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Progeny from three sires of differing genetic background were divided within litters by sex and placed on either a 15 or 19% protein ration. The test period began when the experimental animals weighed 60 pounds and continued until they were slaughtered at 225 pounds. This test period was divided into three growth periods: 60 to 115 pounds; 115 to 170 pounds; and 170 to 225 pounds. Pen feed consumption was recorded and weekly weighings were made from which average daily gain and feed efficiency were calculated. Carcass data were collected only on the males, with a few exceptions, and consisted of loin eye area, ham weight, loin weight, carcass length, carcass backfat, and a color and marbling index score.

Live animal data showed that a high protein ration gave additional growth ( $P < .025$ ) and feed efficiency only during the early stages of growth. Sire effects also were most evident in the early

growth period ( $P < .01$ ) while sex effects showed males gained faster ( $P < .01$ ) and deposited more backfat ( $P < .01$ ) during all three growth periods when compared to the females. Backfat thickness measured at 170 and 225 pounds showed no differences due to sire or ration. No interactions were observed for average daily gain, feed efficiency, or backfat thickness regardless of the feeding period studied.

Carcass data showed the higher protein ration produced no significant effects but did cause minor improvements in loin eye area, carcass backfat depth, ham weight and loin weight. Sire effects were significant for loin eye area ( $P < .01$ ) and ham weight ( $P < .01$ ) but were not significant for the other carcass traits measured. No interactions were found between sire and ration for any of the carcass traits studied. Cost analysis showed that the higher protein ration did not produce enough favorable live animal and carcass results to pay for the extra protein costs.

Genetic-Protein Level Interaction in Growth  
and Carcass Traits of Market Hogs

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# GENETIC-PROTEIN LEVEL INTERACTION IN GROWTH AND CARCASS TRAITS OF MARKET HOGS

## INTRODUCTION

With the increasing cost of production, swine producers must continually attempt to increase lean meat production while maintaining or reducing their cost structure. Since the largest single cost of producing swine is the feed cost, and the protein supplementation is a high cost-per-unit portion of this expense, it is here that much potential exists to make savings. In ruminants non-protein nitrogen is used extensively and has reduced the cost of protein supplements during the growing-finishing period. However, reports of non-protein nitrogen utilization by swine have been contradictory (Hansen and Ferrin, 1955; Kornegay et al., 1965; Hentz et al., 1969) and it is generally agreed that non-protein nitrogen is of limited value, if of any value at all, when included in swine rations.

Because genetic differences in feed utilization have been well established for rations as a whole, it is reasonable to also expect differences in protein utilization due to the genotype of the animal. It is likely the differences caused in both cases are influenced by sex, weight, and heredity for the lean-fat ratio, as well as many other factors controlled by the genetic makeup of the animal. The producer must control as many of these variables as possible to be able to

efficiently produce a lean type animal as demanded by the packer. With this in mind possibly the best way to approach the problem is through a genetic evaluation of the breeding stock being used.

Progeny testing and production testing are two valuable methods of determining genetic capacity for efficient protein utilization. When these efforts are combined with the work of the nutritionist, we can hope to produce an animal that is efficient in feed utilization and deposits a minimum amount of fat during the growing-finishing period. The packer has shaped our goals with his demands for a hog that will give a high percentage of saleable lean and a minimum amount of fat. If the producer is to produce this type of animal and do it efficiently enough to attain a livelihood from his efforts, we must know as much as possible about the interaction between genotype and protein utilization in market swine. Research was conducted at Oregon State University between September 1971 and October 1972 to obtain information in this area.

## REVIEW OF LITERATURE

### Effects of Protein Level and Environmental Factors

Protein levels have for many years been a major consideration in rations fed to livestock. Much research has been conducted, especially since the early 1950's, involving protein levels and their effects on growth, carcass characteristics, and their various interactions.

In a study reported by Wilson et al. (1953) three groups of market hogs were fed rations containing high, medium, or low levels of protein. The initial protein levels were 20, 17, and 14%. When the pigs reached 75 pounds, protein levels were reduced to 16, 13, and 11%; from 150 to 210 pounds, protein was again reduced to 12, 10, and 8%. The animals receiving the high protein diet produced leaner carcasses and less fatty tissue than did the medium or low protein fed animals. Average daily gain was higher in the high protein group but the difference was not statistically significant. Average daily gain was significantly higher ( $P < .01$ ) in the medium protein group when compared to the low protein group. The backfat thickness showed no significant differences due to treatment within or between protein levels in the rations.

Jensen et al. (1955) found an interaction between antibiotics and

protein level on growth rate and feed efficiency. Six protein levels ranging from 10 to 20% were fed to market hogs. In a second experiment, the same rations were fed except for the inclusion of 5 mg of terramycin per pound of ration. In general the average daily gain of the pigs reached a maximum between 16 and 18% protein without antibiotics and at 14% protein with antibiotics. Feed efficiency was not significantly affected by the level of protein fed in the first experiment. In a second experiment, however, protein level had a significant effect ( $P < .05$ ) on feed efficiency which paralleled the performance in daily gains. These same workers (Ashton et al., 1955) in a different experiment then analyzed the interaction between antibiotics and protein level on carcass leanness. They concluded that the inclusion of antibiotics had no important effect on hog carcass quality. They found, however, that feeding higher protein levels over the range of 10 to 20% significantly increased ( $P < .05$ ) the proportion of lean in the carcass as the protein level increased. The increase in protein level between adjacent rations was only 2% and the increase in proportion of lean between adjacent rations was of such small magnitude, however, as to be of minor consideration when a choice must be made between two adjacent protein levels.

Kropf et al. (1959) studied the effects of protein level and quality on growth and carcass traits of market hogs. Pigs were grown from weaning to 200 pounds on rations containing 12 or 16% protein. Gilt

carcasses contained more muscle and less fat than did barrow carcasses. Carcasses from pigs fed a 16% good quality protein ration were more muscular as shown by a larger loin eye area, increased carcass specific gravity, higher levels of carcass protein, and decreased backfat thickness. Intramuscular fat of the loin eye was lowest and percent moisture in the carcass was highest in those animals fed the 16% high quality protein ration. Average daily gain in groups between protein levels was essentially the same while total feed used, average daily feed consumption, and feed efficiency all slightly favored the higher protein rations.

An energy-protein level interaction was reported by Norland et al. (1960) in pigs fed three levels of protein and at three levels of energy. Analysis showed that during the growth period of 40 to 75 pounds there was significant ( $P < .01$ ) protein X energy interaction as well as a significant ( $P < .01$ ) protein level effect for the growth period from weaning to 75 pounds. Pigs fed 16 or 20% protein rations produced longer carcasses ( $P < .01$ ) with a greater yield of primal cuts as compared to pigs fed a 12% protein ration.

These results are in close agreement with those of Aunam et al. (1961) who also found a significant ( $P < .01$ ) decrease in daily gains when weanling pigs were fed a 12% protein diet to a weight of 125 pounds as compared with those fed 14 or 16% protein diets. Carcass data analysis, however, showed no significant differences due to

protein treatment but did show small differences in several measurements in favor of the higher protein levels. The authors concluded that the genotype of the animal is the most important factor in carcass leanness and that initial protein levels within the range of 14 to 18% have only minor effects on carcass quality.

Castain and Morgan (1961) fed pigs individually with various protein-energy ratios and found much the same results as Norland et al. (1960). They concluded that in growth from 100 to 200 pounds the pig can tolerate a wider energy-protein ratio than in earlier life. This results in higher average daily gain but increases carcass fatness.

Greeley et al. (1964) compared several protein levels at each of four energy levels and found highly significant ( $P < .01$ ) differences between protein levels in conversion of digestible protein to gain. They also found a highly significant ( $P < .01$ ) linear trend toward reduced efficiency of utilization of digestible protein with increasing level of dietary protein. Even with reduced efficiency of utilization they still found significant increases in apparent digestibility of protein resulted as the protein content of the diet increased. They also noted that apparent digestibility of energy was also increased with increasing levels of dietary protein.

