIANCE FOR APPARENT DIGESTIBILITIES OF DRY MATTER, PROTEIN AND ETHER EXTRACT

Source of Variation	df	Mean Squares App. D.M. Digestibility	App. Protein Digestibility	App. E.E. Digestibility
Treatment	2	.21664	126.45625**	2987.75240**
Replication	4	1.39017**	10.44921	570.41855
Period	1	.59361	60.46360*	5813.54880**
T X R	8	.10371	2.79814	213.69356
T X P	2	.11602	16.11872*	2011.56870**
R X P	4	.35227*	4.30798	265.71988
Residual	8	.08787	3.16591	211.32044

* $P < .05$
** $P < .01$

in relation to the metabolic fraction was actually involved and that there was substantial variability between individual chromic oxide determinations of the feces and feed content.

The significant increase in apparent protein digestibility and decrease in apparent ether extract digestibility with increased dietary protein levels is similar to results of Kuryvial and Bowland (1962). Lowrey, Pond and Manner (1958) also observed no dietary protein effect on dry matter digestibility; however, they reported that protein and ether extract digestion coefficients were both significantly improved when dietary protein increased from 13 to either 16 or 19%. Greeley, Meade and Hanson (1964a) noted no dietary protein effect on dry matter or ether extract digestibility but reported a significant increase in apparent digestibility of protein and energy. In opposition to previous results, work by Clawson et al.

(1962) and Lowrey et al. (1962) indicated no effect of dietary protein on apparent protein digestibility.

In this study, the 16.5% restriction in feed intake of pigs fed the high protein diet further depressed apparent ether extract digestibility but did not significantly influence apparent protein or dry matter digestibility. Kornegay and Graber (1968), comparing a 25 and 50% feed restriction to ad libitum, reported that apparent digestibilities of dry matter, protein and energy were not significantly affected by feed intake, although limited fed pigs had a small, but consistent advantage. Similar results were shown by Castle and Castle (1957).

It should be noted that apparent digestion coefficients are lowered by the presence of higher levels of metabolic nutrients. The metabolic protein and lipid fraction from the low protein ad libitum fed and high protein restricted fed pigs would represent a relatively greater proportion of the total quantities of protein and ether extract in the feces compared to the high protein ad libitum fed pigs.

Significant differences in digestibility were found between collections. Fecal collection one, obtained at an average weight and age of 41 kg and 96 days, resulted in significantly ($P < .05$) higher protein but significantly ($P < .01$) lower ether extract digestibilities than collection two, obtained at an average weight and age of 77 and 143 days, respectively. The analysis of variance for apparent nutrient digestibility by collection is shown in table 8. Although the 12 - 10% protein diet had significantly ($P < .01$) lower

TABLE 8. ANALYSIS OF VARIANCE FOR APPARENT DIGESTIBILITIES OF DRY MATTER, PROTEIN AND ETHER EXTRACT IN PERIODS ONE[a] AND TWO[b]

Source of Variation	df	Mean Squares (1) App. D.M. Digestibility	(2) App. D.M. Digestibility	(1) App. Protein Digestibility	(2) App. Protein Digestibility	(1) App. E.E. Digestibility	(2) App. E.E. Digestibility
Treatment	2	.29646	.03621	28.40249**	114.17249**	4854.96550**	144.35565
Replication	4	1.38488**	.35757**	7.33971**	7.41748	688.24381	147.89462
Residual	8	.16178	.02981	.70107	5.26299	195.51806	229.49594

[a] Determined at an average pig age of 95.6 days.
[b] Determined at an average pig age of 143.4 days.
* $P < .05$
** $P < .01$

protein digestibilities at both collection periods, the ether extract digestibility was significantly ($P < .01$) improved over the 16 - 14% protein diets only in collection one. It appears that as the pigs grow older they tend to have decreased protein digestibility and slightly improved fat absorption. Bell and Loosli (1951) reported similar results of decreased apparent nitrogen digestibility with increasing age. These authors suggest that as the pig matures, the relative amount of protein required for growth decreases and thus at a constant level of protein intake a decreasing proportion would be used for tissue growth.

Quantitative Carcass Traits

The effects of dietary protein level and feed restriction on quantitative carcass traits are presented in table 9. The analysis of variance for average carcass length, _l. dorsi_ muscle area and backfat thickness are shown in table 10.

No significant differences in carcass length were observed between dietary treatments. Average carcass length was 75.5, 76.1 and 77.2 cm for treatment 1, 2 and 3, respectively. Gilt carcasses were significantly ($P < .05$) longer than those of barrows. Kroff _et al_. (1959), Self _et al_. (1957) and Hale and Southwell (1967) reported a similar effect of sex on carcass length.