Robinson et al. (1964) fed four levels of dietary energy in combination with four levels of crude protein and found average daily

gain and feed efficiency to be superior with the diets containing 18% crude protein at 3300, 3080, or 2640 Kcal/kg D. E. and 20% crude protein with 2860 Kcal/kg D. E. They also noted that higher protein levels during the initial stages of growth improved carcass quality by significantly reducing ( $P < .05$ ) the fat content. Also found was a significant increase ( $P < .05$ ) in loin eye area and a slight increase in percent lean. Backfat depth at time of slaughter was also significantly less ( $P < .01$ ) in hogs fed the higher protein level. These carcass data results are generally in agreement with those of Holme et al. (1965) who found that irrespective of growth patterns, there is a favorable carcass response to level of protein. They found no interaction between rate of gain and protein level.

Lee et al. (1967) reported contradictory results of live animal performance. They found higher protein levels resulted in a significant increase ( $P < .05$ ) in rate of gain and increased feed efficiency as well as carcass leanness. The lowest protein level was associated with more intramuscular fat and greater tenderness of the meat which resulted in higher taste panel scores. Protein consumed per unit gain in lean cuts was found to be significantly greater ( $P < .01$ ) with the high protein level ration when compared to the low protein level ration. The medium level of protein also gave a significantly greater ( $P < .05$ ) protein consumed per unit gain in lean cuts ratio than did the low protein ration. Hale et al. (1967) used several different breeds of pigs



in a similar experiment and found greater differences between breeds within a protein level than within a breed between protein levels. These differences were reported both on live animal performances and carcass data.

Hale and Southwell (1967) reported on a sex by protein level interaction and found that barrows gained faster than gilts, but that gilts had a higher dressing percentage and produced longer carcasses with less backfat, larger loin eye areas, and higher yields of lean cuts. These differences remained fairly constant between the protein levels. These carcass data results between protein levels were very consistent with the results found by Norland et al. (1960), Holme et al. (1965), and Lee et al. (1967). The findings by Hale of a sex by protein interaction were confirmed by Kline et al. (1967) whose results closely paralleled Hale's.

Wong et al. (1968) also reported on a protein level by sex interaction. Gilts, barrows and boars were included in this work in which it was concluded that no significant treatment differences existed for any of the performance traits studied. Significant differences among sexes were found, however, for all performance traits studied except daily feed consumption. No important treatment by sex interactions were observed.

Seymour et al. (1964) investigated protein level by environmental temperature interaction on live animal performance and carcass

traits. High and normal protein level rations were fed to two groups of pigs living in an environmental temperature of 60 degrees F and the same rations were fed to two comparable groups of animals maintained at 90 degrees F. Pigs fed the higher level of protein grew significantly faster ( $P < .05$ ) and yielded carcasses containing a higher percent of lean cuts ( $P < .05$ ) when compared with pigs fed the normal protein ration regardless of the environmental temperature. A significant protein by temperature interaction ( $P < .05$ ) was detected for the average feed efficiency for the winter experiment as pigs fed the high protein ration required more feed per pound of gain. This interaction was in the early growth period from weaning to 110 pounds. There was no interaction in the later growth period nor in the summer experiment.

Wahlstrom et al. (1971) found a significant ( $P < .05$ ) interaction between protein level and housing on rate of gain when the diets contained 17 to 14% and 15 to 12% protein. This was a winter experiment and confirms Seymour's results.

Blair et al. (1969) fed four levels of protein ranging from 12 to 18% and killed the experimental animals at weights ranging from 100 to 250 pounds. Carcass quality was influenced significant by diet ( $P < .05$ ) and sex ( $P < .05$ ). Increasing the level of protein in the diet for the four respective live weight groups gave a significant increase ( $P < .05$ ) in carcass leanness. Protein content of the carcass dry

matter remained fairly constant at all weights, while color and shear value rose with increasing weight but were not significantly influenced by dietary treatment or sex.

McConnell et al. (1971) fed two levels of protein (14 and 18%) to fat-type and lean-type hogs. Digestion and N-metabolism determinations were made at 41, 71, and 91 kg live weight. No differences were found in the digestibilities of dry matter, gross energy, or protein within trials regardless of the protein content of the diet or the leanness of the pig. They found improved nutrient digestibility with increasing age and higher protein digestibility in pigs fed the higher protein ration. No improvement in carcass leanness was noted when the high protein diet was fed to fat-type pigs indicating that the low level of protein was adequate for maximum carcass leanness in fat-type hogs. However, the higher protein level substantially improved carcass leanness in lean-type hogs.

Cookie et al. (1972) investigated response to protein intake on a high-energy diet and confirmed the results of Norland et al. (1960), Aunan et al. (1961), and Costain et al. (1961). They fed six protein levels ranging from 15.5 to 27.3% crude protein at a common energy level of approximately 3500 Kcal/kg D. E. The experimental animals were fed from weights of 23 to 59 kg and carcass data were collected when the animal reached terminal weight. Improved growth rate and efficiency of feed conversion resulted from increasing protein levels

from 15.5 to 17.4% and significant ( $P < .05$ ) reductions in both traits resulted from the 25.3 to 27.3% crude protein diets. Carcass leanness increased linearly ( $r=0.976$ ) and fat decreased linearly ( $r= -0.992$ ) with dietary protein increment increases over the full range studied. As best growth performance and maximum lean content were attained at different dietary crude protein levels, a combined measure of rate and efficiency of daily lean deposition was calculated. This indicated that maximum rate of lean growth and efficiency of feed conversion to lean were reached at the 22.3% crude protein level. In terms of efficiency of utilization of nutrients, maximum retentions of both digestible energy and digestible crude protein in the edible part of the carcass appeared to be attained on the two lowest dietary protein levels. This same group of workers (Lodge et al., 1972) then investigated the effect of differing nutrient densities at a constant energy-protein ratio. They formulated three rations with varying levels of protein but equivalent ratios of digestible energy to crude protein (160 Kcal D. E. /unit % CP). Each of these rations were fed on two levels. They found, on the lower level of feeding, that growth rate, feed efficiency, and carcass fat content increased linearly ( $P < .05$ ) with each increment in nutrient concentration. On the higher level of feeding, growth rate and feed efficiency increased from the low protein diet to the medium protein diet ( $P < .05$ ), but did not increase from the medium to the high protein diet. Carcass fat

content increased linearly ( $P < .05$ ) with diet from the lowest to the highest energy concentration. There was a nonsignificant tendency for the higher density diets at a similar level of nutrient intake to give better feed efficiency and fatter carcasses than lower density rations.

Cookie et al. (1972) then proceeded to research the responses of different protein and energy levels. The results obtained are generally the same as reported by Norland et al. (1960), Aunan et al. (1961), Costain et al. (1961), and Robinson et al. (1964). Cookie found a significant ( $P < .05$ ) energy by protein interaction only for dressing percentage. All other parameters acted independently. Increase in dietary energy gave a linear increase in growth rate and feed efficiency. There was also, as expected, a linear decrease in lean percentage and an increase in fat percentage. Increase in dietary protein level gave an increase in growth rate and increased feed efficiency with the first increment (21 to 24% CP), but showed no further significant changes. Lean percentage increased and fat percentage decreased with the first protein increment, with no further significant changes.

Investigations of the interaction between genotype and protein utilization or plane of nutrition has been very limited. However, there are a few select instances in which this interaction was investigated. Berg and Bowland (1959) fed rations ranging from 69 to 88% digestible energy and from 13 to 21% crude protein to pigs of four

different strains. They found rate of liveweight gain tended to be fastest in pigs fed high energy-high protein rations throughout. Males gained faster than females with strain differences being evident. They found a strain by sex interaction ( $P < .05$ ) in rate of gain in both the growing and finishing period. There was also a ration by strain interaction present in the growing period ( $P < .01$ ) for average daily gain as well as for the total period ( $P < .01$ ). Ration by strain interactions were not significant for daily feed consumption, nor feed efficiency. There was evidence that high protein alone or in combination with high energy rations improved efficiency of feed utilization in the finishing period. They also noted leaner carcasses in the animals fed high protein rations. Strain differences in carcasses existed but no significant strain by ration interactions were present.

Plank and Berg (1963) confirmed the significant interactions found by Berg et al. (1959) but were in disagreement over some of the reported nonsignificant interactions. In this experiment pigs were fed to the scale of 75% of the U. S. N. R. C. recommended levels. Feeding was either by ad libitum or liberal feeding wherein pigs were fed to appetite three times daily. They found genotype by plane of nutrition interactions were significant for average daily feed consumed ( $P < .05$ ), average daily gain ( $P < .01$ ), and carcass length ( $P < .05$ ). Under equalized limited feeding, pigs with the ability to gain more rapidly and efficiently tended to produce superior carcasses

while under liberal feeding rapid gains seemed to reflect mainly increased feed consumption and a trend toward inferior feed efficiency and fatter carcasses.

Kroeske (1968) split litter mates into two experimental groups and fed one group a fattening ration and the other a breeding ration. Upon slaughter he found a litter by ration interaction ( $P < .05$ ) only for total feed consumption and percentage of ham. He concluded that there is little danger of an undesirable interaction between ration and inherited characters.

Davey et al. (1969) fed rations containing 12 or 20% protein to pigs selected for high and low backfat thickness. The animals were slaughtered at ages ranging from 84 to 224 days and carcass measurements were taken. Carcasses from pigs fed 20% protein had significantly ( $P < .05$ ) more lean but about equal weights of fat when compared with those animals fed 12% protein. They found a significant ( $P < .05$ ) line by ration interaction for weight of carcass lean. The rest of the parameters acted independently and no further interactions were observed. The high protein ration produced significantly heavier carcasses ( $P < .01$ ), more lean per carcass ( $P < .01$ ), and less fat ( $P < .01$ ).

Very few research projects contain a cost analysis in the reported findings. Rickaby (1967), however, included a cost analysis on two groups of hogs fed two different protein levels. Although the

animals on the high protein diet were more efficient, gained faster, and graded slightly higher, the pigs on the lower protein level returned a greater net profit per animal. From this he concluded that it may be economically sound to sacrifice quality for greater net profit.

### Genetic Effects on Live Animal Performance and Carcass Traits

Since a sire usually produces many more offspring in his lifetime than does a dam, it is feasible to determine the effects of sire contribution to the genetic capacity of this offspring. With this knowledge selection pressure can be applied and expected progress can be calculated. It is also desirable to understand genotype by ration interactions that may occur among animals of different genetic backgrounds.

Dickerson (1947) recorded feed and gain data as well as carcass yield and measurements from weaning to 225 pounds. He concluded that differences for rate of gain to 225 pounds was largely heritable for fat deposition. Bone and lean growth differences showed a lesser dependency upon the sire's transmitted influence. Variance due to the sire's influence was relatively larger, and the coefficient of variation was several times larger, for yield of fat cuts, ratio of fat to lean cuts, and thickness of backfat than for yield of lean cuts and for length of body and leg. Also sire and line deviations in rate of gain to 225



pounds were strongly correlated ( $r = .60$ ) positively with fatness and negatively with yield of lean cuts and leg length. He concluded that rapid fat deposition and low feed requirements tended to be caused by the same genes, as evidenced by strong correlations of the sire's influence on feed requirement with his effect on the parameters indicating fatness ( $r = -.6$  to  $-.7$ ) and on yield of lean cuts ( $r = .60$ ). These live animal performance data were confirmed by Kline et al. (1967) who found the greatest sire effects on average daily gains, which varied between sire groups from 1.49 to 1.73 pounds per day.

Blunn et al. (1953) divided the growth period of market pigs into three parts so that the heritability of gain in these growth periods could be determined. The growth periods were: birth to 56 days, 56 to 112 days, and 112 to 154 days. Heritability of gain was .22, .51, and .25 respectively. These data were interpreted as indicating that gain in the period of 56 days to 112 days reflected more accurately the pig's own genes than does gain in either the preceding or the succeeding period.

King (1957) calculated heritability estimates from differences between inbred lines. The estimate for more important measurements were: carcass weight 30.2%; width of body 47.3%; depth of body 0.2%; length of body 53.7%; average backfat thickness 46.0%; average belly thickness 51.5%; and depth of loin eye muscle 29.3%. These heritability estimates are in close agreement with those of McCarty

(1959) who studied the variation among progeny from different sire groups. He used 18 sires to produce 122 progeny from three breeds and measured the heritability estimates across breeds. He found carcass length, backfat thickness, and loin eye area to have heritability estimates of 59, 49, and 48% respectively.

Enfield et al. (1961) used data from 531 carcasses to estimate heritability of carcass length, carcass backfat thickness and loin eye area and to determine the phenotypic and genetic correlation between these traits. Heritability estimates were calculated from intraclass correlations from components of variance and indicated that all three traits are moderately heritable in the range of 0.4 to 0.6. They also determined that the source of variations is significantly higher ( $P < .01$ ) for sires in carcass length and loin lean area than it is for dams or littermates. Contributions to variations in backfat thickness was higher for dams ( $P < .01$ ) than for sires or littermates. They also noted that heritability estimates for carcass length and loin eye area were higher for sires than for dams. However, as is expected, the dam showed higher heritability estimates for backfat thickness than did the sire. Phenotypic correlations, when calculated, were small in absolute magnitude with the largest correlations being a  $-.36$  between backfat thickness and carcass length and  $-.27$  between backfat thickness and lean areas. The genetic correlation between these traits was all negative and also very small in absolute magnitude.

The above estimates of source of variations are not totally in agreement with Uhlveroy (1970) who found the proportion of total variance accounted for by sire and dam respectively was 26.2 and 4.9 for backfat thickness, 32.9 and 6.3 for meat percentage, and 21.1 and 14.4 for fat percentage. In each case the sire provided the greatest proportion of variances.

The results of Engield et al. (1961) were confirmed by Jensen et al. (1967) who also worked with phenotypic and genetic associations among carcass traits. In addition this group of researchers found that backfat thickness, area of loin eye, percent lean cuts, either extract, total moisture, taste panel scores, and flavor were highly heritable ( $h^2 > 0.40$ ). Intermediate heritabilities ( $0.20 \leq h^2 \leq 0.40$ ) were found for firmness, color, meat film area, shear value and softness scores. Low heritability scores ( $h^2 < 0.20$ ) were found for pH, marbling and juiciness.

Sidor et al. (1970) found wider ranges and lower heritability estimates on most carcass traits when compared to estimates found by Jensen et al. (1967) and Enfield et al. (1961). Sidor et al. (1970) found heritability estimates of average daily gain from 20 to 90 kg body weight to be 0.50 to 1.0; consumption of feed per kg gain -0.12 to -0.53; percentage of meat in the carcass 0.03 to 1.0; and average backfat thickness 0.02 to 1.0.

McGloughlin (1968) investigated sire by sex interaction and found

significant sire effects ( $P < .05$ ) for weight gain, carcass grade, carcass length, and shoulder fat thickness. The sire by sex interaction was not significant for any of the four traits. Sex effects were significant ( $P < .05$ ) for grade and shoulder fat only.