Carcass backfat thickness (3.0 cm) of pigs fed the 16 - 14% protein diets at a restricted level of intake was significantly ($P < .01$) less than the 3.5 and 3.3 cm of carcass backfat of pigs full fed the

TABLE 9. EFFECT OF DIETARY PROTEIN AND FEED RESTRICTION ON QUANTITATIVE CARCASS TRAITS

Treatment Protein Level, Percent Feeding Method	(1) 16 - 14 *ad libitum*	(2) 12 - 10 *ad libitum*	(3) 16 - 14 restricted
No. of pigs	19[a]	17[b]	20
Avg. backfat, cm	3.33[e]	3.50[e]	2.96[f]
Avg. length, cm	75.46	76.11	77.22
Avg. *l. dorsi* area, sq. cm	28.06[e]	22.64[f]	28.91[e]
Avg. dressing percent	71.83	71.16	70.94
Avg. percent ham[c]	21.18[e]	20.09[f]	22.37[g]
Avg. percent loin**	17.52[e]	16.09[f]	18.20[e]
Avg. percent ham-loin	38.71[e]	36.18[f]	40.59[g]
Avg. percent shoulder[c]	17.59[e]	16.98[f]	18.22[e]
Avg. percent lean cuts[c]**	56.30[e]	53.16[f]	58.81[g]
Avg. percent belly	12.07[e]	11.99[e]	11.25[f]
Avg. percent ham (boneless)[d]	14.76[e]	13.04[f]	15.48[g]
Avg. percent shoulder (boneless)[d]	12.05[e]	11.25[f]	12.47[e]

[a] One pig died of loading stress.
[b] Three pigs were removed before reaching slaughter weight.
[c] Bone in - packing house trim.
[d] Boneless - closely trimmed.
[e,f,g] Means on the same line without a common superscript were significantly different ($P < .05$).

TABLE 10. ANALYSIS OF VARIANCE FOR BACKFAT, LENGTH AND L. DORSI AREA

Source of Variation	df	Mean Squares Backfat	Length	L. Dorsi Area
Treatment	2	1.43438**	15.17089	191.74079**
Replication	4	.33946*	3.90361	3.63561
Sex	1	.74132*	43.20058*	7.18250
T X R	8	.05727	3.81174	12.88683
T X S	2	.00710	.59692	1.95883
R X S	4	.06554	4.35294	7.23340
T X R X S	8	.07458	2.51791	7.55015
Residual	26	.11211	1.93654	9.25173

* $P < .05$
** $P < .01$

12 - 10 and 16 - 14% protein diets, respectively. No significant differences were noted in carcass backfat between the high and low protein diets fed ad libitum.

Gilts were noted to have significantly ($P < .05$) lower backfat thickness than barrows. Similar results were obtained by Wagner et al. (1963), Bowland and Berg (1959) and Waldren (1964).

Pigs fed the 12 - 10% protein diets had an average l. dorsi muscle area of 22.6 cm^2 which was significantly ($P < .01$) less than the 28.1 and 28.9 cm^2 l. dorsi areas of pigs fed the high protein diets ad libitum or at a restricted level, respectively. The two levels of feeding the 16 - 14% protein diets did not result in a significant effect on the area of the l. dorsi muscle.

Thus in this study, dietary protein level did not significantly affect carcass length or backfat thickness. However, the high protein diets produced a larger _l. dorsi_ muscle area. This lack of protein effect on carcass length and backfat thickness is in agreement with work by Gilster (1972) and Jurgens _et al_. (1967), but differs from the reports of Noland and Scott (1960) and Wilson _et al_. (1953) who found that a 16 or 20% protein diet produced significantly longer carcasses than a 12% protein diet. However, neither of these studies showed a significant effect of protein level on backfat thickness. Ashton _et al_. (1955), feeding 10, 12, 14, 16, 18 and 20% protein diets, found no significant difference in backfat thickness between any two adjacent levels of protein. However, there was a significant linear trend toward decreased backfat thickness with increased protein levels. Seymour _et al_. (1964), Hale and Southwell (1967) and Lee _et al_. (1967) also observed a reduced carcass backfat due to increasing levels of dietary protein.

A similar increase in _l. dorsi_ area, as noted in this study due to increased dietary protein level, was observed by Seerley, Poley and Wahlstrom (1964) and Clawson (1967) feeding 14.5, 12.5 and 9.0% protein diets. In contrast to these results, Dukelow _et al_. (1963) reported no significant differences in _l. dorsi_ area between pigs fed a 12, 14 or 16% protein diet.

The decrease in carcass backfat observed when pigs received a 16.5% reduction in feed intake agrees with work by Braude _et al_. (1959) and Passbach _et al_. (1968). However, these authors noted that a restricted level of feed intake also produced a longer carcass and an increased _l. dorsi_ muscle area.

TABLE 11. ANALYSIS OF VARIANCE FOR DRESSING PERCENT AND PERCENTAGE OF HAM, LOIN, HAM-LOIN, SHOULDER AND LEAN CUTS

Source of Variation	df	Mean Squares					
		Dressing Percent	Ham[a] Percent	Loin Percent	Ham-Loin[a] Percent	Shoulder[a] Percent	Lean Cuts[a] Percent
Treatment	2	3.96329	22.83882**	19.70978**	79.83314**	6.72950**	119.79227**
Replication	4	2.57222*	1.41858	2.20804	5.83005	1.05019	7.51751
Sex	1	.82720	2.18882	13.14721*	28.99058	.27191	11.28367
T X R	8	1.06758	.88936	1.30280	.98072	.65741	2.05725
T X S	2	.94042	.42694	.85002	.13771	.23015	3.64164
R X S	4	1.52111	1.11554	1.44951	5.09986	.43592	6.00337
T X R X S	8	1.91202	.66803	1.19877	1.65500	.99890	3.66867
Error	26	.94019	1.06884	1.60211	3.95154	1.13596	6.46788

[a] Ham and shoulders - bone in, packing house trimmed.

* $P < .05$

** $P < .01$

TABLE 12. ANALYSIS OF VARIANCE FOR PERCENTAGES OF BELLY, BONELESS HAM AND BONELESS SHOULDER

Source of Variation	df	Mean Squares: Belly Percent	Boneless Ham[a] Percent	Boneless Shoulder[a] Percent
Treatment	2	3.85272*	26.52428**	6.24542**
Replication	4	.43487	1.64786	.98725
Sex	1	.33882	1.05657	1.02722
T R	8	.76303	.32471	.52717
T S	2	2.74786	1.24497	.08687
R S	4	2.85585	.77138	1.11850
T R S	8	1.76590	.55969	.78642
Residual	24	2.20423	1.53520	.95000

[a] External fat layer removed.
* $P < .05$
** $P < .01$

The approximate 18 day increase in age at slaughter, due to a slower rate of growth, did not significantly affect carcass length, backfat thickness or l. dorsi area of pigs.

The analysis of variance for dressing percent and percentages of ham, loin, ham-loin, shoulder and lean cuts are shown in table 11. Dressing percent was not significantly affected by dietary treatment. Pigs fed the 12 - 10% protein diets ad libitum had significantly ($P < .01$) lower percentages of ham, loin, ham-loin and lean cuts than pigs fed the 16 - 14% protein diets ad libitum or at the restricted level of intake. Restricting the feed consumption of pigs fed the 16 - 14% protein diets significantly ($P < .01$) increased the percentages of ham, ham-loin and lean cuts compared to pigs fed the high protein diet ad libitum. Percent ham-loin was 38.7, 36.2 and 40.6 and percent lean cuts were 56.3, 53.2 and 58.8 for pigs fed the 16 - 14% protein diets ad libitum, the 12 - 10% protein diets ad libitum and the 16 - 14% protein diets at a 16.5% restricted level of intake, respectively.

Gilts were shown to have significantly higher percent loins than barrows. This agrees with the concept of a leaner, more muscular carcass produced by gilts versus barrows as shown in work by Wong et al. (1968), Wagner et al. (1963), Waldren (1964), Bowland and Berg (1959) and Hale and Southwell (1967).

The analysis of variance for percentages of boneless ham, boneless shoulder and belly are shown in table 12. With complete removal of the outside fat cover on the boneless ham and shoulder to minimize effects of variation in fat deposition due to diet, feeding the two high protein diets still resulted in significantly ($P<.01$) greater percent ham and percent shoulder than when the low protein diet was fed. Pigs fed the 16 - 14% protein diets at a restricted level of intake had a significantly ($P<.01$) increased percent boneless ham and a significantly ($P<.05$) lower percent belly.

In this study, increased dietary protein levels significantly increased the production of lean or muscle development of the carcass. This effect of protein level on quantitative carcass traits is similar to results by Crum et al. (1964) who found that increased protein levels significantly increased the percentages of ham, loin and lean cuts. Ashton (1955), feeding 10, 12, 14, 16, 18 or 20% protein diets, noted that each increase in protein level from 10 - 18% resulted in a increased percent lean cuts and l. dorsi area but a decreased backfat thickness. Young et al. (1968), Gilster (1972) and Hale and Southwell (1967) reported similar improvements in carcass development with increasing dietary protein levels.