### Lean Predictors and Carcass Measurements

Lean predictors and carcass measurements have long been studied in hopes of finding an accurate method of evaluating a carcass as well as determining the amount of lean contained in the carcass without destroying the saleable product. Attempts have also been made to predict the amount of lean in live animals. One of the most accurate and widely used lean predictors was developed by Hazel and Kline (1952) who devised a probing technique to measure the backfat covering a live pig. They measured fat thickness at four locations and averaged the readings. They found a correlation of .81 ( $P < .01$ ) between live animal measurements and carcass measurements. Live backfat measurements were slightly more accurate as indicators of leanness and percentage primal cuts than were carcass measurements of backfat thickness. These results were confirmed by DePape et al. (1956) who used averages of six backfat probes at a live weight of 210 pounds. The live probes gave higher correlations with percent primal cuts ( $r = -.67$ ), carcass index ( $r = -.55$ ), and ham specific gravity ( $r = -.36$ ) than did backfat thickness measured on the carcass which

was -.58, -.43, and -.30 respectively. They also noted that correlations between thickness of backfat on the carcass and live hog measurements taken at various ages were all positive and showed a definite upward trend with increasing age.

Hetzer et al. (1956) measured backfat thickness at three locations on the live pig to determine their accuracy as criteria of carcass value. The measurements were made at 150, 175, 200, and 225 pounds at the shoulder, middle of back, and middle of loin. The results of this study showed thickness of backfat in barrows to be intermediate between that in boars and gilts at 150 pounds, but barrows laid on fat significantly faster ( $P < .01$ ) until at 250 pounds they exceeded boars in backfat thickness. The correlation between measurements at 225 pounds and percent preferred cuts was -.28 which is slightly lower than the correlation reported by DePape et al. (1956). At both 175 and 225 pounds, the probe taken at the middle of the back proved more accurate as a measure of yield of preferred cuts than either of the others.

King et al. (1962) reported that live backfat measurements were generally more accurate than any other single measurement for predicting carcass traits in barrows. Their work consisted of measuring backfat at 75, 125, and 225 pounds and testing the results for accuracy as lean predictors. They also reported backfat thickness as being the most accurate single measurement for predicting yield of fat cuts in

gilts. At 225 pounds, backfat thickness also excelled any other single measurement in predicting the other carcass traits. At 75 and 125 pounds, however, depth of middle, width of middle, and width over ham gave better results for predicting the remaining carcass traits than did backfat thickness.

Bruner et al. (1958) noted that gilts produced leaner carcasses than the barrows. This assumption was based on lean cuts as a percent of carcass weight, backfat thickness, and weight of ham and loin. They found the loin eye area to be positively correlated with primal cut yield ( $r = .57$  for males and  $r = .52$  for females) and backfat measurements to be negatively correlated with primal cut yield ( $r = -.44$  for males and  $r = -.48$  for females) for both barrows and gilts. They also found positive correlations for pounds of ham with loin eye area ( $r = .60$  for males and  $r = .54$  for females) as well as pounds of loin with loin eye measurements ( $r = .61$  for males and  $r = .54$  for females). Backfat and loin eye were more closely correlated ( $r = -.21$ ;  $r = .19$ ) than carcass length with lean cuts of carcass ( $r = .24$ ;  $r = .31$ ) and/or for primal cuts of live weight ( $r = .55$ ;  $r = .52$ ) for barrows and gilts respectively.

Buck (1962) found generally similar results and noted that in carcass characteristics differences between sexes were generally greater within a breed than the mean differences between breeds. He noted that within a sex the best predictors of leanness, from live

animals, were derived from measurements of shoulder and medium loin backfat.

## METHODS AND MATERIALS

An experiment was designed to determine whether significant sire by ration, sire by sex, or sex by ration interactions exist. It was also intended to determine whether mean differences in performance and carcass traits of progeny of different sires were significant as well as to determine the effect of ration differences on performance and carcass traits in market pigs fed from 60 to 225 pounds. If differences do exist, the data will reveal in which period of growth these differences are the greatest.

The animals used were a part of the Oregon State University Swine herd and it was at the Oregon State University Swine Center that this experiment was conducted. The experimental animals were slaughtered at the Oregon State University Meat Science Laboratory and carcass data were collected there.

### Experimental Design and Procedure

Three purebred Yorkshire boars were used in this study. The genetic background of sire one is such that he is one-half derived from the OSU herd and one-half from an A. I. sire. The heritage of sire two is three-fourths OSU herd and one-fourth A. I. Sire three is a product of the OSU herd only. Animals within the OSU herd have been mildly inbred for four to six generations. Due to the genetic background



of these sires, it would therefore be expected that the greatest differences would be found between offspring of sires one and three. The three boars were mated to a random sampling of Yorkshire, Berkshire, and crossbred sows all from the OSU herd. Litters were farrowed in farrowing crates and the newborn were allowed to nurse the dam until approximately 56 days of age. At this time they were weaned and continued on a creep ration until the litters weighed approximately 60 pounds. As the litters of a particular sire approached 60 pounds, they were randomly divided, within sex, into two groups of eight animals each. Each group, consisting of four males and four females, was placed in an 8' x 10' pen with slotted floors covering the entire area except for a cement feeding area on one side. Several replications were established for each sire. Table 1 shows the number of animals obtained from each sire.

Table 1. Animal numbers obtained from each sire by sex.

Sire	Males	Females	Total
No. 1	30	31	61
No. 2	33	27	60
No. 3	21	25	46

### Feeding Procedure and Rations

The experimental animals were group fed ad libitum from 200-pound-capacity self feeders that were permanently placed in the pens. Each group received one of the two experimental rations which varied in protein content. The composition of the experimental rations is shown in Table 2.

Table 2. Ingredient composition of experimental rations.

Ingredient	% of Ration 1	% of Ration 2
Wheat	75.0	66.0
Alfalfa meal	4.0	5.0
Soybean oil meal	10.0	16.0
Meat meal	5.0	8.0
Molasses	4.5	4.5
Salt	0.5	0.5
Zinc sulphate	12 oz /ton	12 oz /ton
Vitamin D	120,000 IU /ton	120,000 IU /ton
Vitamin A	1,200,000 IU /ton	1,200,000 IU /ton
Dicalcium phosphate	1.0	None
ASP-250	0.1	0.1

Ration one was formulated in accordance with U. S. N. R. C. recommendations and was designed to provide approximately 14% crude protein. Ration two was designed to provide 18% crude protein and adequate levels of all other nutrients as designated by U. S. N. R. C. Two protein supplements were used to insure a high quality

protein content in both rations and both supplements were increased proportionally when formulating the high protein ration. Kjeldahl analyses were performed at the beginning and end of the feeding period and confirmed the two rations to be 15.3 and 19.8% crude protein respectively. The rations were formulated to be very nearly equal in digestible energy and in both cases slightly exceeded the U. S. N. R. C. recommendations. An amino acid analysis for lysine and methionine was also performed to further insure the quality of the protein; in both rations the contents were found to be adequate. Table 3 shows the analysis of the experimental rations.

Table 3. Composition analysis of experimental rations.

Ration	% Protein	% Methionine	% Lysine	% Calcium	% Phosphorus	DE (Kcal / kg)
No. 1	15.3	.21	.67	.769	.602	3245
No. 2	19.8	.27	.83	.827	.588	3121

The rations were fed with the antibiotic ASP-250 included until the experimental animals reached approximately 150 pounds. Beginning at this time rations without antibiotics were fed until the animals reached market weight. Both rations were provided in pelleted form.

Due to space limitations, the experimental animals were fed as pen groups of four males and four females; pen averages of feed consumed were used for feed efficiency data. The ideal situation, of course, would have been to have individual feed efficiency data.

Scouring and death loss among the baby pigs prior to the testing period made it very difficult to obtain at a given time the necessary number of animals to put together a pen uniform in weight and evenly divided by sex. Because of this, sire three did not have as many offspring tested as did sires one and two. Due to the limited number of males on test from sire three it was necessary to also kill the females from this particular sire to gain adequate carcass data. Thus, data from females were adjusted to male means and used to supplement male carcass data for sire three. Otherwise, males only were slaughtered because it was necessary to use several of the females as replacements in the breeding herd. Consequently, it was not possible to test for sex effects or sex interactions in the carcass data.

### Data Collection

The test period began when the experimental animals weighed approximately 60 pounds and continued until the animals were slaughtered at approximately 225 pounds. This test period was divided into three even parts: 60 to 115 pounds; 115 to 170 pounds; and 170 to 225 pounds. Feed consumption and weight gains were recorded; from these, average daily gains and feed efficiency were calculated for each growth period. The animals were weighed weekly and live backfat probes were taken at 170 and 225 pounds on both sexes. The probing technique used was basically the same as that developed by

Hazel and Kline (1952), with a few modifications. Probes were taken over the shoulder, in the middle of the back, and even with the flank, 1-1/2 inches off the midline of the body. The probes were taken on both sides of the body midline for a total of six probes. These values were then averaged and used as a live measure of carcass leanness.

Carcass measurements were recorded on the males only, with slight exception, and consisted of cold carcass weight, loin weight, ham weight, three backfat measurements, loin eye area, carcass length, and a color and marbling index score (Rust et al., 1969).

### Statistical Analysis

A 3x2x2 factorial analysis was used to determine the mean squares for the sire by ration, sire by sex, and sex by ration interaction terms as well as the main effects of sire, sex and ration. F tests were used to determine if there were significant differences between the mean square terms.

Student's t test was used in conjunction with Duncan's Multiple Range Test to test differences between mean values for feed efficiency.

Linear regression and simple correlation values were also computed for selected traits.

## RESULTS

### General Results

Live animal data show that the high protein ration resulted in additional growth and improved feed efficiency only in the early stages of growth. Sire effects are also most evident in the early growth period while sex effects are consistent throughout the feeding period for average daily gain and depth of backfat. No interactions were observed for average daily gain or feed efficiency in this trial in any of the feeding periods studied. Live backfat thickness measured at 170 and 225 pounds showed no differences due to sire or ration. Females, however, showed significantly less ( $P < .01$ ) backfat than males at both 170 and 225 pounds. Again no significant interactions were observed.

The higher protein ration produced no significant effects in any carcass trait but did result in minor improvements in loin eye area, leanness, ham weight and loin weight. Sire effects were significant for loin eye area ( $P < .01$ ) and ham weight ( $P < .01$ ) but were not significant for the other carcass traits measured. Since only males were slaughtered, with a few exceptions, sex effect on the carcass data cannot be determined. No interactions were found between sire and ration for any of the carcass traits.

Upon slaughter four animals were found to exhibit pale, soft,

exudative (PSE) pork. Three of the animals were litter mates, and all four of the animals were progeny of sire three and had been on the high protein ration. The litter mates of these animals on the normal protein ration did not exhibit the PSE syndrome. These findings suggest that a genotype by ration interaction may possibly be involved in the etiology of this syndrome.

#### Live Animal Data

Animals fed the 19% protein ration (ration 2) showed significantly greater ( $P < .025$ ) average daily gains during the 60 to 115 pound growth period than did the animals fed the 15% protein ration (ration 1). No significant ration effects during the 115 to 170 pounds, or 170 to 225 pounds growth periods were observed. Table 4 shows the average daily gains for each period for animals fed each of the two rations.

Table 4. Effect of protein level on ADG during three growth periods.<sup>1</sup>

Ration	60-115 lbs.	s. d. <sup>2</sup>	115-170 lbs.	s. d.	170-225 lbs.	s. d.
No. 1	1.49 <sup>a</sup>	0.24	1.90 <sup>a</sup>	0.27	1.96 <sup>a</sup>	0.36
No. 2	1.60 <sup>b</sup>	0.24	1.89 <sup>a</sup>	0.25	1.96 <sup>a</sup>	0.29

<sup>1</sup> Different superscripts within a column indicates  $P < .025$ .

<sup>2</sup> Standard deviation.

Feed efficiency differences roughly paralleled average daily gain differences and animals fed the higher protein ration required slightly less feed per pound of gain during each of the feeding periods as well as the total period. These differences were not statistically significant although the first-period differences approached significance at the .05 level of probability (Table 5). Differences due to ration in live backfat probes at 170 and 225 pounds were not significantly different for animals fed the two rations (Table 6).

Table 5. Effect of protein level on feed efficiency.<sup>1</sup>

Ration	60-115 lbs.	s. d. <sup>2</sup>	115-170 lbs.	s. d.	170-225 lbs.	s. d.	Total
No. 1	3.28	1.44	3.52	1.46	4.00	2.25	3.63
No. 2	3.01	0.86	3.45	0.82	3.76	0.94	3.41

<sup>1</sup>No significant differences existed.

<sup>2</sup>Standard deviation.

Table 6. Effect of protein level on live backfat depth.<sup>1</sup>

Ration	170 lbs	s. d. <sup>2</sup>	225 lbs	s. d.
No. 1	0.72	0.19	1.02	0.21
No. 2	0.67	0.14	1.01	0.21

<sup>1</sup>No significant differences existed.

<sup>2</sup>Standard deviation.



The data indicate that higher protein levels are beneficial in increasing feed efficiency, average daily gain, and possible leanness during the early growth period. The advantages of the higher protein ration, however, are nearly lost by the time the animals reach the final finishing period and no additional benefits are derived by keeping the animals on the higher protein diet. The effects of the high and normal protein rations are illustrated in Figures 1, 2, and 3.

Sire effect on average daily gain was significant ( $P < .01$ ) for the 60 to 115 pound growth period but was not significant for the later two growth periods. Average daily gains for the three sire groups are given in Table 7.

Feed efficiency for the sire groups roughly paralleled average daily gains (Table 8). As was expected, the sire group that demonstrated the highest average daily gain also demonstrated the best feed efficiency.

Backfat probes taken at 170 and 225 pounds live weight showed no significant sire differences (Table 9).

Sire effect for average daily gain was greatest during the first feeding period while feed efficiency showed the greatest sire effect during the second feeding period. Sire effect on backfat depth showed no significant differences at either 170 or 225 pounds. Figures 4, 5, and 6 show the effects of sires on live backfat probes.