In contrast, Aunan et al. (1961) observed no significant differences in carcass backfat, length, dressing percent, percent lean cuts, l. dorsi area, fat or lean content of pigs fed 16 - 11, 14 - 11 or 12 - 11% protein combinations. This lack of effect of protein level on quantitative carcass development may be at least partially explained by the low level of protein fed in the finishing phase of all three dietary treatments. Work by Gilster (1972) has indicated that the protein levels fed to pigs during the 50 - 95 kg period of growth has the most significant effect on carcass development.

Restricting the feed intake of pigs fed the high protein diet further improved carcass leanness. Similar results were obtained by Keese et al. (1964), who reported significantly increased percentages of ham, picnic and lean cuts accompanied by a decreased percent belly and backfat thickness of pigs fed 2.27 kg of feed per day compared to those on a full feed regime. There was a consistent, but nonsignificant, trend for the limited fed pigs to be longer with a larger l. dorsi area than ad libitum fed pigs. In three trials, Klay et al. (1969) found increased percent lean cuts and l. dorsi area and decreased backfat thickness due to restricted feed intakes. Work by Babatunde et al. (1966), Braude et al. (1959) and Crampton, Ashton and Lloyd (1954) also indicated that a restricted level of feeding improved carcass lean parameters and reduced fat measurements compared to an ad libitum feeding regime. Merkel et al. (1958) reported that pigs fed 70% of ad libitum were significantly longer with higher percentages of ham and lean cuts than those fed to appetite. However, no significant differences in backfat thickness or l. dorsi area were observed.

Differences in age between the faster growing treatment one pigs and the slower growing treatment two and three animals had little influence on quantitative carcass characteristics. This is in agreement with work by Van Stavern (1960) who compared pigs varying in age at slaughter weight from 129 to 183 days. No significant relationship between age and the carcass characteristics of percent primal cuts, percent lean cuts, l. dorsi area and backfat thickness could be shown.

These authors concluded that carcasses from young, rapid gaining pigs are not significantly different from carcasses produced by older, slower gaining pigs. Judge _et al_. (1959) also reported no significant effect of age of pigs on _l_. _dorsi_ area or percent lean cuts. Brunner and Van Stavern (1961), studying pigs ranging in age from 126 to 185 days at 91 kg liveweight, found no significant difference between age groups in carcass length, _l_. _dorsi_ area or percent lean cuts from barrows. However, _l_. _dorsi_ area and percent lean cuts were significantly correlated with age groups for gilts. As the gilt matured, the _l_. _dorsi_ area and percent lean cuts increased.

Qualitative Carcass Traits

The effects of protein level and feed restriction on qualitative carcass traits are presented in table 13. The analysis of variance for moisture, protein, ether extract, marbling score and color and firmness score of the _l_. _dorsi_ muscle are shown in table 14. Significantly ($P < .01$) less moisture and protein and significantly ($P < .01$) more ether extract was present in the _l_. _dorsi_ muscle of pigs fed the low protein diets compared to those fed either of the 16 - 14% protein diets. Muscles from pigs fed the low protein diets had 70.5, 19.4 and 9.2 percent moisture, protein and fat, respectively, compared to 72.3, 21.9 and 4.7 percent when the higher protein diets were fed _ad libitum_ and 73.0, 21.6 and 3.6 percent of these respective nutrients when the high protein diets were restricted. No significant differences were observed in the chemical composition of the _l_. _dorsi_ muscle from

TABLE 13. EFFECT OF PROTEIN LEVEL AND FEED RESTRICTION ON QUALITATIVE CARCASS TRAITS

Treatment	(1)	(2)	(3)
Protein Level, Percent	16 - 14	12 - 10	16 - 14
Feeding Method	*ad libitum*	*ad libitum*	restricted
No. of pigs	19	17	20
L. Dorsi, fresh			
Avg. moisture, %	72.25[g]	70.47[h]	72.95[g]
Avg. protein, %	21.90[g]	19.38[h]	21.60[g]
Avg. ether extract, %	4.66[g]	9.20[h]	3.62[g]
Avg. marbling score[a]	2.55[g]	3.60[h]	2.35[g]
Avg. color and firmness score[b]	2.90	2.90	2.85
L. Dorsi, cooked			
Avg. shear value, kg[c]	7.06	6.57	7.02
Avg. tenderness score[d]	3.67	3.13	3.95
Avg. flavor score[e]	3.49	3.34	3.47
Avg. juiciness score[f]	4.16[g]	3.09[h]	4.55[g]
Avg. cooking loss, %	22.21	22.10	23.53
Avg. drip loss, %	8.79	8.99	8.88
Avg. volatile gas loss, %	13.42	13.11	14.65

[a] Based on 1 to 5 scale, 1 = trace to 5 = abundant.
[b] Based on 1 to 5 scale, 1 = pale, soft and watery to 5 = dark and firm.
[c] Kilograms of force to shear a core 2.54 cm in diameter.
[d] Based on a 1 to 8 scale, 1 = extremely tender to 8 = extremely tough.
[e] Based on a 1 to 8 scale, 1 = extremely desirable to 8 = extremely undesirable.
[f] Based on a 1 to 8 scale, 1 = extremely juicy to 8 = extremely dry.
[g,h] Means on the same line without a common superscript were significantly different ($P < .05$).

TABLE 14. ANALYSIS OF VARIANCE FOR MOISTURE PERCENT, PROTEIN PERCENT, ETHER EXTRACT PERCENT, MARBLING SCORE AND COLOR AND FIRMNESS SCORE OF THE FRESH L. DORSI

		Mean Squares				
Source of Variation	df	Moisture Percent	Protein Percent	Ether Extract Percent	Marbling Score	Color and Firmness Score
Treatment	2	27.55125**	147.08044**	31.23548**	7.50196**	.01566
Replication	4	2.13330	2.21327	4.28735*	.48586	.70700
Sex	1	6.78515	14.25113	12.24003*	.94118	.014706
T X R	8	1.18352	2.38059	.60509	.85928	.31371
T X S	2	6.02531	8.86891	2.06407	3.06070*	.17754
R X S	4	2.29321	3.01512	.90091	.99652	.25252
T X R X S	8	2.65813	7.72993*	2.07598	.45676	.50173
Residual	26	1.86954	2.42600	1.06665	1.42308	.55769

* $P < .05$
** $P < .01$

pigs fed the 16 - 14% protein diets ad libitum or restricted. Jurgens et al. (1967), comparing 12 and 16% protein diets, reported similar results of decreased fat content and increased protein in the l. dorsi muscle of pigs fed higher protein diets. Lee et al. (1967) also noted a decreased fat and increased protein and moisture content in pigs fed either a 18 - 15 or 21 - 18 - 15 protein level combination compared to a 15 - 12 - 9% protein sequence. These authors suggest that the alterations in chemical composition of the carcass is mainly due to changes in the fat content. The ether extract values of the l. dorsi muscle were shown to be inversely related with the protein content; however, the crude protein content of the carcass was not significantly affected by dietary protein level if converted to a fat-free basis. Vipperman et al. (1963) also showed that an increase in moisture and ash content of the muscle is accompanied by a decrease in fat. O'hea and Leveille (1969), studying possible modes of action of dietary protein level on fat deposition, showed that a high protein diet fed to pigs reduced the activity of certain key enzymes in adipose tissue that are associated with fatty acid synthesis. Thus, it may be suggested that dietary protein level may influence the amount and type of fatty acid synthesis in the body. The low quality protein in the 12 - 10% ad libitum fed diets could possibly further explain the decreased protein and increased ether extract content of the l. dorsi muscle of pigs fed the low protein diets. The amino acids absorbed into the body, but which remain unused in the formation of body protein because of the deficiency or imbalance of amino acids, may be deaminized to serve as an energy source. The amino acids carbon skeleton may be converted to acetyl-CoA from which fatty acids could be synthesized and deposited in the meat.

A significantly ($P < .05$) greater degree of marbling was noted in pigs fed the low protein diets compared to those fed either of the 16 - 14% protein treatments. This corresponds to the increased ether extract content of the meat in the low protein fed pigs. Color and firmness scores were not significantly different between dietary treatments. Jurgens et al. (1967) reported significantly decreased marbling scores but increased firmness scores when pigs were fed higher protein diets. However, work by Crum et al. (1964) indicated that a 17 - 15% protein sequence significantly lowered both marbling and firmness scores compared to a 13 - 11% dietary protein level. No significant differences were found in color scores due to dietary protein levels in work by Lee (1967).

The analysis of variance for taste panel, shear test and percent cooking losses of the meat are shown in tables 15 and 16. Loin chops from pigs fed the 12 - 10% protein diets were rated significantly ($P < .01$) juicier than the samples from either of the 16 - 14% protein treatments. A consistent, but nonsignificant, higher tenderness and flavor score of the _l. dorsi_ muscle was obtained from pigs fed the low protein diets compared to those fed the high protein diets. This improvement in basic eating desirability of the loin chops from the low protein fed pigs may be due to the increase in intramuscular

TABLE 15. ANALYSIS OF VARIANCE FOR SHEAR TEST, TENDERNESS SCORE, FLAVOR SCORE AND JUICINESS SCORE OF THE COOKED L. DORSI

		Mean Squares			
Source of Variation	df	Shear Test	Tenderness Score	Flavor Score	Juiciness Score
Treatment	2	1.18833	2.92574	.11185	9.62765**
Replication	4	2.94674	.31240	.08123	.09684
Sex	1	.05308	.42882	.35309	1.65235*
T X R	8	1.14644	.76453	.03797	.32175
T X S	2	2.08259	.14893	.08397	.76050
R X S	4	2.09513	.63976	.12734	.13431
T X R X S	8	2.47547	1.00457	.19321	.56417
Residual	26	3.38558	1.01115	.10750	.36231