The effect of sex caused greater mean differences in the

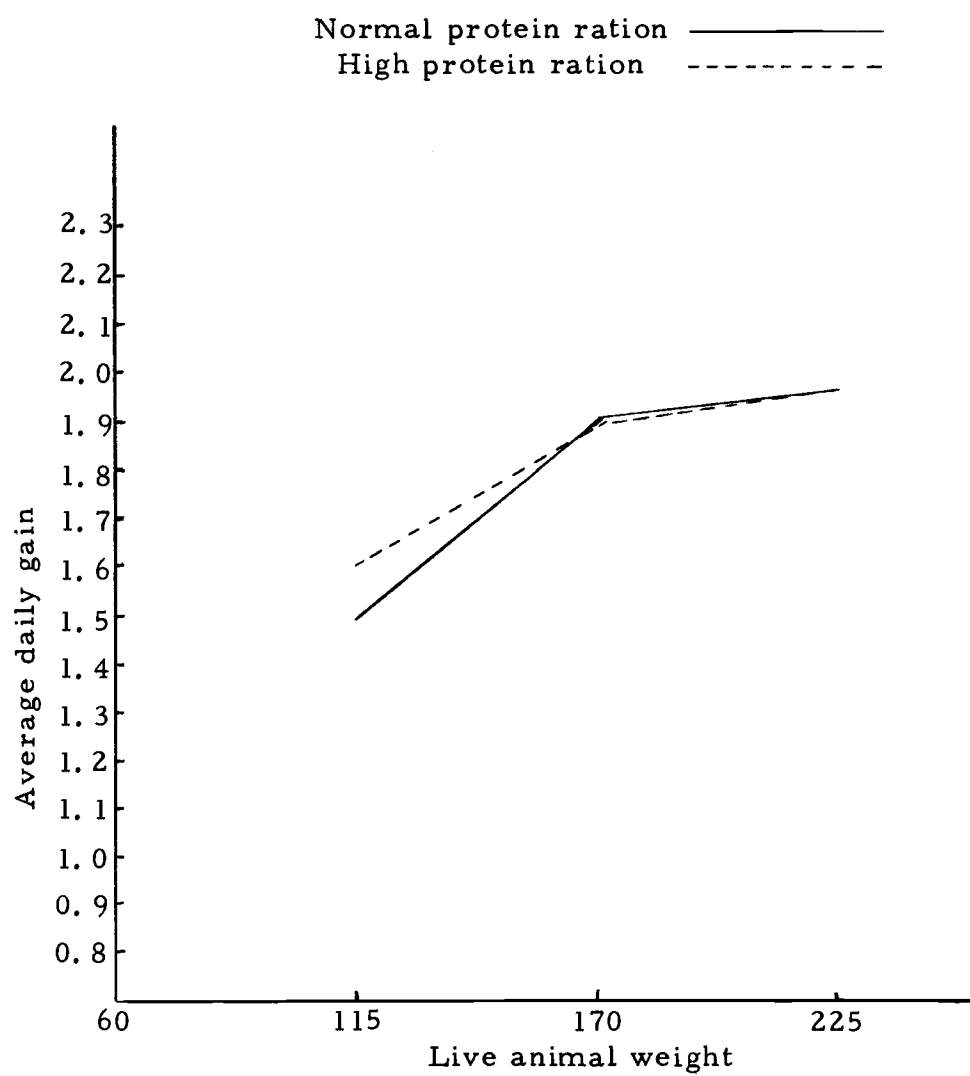


Figure 1. Average daily gain by ration.

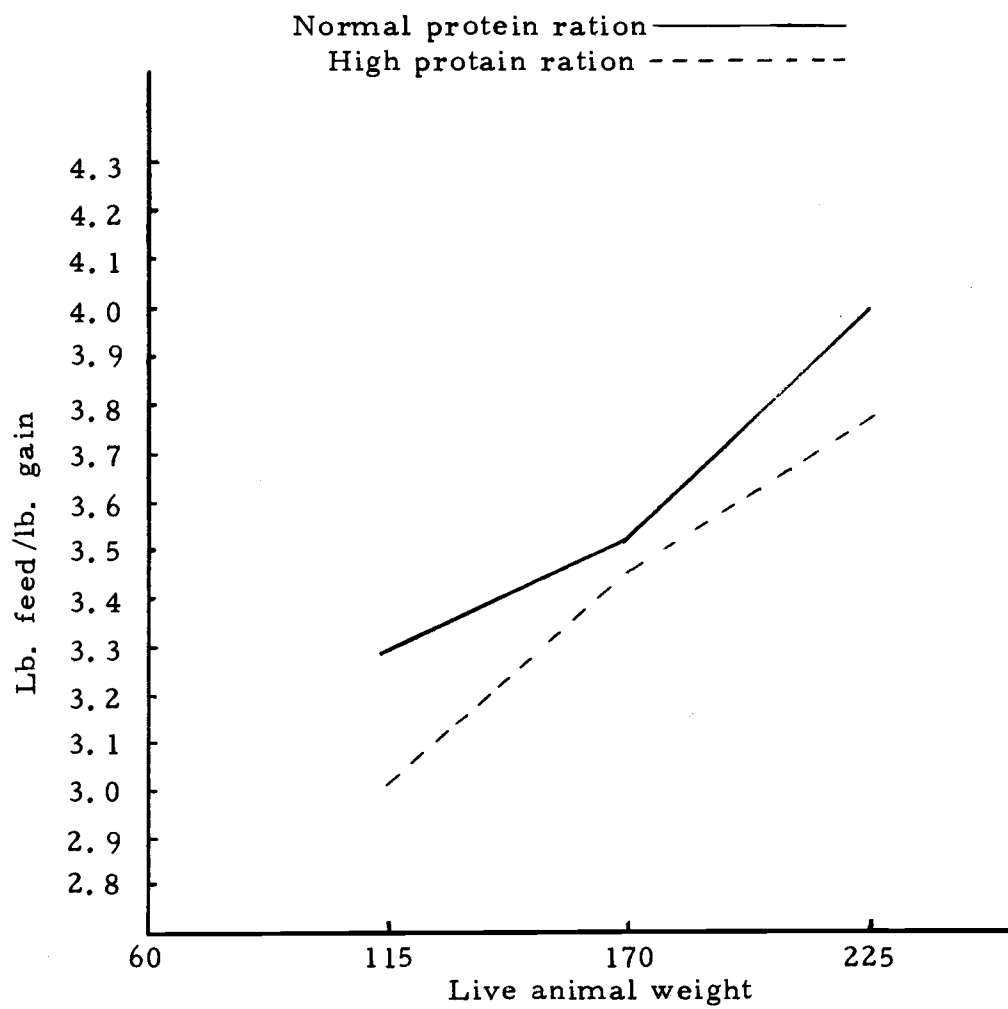


Figure 2. Feed efficiency by ration.