* P <.05
** P <.01

TABLE 16. ANALYSIS OF VARIANCE FOR COOKING LOSS PERCENT, DRIP LOSS PERCENT AND VOLATILE GAS LOSS PERCENT OF THE COOKED L. DORSI

		Mean Squares		
Source of Variation	df	Cooking Loss Percent	Drip Loss Percent	Volatile Gas Loss Percent
Treatment	2	11.73311	.15856	14.74839
Replication	4	7.87627	8.98608	.71871
Sex	1	.00941	.70015	2.33470
T X R	8	4.23691	2.96215	3.82637
T X S	2	4.32423	3.42396	6.40724
R X S	4	3.48556	5.28098	3.24548
T X R X S	8	7.74979	3.04725	9.29326
Residual	26	10.69923	5.83327	7.95654

* P <.05
** P <.01

fat, as indicated by the chemical analysis and marbling scores of these carcasses. Thorton et al. (1968) suggests that the fat content of the carcass may be linked with or responsible for good meat palatability. Kaufman et al. (1964) and Henry, Bratzler and Luecke (1963) also showed that an increase in intramuscular fat in pork was associated with higher flavor, tenderness and, especially, juiciness scores of the cooked, fresh product.

The l. dorsi muscle of gilts had a significantly ($P < .05$) lower juiciness score than barrows. Kroff et al. (1959) reported the lean tissue of gilts to be higher in protein and moisture and lower in fat content than barrows. Thus, this sex difference might be expected since a low fat content is associated with decreased juiciness.

No significant differences were found in the tenderness, juiciness or flavor between the cooked loin chops from pigs on the full fed or restricted fed 16 - 14% protein diets. Tenderness, as evaluated by the shear test, was not significantly affected by dietary protein content or feed intake level, although chops from the low protein fed pigs had a slightly lower shear value. In work by Lee et al. (1967) only the tenderness of the meat, as determined by taste panel and shear test values, was significantly different between pigs fed diets differing in protein content. Gilster (1972) reported a general but nonsignificiant trend for more desirable tenderness, flavor and juiciness scores of loin chops from low protein fed pigs.

Percentages of drip loss, volatile gas loss and total cooking loss were not significantly different between dietary treatments.

Gilster (1972) reported that losses during cooking were not affected by dietary protein combinations ranging from 20 - 20 - 20 to 12 - 10 - 10%.

In this experiment, neither feed restriction nor age significantly affected the chemical composition, consumer acceptability or cooking characteristics of the l. dorsi muscle.

Restricted feeding, as reported by Passbach et al. (1968), tended to increase the occurrence of pale, soft, exudative pork and percent cooking loss of loin roasts, but did not significantly affect the marbling, percent moisture or ether extract, pH of the l. dorsi muscle, shear force or overall palatability values of the meat. However, Klay et al. (1969) reported that a limited feed intake regime tended to decrease the tenderness and desirable flavor and increase the shear test values and percent cooking losses of the meat. Keese et al. (1964) reported that limited feeding did not significantly affect palatability scores, but indicated a trend toward higher juiciness and lower flavor scores in pigs fed a restricted level of feed intake. Decreased tenderness and palatability of the carcass due to limited feed consumption was also observed by Thornton et al. (1968).

Increased age is generally accepted to be associated with increased fat and decreased moisture and protein content of the carcass (McMeekan, 1940a; Buck, 1963; Stant et al., 1968 and Callow, 1949). Judge et al. (1959) found no significant ffect of age on color, marbling or firmness of the meat. Klay et al. (1969)

reported nonsignificant differences in juiciness and overall desirability of meat from pigs ranging in age from 85 to 392 days.

Fatty Acid Composition

The fatty acid composition data and the analysis of variance for the concentration of myristic, palmitic, palmitoleic, stearic, oleic and linoleic acid are shown in tables 17 and 18. Only the fatty acid concentrations of palmitoleic, oleic and linoleic acid were significantly affected by dietary treatment. Shoulder backfat from pigs fed the 16 - 14% protein diets had significantly ($P < .01$) higher concentrations of palmitoleic and linoleic acid and significantly ($P < .05$) lower levels of oleic acid than the fat of pigs fed the low protein diets ad libitum. Restricting the level of intake of pigs fed the high protein diets significantly ($P < .01$) increased the linoleic acid concentration.

Feed restriction and increased age tended to produce a more unsaturated fat. This difference could be mainly due to the rate of gain of these pigs. Babatunde et al. (1966) concluded that the softening of backfat is a phenomenon accomplished by the gradual replacement or dilution of the already existing saturated fats with unsaturated ones. Furthermore, these authors observed that average daily gains were related positively to saturated fatty acids and negatively to the unsaturated ones. Similar results by Callow (1935), as cited by Babatunde et al. (1966), showed that a slower growing pig usually has a slower rate of fat synthesis and deposition, which in turn was related to a softer backfat.

TABLE 17. EFFECT OF PROTEIN LEVEL AND FEED RESTRICTION ON THE CONCENTRATIONS OF MYRISTIC, PALMITIC, STEARIC, PALMITOLEIC, OLEIC AND LINOLEIC ACID IN SHOULDER BACKFAT

Treatment Protein Level, Percent Feeding Method	(1) 16 - 14 ad libitum	(2) 12 - 10 ad libitum	(3) 16 - 14 restricted
No. of pigs	19	17	20
Saturated, %	41.59	40.80	40.41
Myristic, %	1.73	1.64	1.78
Palmitic, %	26.37	25.74	25.74
Stearic, %	13.49	13.42	12.89
Unsaturated, %	58.61	59.20	59.59
Palmitoleic, %	3.37[a]	2.87[b]	3.58[a]
Oleic, %	42.91[a,b]	44.17[a]	42.30[b]
Linoleic, %	12.33[a]	12.18[a]	13.71[b]

[a,b] Means on the same line without a common superscript were significantly different ($P < .05$).

TABLE 18. ANALYSIS OF VARIANCE FOR PERCENTAGES OF MYRISTIC, PALMITIC, STEARIC, PALMITOLEIC, OLEIC AND LINOLEIC ACIDS IN SHOULDER BACKFAT

		Mean Squares					
Source of Variation	df	Percent Myristic	Percent Palmitic	Percent Stearic	Percent Palmitoleic	Percent Oleic	Percent Linoleic
Treatment	2	.08632	2.37689	2.06200	2.26068**	15.32843*	13.27099**
Replication	4	.07342	1.78218	6.04384**	.89596**	5.43974	2.99560
Sex	1	.03049	5.64941	6.62813	.05142	3.09191	11.50471
T X R	8	.03145	1.13255	1.03424	.13568	2.46898	.63099
T X S	2	.03118	.32910	3.23658	.27636	.13541	1.21067
R X S	4	.05812	.88624	4.38790*	.56768**	3.72156	2.01672
T X R X S	8	.02306	1.49348	1.09048	.13870	1.64395	1.22686
Residual	26	.04151	1.43750	1.44594	.09262	2.00706	2.14056

* P <.05
** P <.01

Work by Dahl and Persson (1965), as cited by Koch et al. (1968), indicated that polyunsaturated fatty acids, especially linoleic, were preferentially deposited. These authors concluded that due to the longer growth period of the slow gaining animals, more time was allowed for the preferential deposition of the unsaturated fatty acids. Similar effects of growth rate on fatty acid composition were obtained by McMeekan (1940b).

A slight trend toward increased unsaturation of fatty acids was noted in work by Merkel et al. (1968) and Braude and Townshend (1958) when feed intake was restricted. These authors reported the difference in unsaturation was produced by a decreased level of palmitic acid and an increased level of linoleic acid. Greer et al. (1965) reported similar decreases in saturation and increases in levels of linoleic acid in pigs fed 85% of full feed. But further restriction below 75% of full feed greatly reduced the effect of limited feed intake on unsaturation, especially the linoleic acid concentration. The increased levels of linoleic acid found in this study due to the approximate 16.5% restriction in feed intake would tend to be in agreement with these results. However, Koch et al. (1968) reported significantly less saturated fats when feed intake was restricted below 80% of ad libitum whereas less restricted diets produced no change in fatty acid composition.

SUMMARY

Sixty crossbred pigs were assigned to five replicates of three treatments and fed from a weight of approximately 20 to 95 kg to determine the effects of dietary protein level and age on rate and efficiency of gain, quantitative and qualitative carcass characteristics and apparent nutrient digestibility.

From initial weight to 50 kg, pigs fed a 16% protein, corn-soybean meal diet *ad libitum* gained significantly ($P < .01$) faster than pigs fed a 12% protein, corn-soybean meal diet *ad libitum* or a 16% protein diet at a restricted level of intake. Feed consumption and feed efficiency were not significantly different between pigs fed the 16 or 12% protein diets *ad libitum*. However, pigs limited fed the 16% protein diet to obtain gains equal to those of pigs fed the low protein diet *ad libitum* consumed approximately 16.5% less feed and were significantly ($P < .01$) more efficient in converting feed to gain than the low protein *ad libitum* fed pigs.