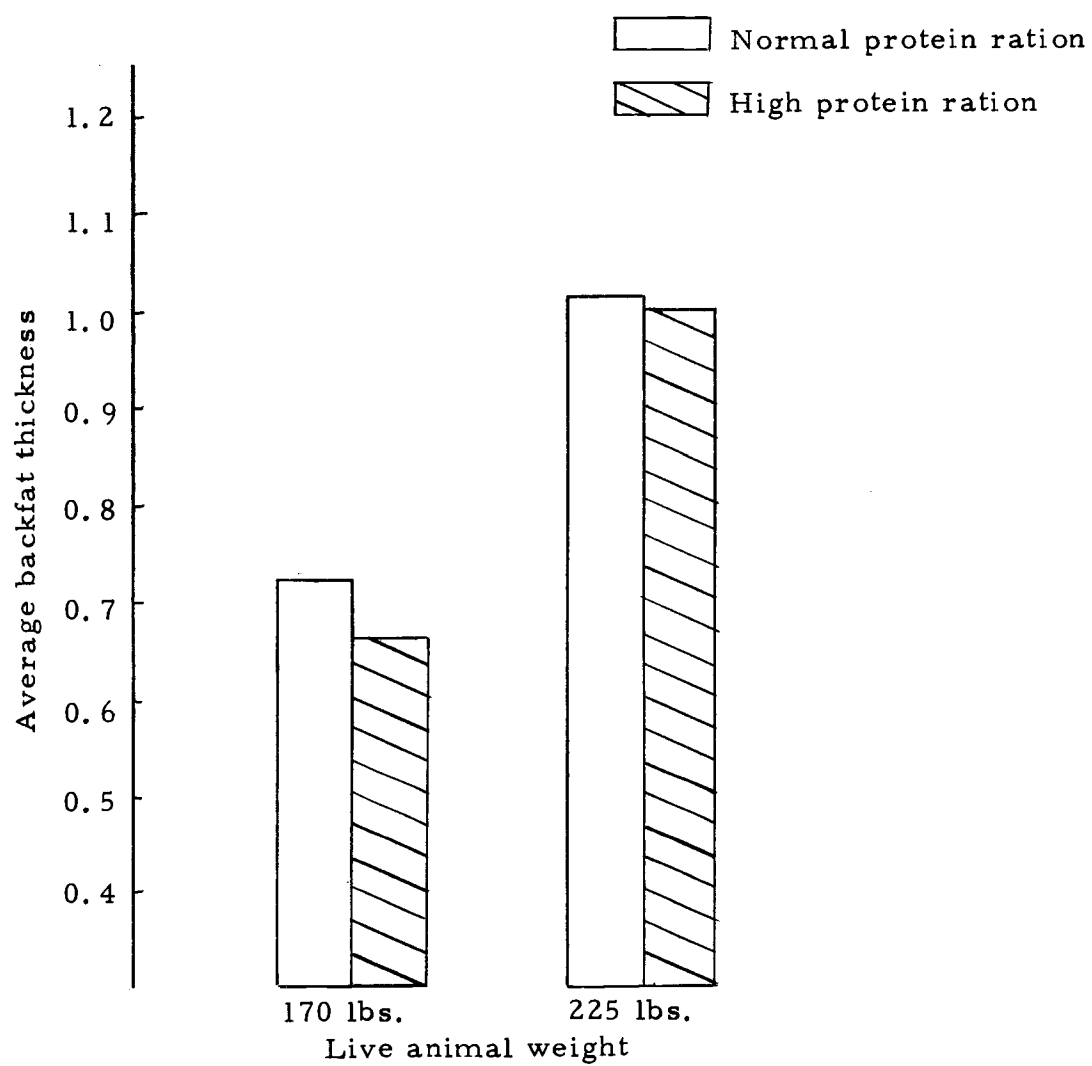


Figure 3. Average backfat thickness by ration.

Table 7. Effect of sire on ADG for three growth periods.<sup>1</sup>

Sire	60-115	s. d. <sup>2</sup>	115-170	s. d.	170-225	s. d.
	lbs.		lbs.		lbs.	
No. 1	1.53 <sup>a</sup>	0.26	1.84 <sup>a</sup>	0.23	1.94 <sup>a</sup>	0.28
No. 2	1.66 <sup>a</sup>	0.22	1.97 <sup>a</sup>	0.27	1.97 <sup>a</sup>	0.32
No. 3	1.42 <sup>b</sup>	0.23	1.87 <sup>a</sup>	0.29	1.96 <sup>a</sup>	0.38

<sup>1</sup> Different adjacent superscripts within a column indicate  $P < .01$ .<sup>2</sup> Standard deviation.Table 8. Sire effect on feed efficiency for three growth periods.<sup>1</sup>

Sire	60-115	s. d. <sup>2</sup>	115-170	s. d.	170-225	s. d.
	lbs.		lbs.		lbs.	
No. 1	3.21	1.20	3.73	1.02	3.98	1.64
No. 2	3.00	1.02	3.26	0.76	3.86	1.19
No. 3	3.24	0.64	3.46	0.63	3.98	1.63

<sup>1</sup> No significant differences existed.<sup>2</sup> Standard deviation.Table 9. Sire effect on live backfat depth (inches) at two weights.<sup>1</sup>

Sire	170	s. d. <sup>2</sup>	225	s. d.
	lbs		lbs	
No. 1	0.68	0.14	0.99	0.18
No. 2	0.71	0.18	1.04	0.24
No. 3	0.69	0.16	1.03	0.21

<sup>1</sup> No significant differences existed.<sup>2</sup> Standard deviation.

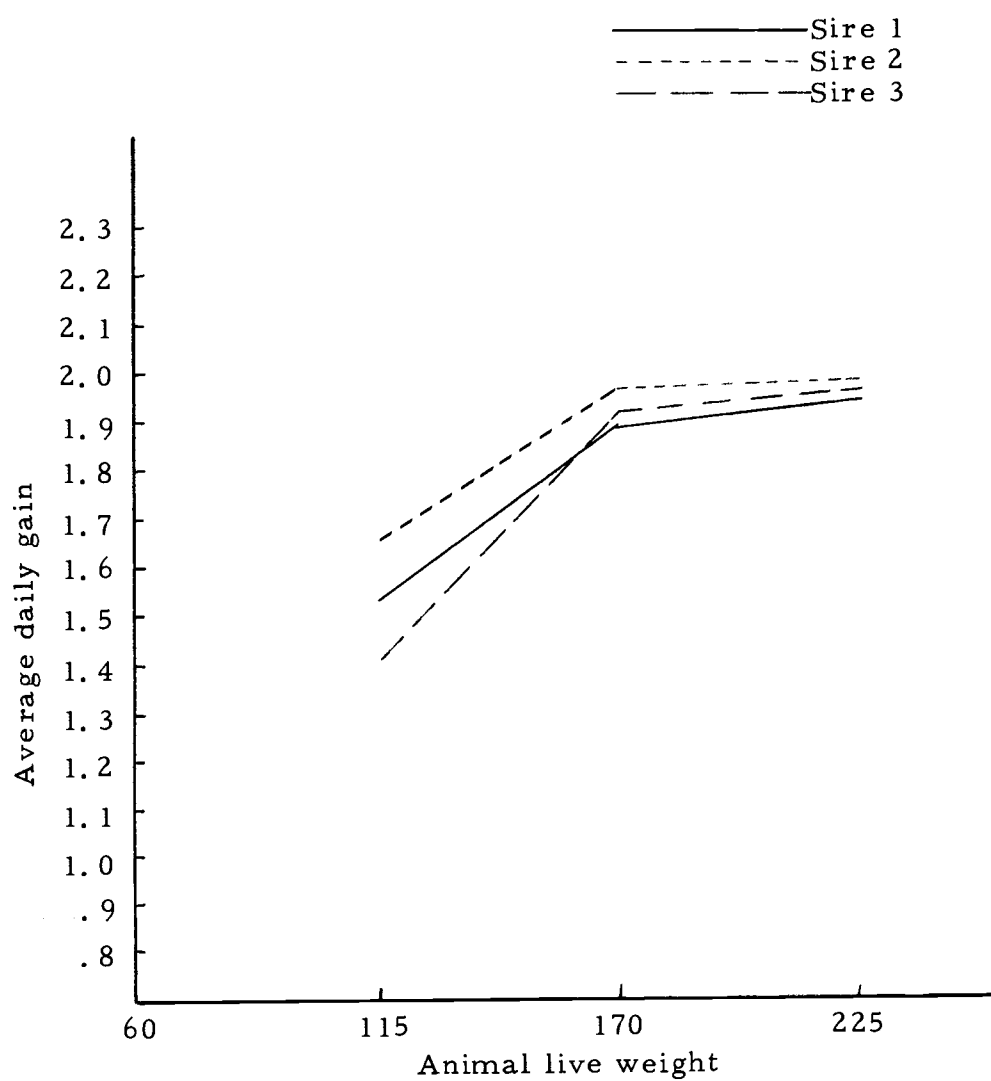


Figure 4. Average daily gain by sire.