During the 50 - 95 kg weight period, pigs fed the 14% protein diet *ad libitum* grew significantly ($P < .05$) faster than pigs fed the restricted 14% protein diet or the 10% protein diet *ad libitum*. No significant difference in feed consumption was obtained between pigs fed the 14 and 10% protein diets *ad libitum*; however, pigs fed the high protein diet *ad libitum* or at a restricted level of intake required significantly ($P < .01$) less feed per kg of gain than those fed the low protein diet.

Overall growth rate of pigs fed the 16 - 14% protein sequence *ad libitum* was significantly higher than that of pigs fed either of the other dietary treatments. This faster rate of growth of the high protein *ad libitum* fed pigs resulted in an increased average age at slaughter of 17.1 and 18.2 days for pigs fed the low protein and restricted diets, respectively. The low protein *ad libitum* fed pigs required significantly ($P < .05$) more feed per unit of gain for the entire experiment than pigs fed the 16 - 14% protein diets at either level of intake.

Backfat thickness was significantly ($P < .01$) reduced in pigs limited fed the 16 - 14% protein diets. No significant difference in carcass backfat thickness was observed between pigs fed the 16 - 14% or 12 - 10% protein diets *ad libitum*. The *l. dorsi* muscle areas of pigs full fed or restricted fed the 16 - 14% protein diets were 23.9 and 27.7% larger ($P < .01$), respectively, than the *l. dorsi* areas of pigs fed the 12 - 10% protein diets. No significant differences in carcass length or dressing percent were observed between dietary treatments. Carcasses of gilts were significantly ($P < .05$) longer than those of barrows.

Percentages of ham, loin, lean cuts, boneless ham and boneless shoulder from pigs fed the low protein diet *ad libitum* were significantly ($P < .01$) lower than from pigs fed the 16 - 14% protein diets at either level of intake. Restricting the feed intake of pigs fed the 16 - 14% protein diets significantly ($P < .01$) increased percentages of ham, ham-loin, lean cuts and boneless ham and significantly ($P < .05$)

decreased the percent belly. The percent loin was significantly ($P < .01$) greater in carcasses from gilts than from barrows.

A significant ($P < .01$) reduction occurred in protein and moisture content of the _l_. _dorsi_ muscle of pigs fed the 12 - 10% protein diets while the ether extract content was significantly ($P < .01$) higher than pigs fed the 16 - 14% protein diets. As would be expected with the increased intramuscular fat content, the marbling and juiciness scores of the _l_. _dorsi_ muscle of pigs fed the low protein diets were significantly ($P < .01$) higher than pigs fed the 16 - 14% protein diets, regardless of level of feeding. However, flavor tenderness and shear test values were not significantly affected by protein level of feeding rate. The loin chops of gilts were rated significantly ($P < .05$) less juicy than those from barrows.

Percentages of drip loss, volatile gas loss, cooking loss and color and firmness scores were not significantly different between dietary treatments.

Slightly higher concentrations of saturated fatty acids in shoulder backfat were obtained when pigs were fed the 16 - 14% protein diets _ad libitum_. Shoulder backfat samples from pigs fed the 12 - 10% protein diets _ad libitum_ contained significantly ($P < .01$) less palmitoleic and linoleic acid and significantly ($P < .05$) more oleic acid than those from pigs restricted fed the 16 - 14% protein diet. The 16 - 14% protein diet, _ad libitum_ fed, produced significantly ($P < .01$) higher concentrations of palmitoleic acid than the low protein _ad libitum_ fed diet. Restricting the level of feed intake of pigs fed the 16 - 14% protein diets significantly ($P<.01$) increased the linoleic acid concentrations.

Pigs fed the 12 - 10% protein diets had significantly ($P<.01$) lower protein digestibilities at both weight periods; however, the ether extract digestibility was significantly ($P<.01$) improved over the 16 - 14% protein diets only in period one.

In the overall trial, apparent protein digestibility was significantly ($P<.01$) depressed and apparent ether extract digestibility significantly ($P<.01$) improved in pigs fed the 12 - 10% protein diets. Pigs fed the 16 - 14% protein diets had significantly ($P<.01$) lower apparent ether extract digestibility when feed intake was restricted. Apparent dry matter digestibility was not significantly affected by dietary treatment.

Significant differences in digestibilities between growth periods were observed. Fecal collections obtained at an average weight of 41 and 77 kg and age of 96 and 143 days in period one and two, respectively, resulted in significantly ($P<.01$) higher protein and significantly ($P<.01$) lower ether extract digestibilities in collection one compared to collection two.

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