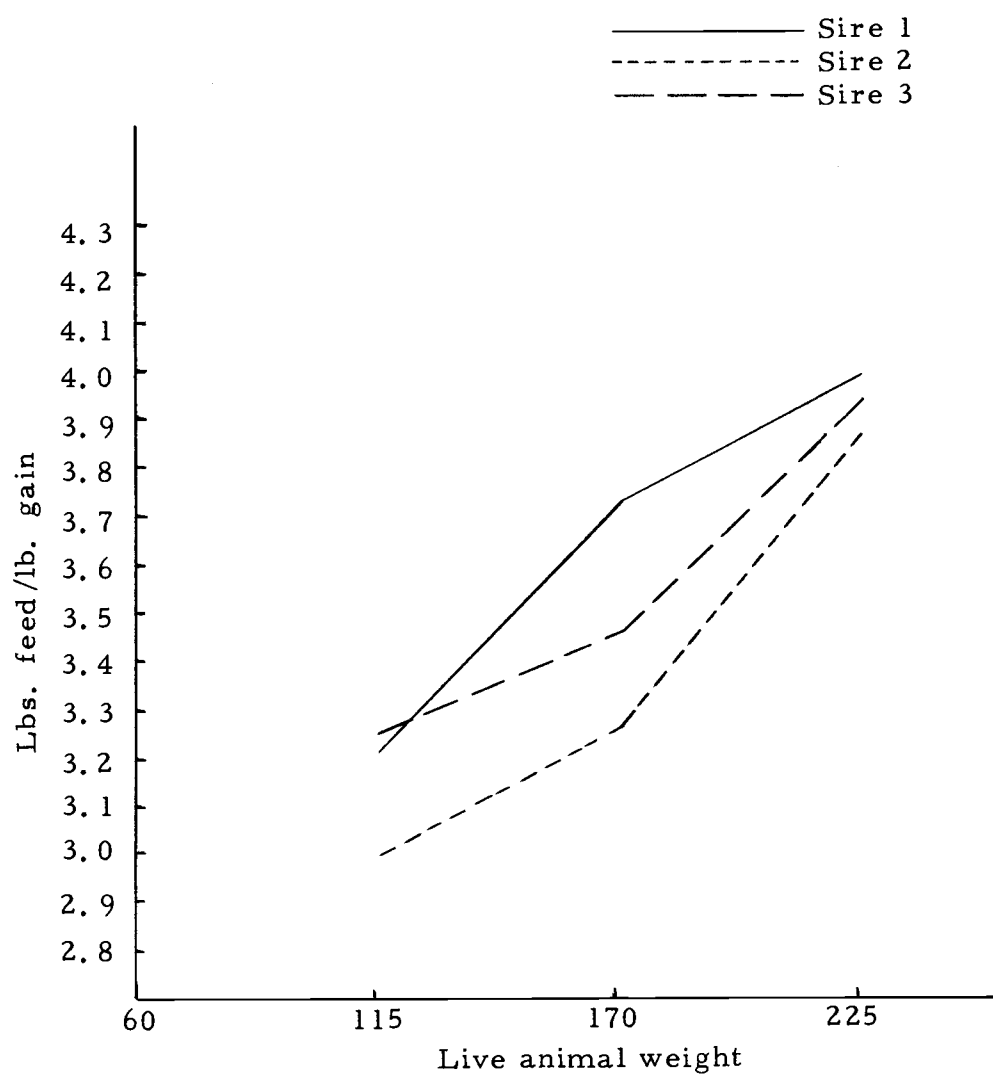


Figure 5. Feed efficiency by sire.

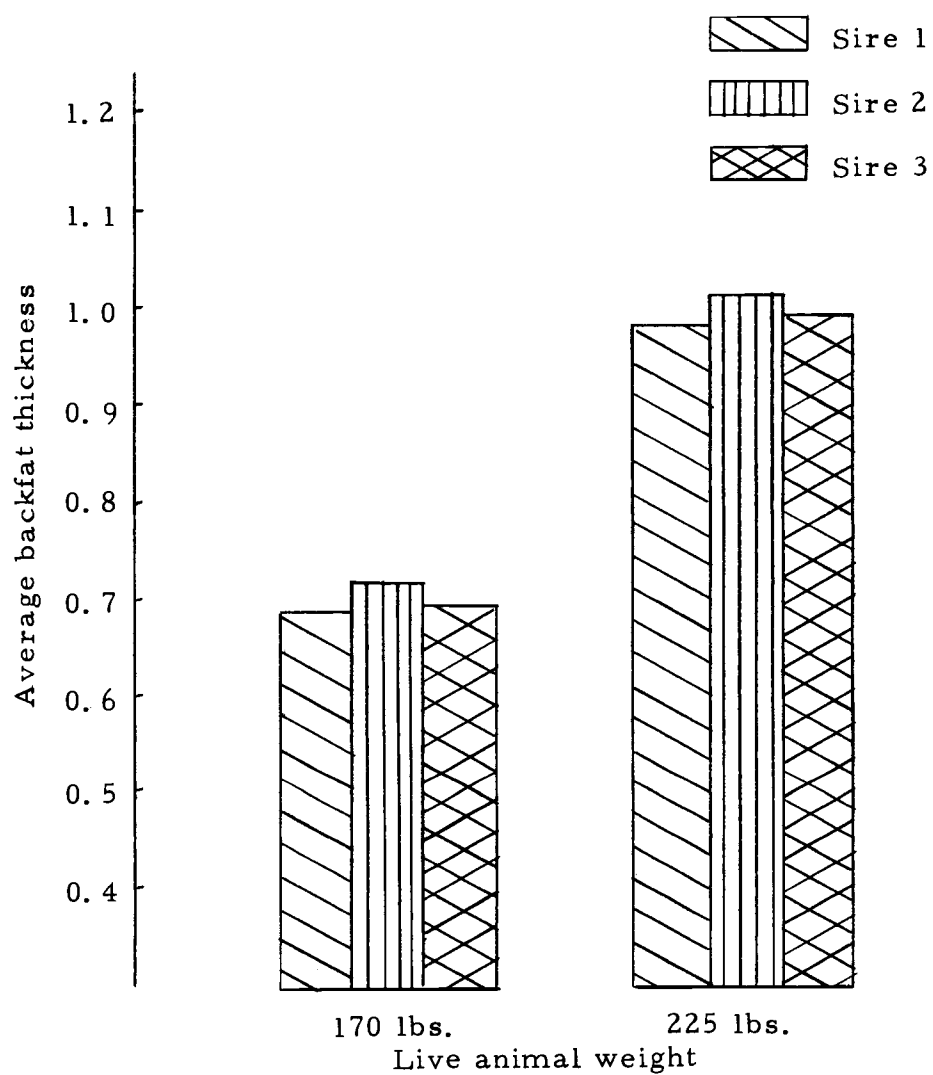


Figure 6. Average backfat thickness by sire.



parameters measured than did either sires or rations. When compared to the females, the males showed a significantly greater ( $P < .01$ ) average daily gain during all three periods of growth (Table 10).

The depth of backfat, as determined by live probes, was also significantly affected by sex. Females were significantly leaner ( $P < .01$ ) than males at both 170 and 225 pounds (Table 11). This follows the established pattern of greater fat deposition by males as shown by Hetzer et al. (1965) and Bruner et al. (1958).

The effect of sex on average daily gain and live backfat thickness are illustrated in Figures 7 and 8.

The interactions between sex, sire, and ration in all possible combinations were also tested. No significant interaction was found to occur between sex by sire, sex by ration, sire by ration, or sex by sire by ration. However, a slight nonsignificant interaction did occur between sires and ration. This is illustrated in Figure 9 by the relative change in sire positions between rations for the last two growing periods. This slight interaction is evidenced by the fact that sire two has the highest average daily gain for the high protein ration and the lowest average daily gain for the normal protein ration in the final feeding period. Sire one demonstrates just the opposite effect by having the highest average daily gains for the normal protein ration and the lowest average daily gains for the high protein ration all during the final feeding period.

Table 10. Sex affect on ADG during three growth periods.<sup>1</sup>

Sex	60-115 lbs.	s. d. <sup>2</sup>	115-170 lbs.	s. d.	170-225 lbs.	s. d.
Males	1.61 <sup>a</sup>	0.29	1.99 <sup>a</sup>	0.27	2.05 <sup>a</sup>	0.27
Females	1.49 <sup>b</sup>	0.25	1.80 <sup>b</sup>	0.25	1.87 <sup>b</sup>	0.38

<sup>1</sup> Different superscripts within a column indicate  $P < .01$ .

<sup>2</sup> Standard deviations.

Table 11. Sex effect on live backfat depth (inches) at two weights.<sup>1</sup>

Sex	170 lbs	s. d. <sup>2</sup>	225 lbs	s. d.
Males	0.77 <sup>a</sup>	0.19	1.11 <sup>a</sup>	0.20
Females	0.63 <sup>b</sup>	0.14	0.93 <sup>b</sup>	0.22

<sup>1</sup> Different superscripts within a column indicates  $P < .01$

<sup>2</sup> Standard deviation.

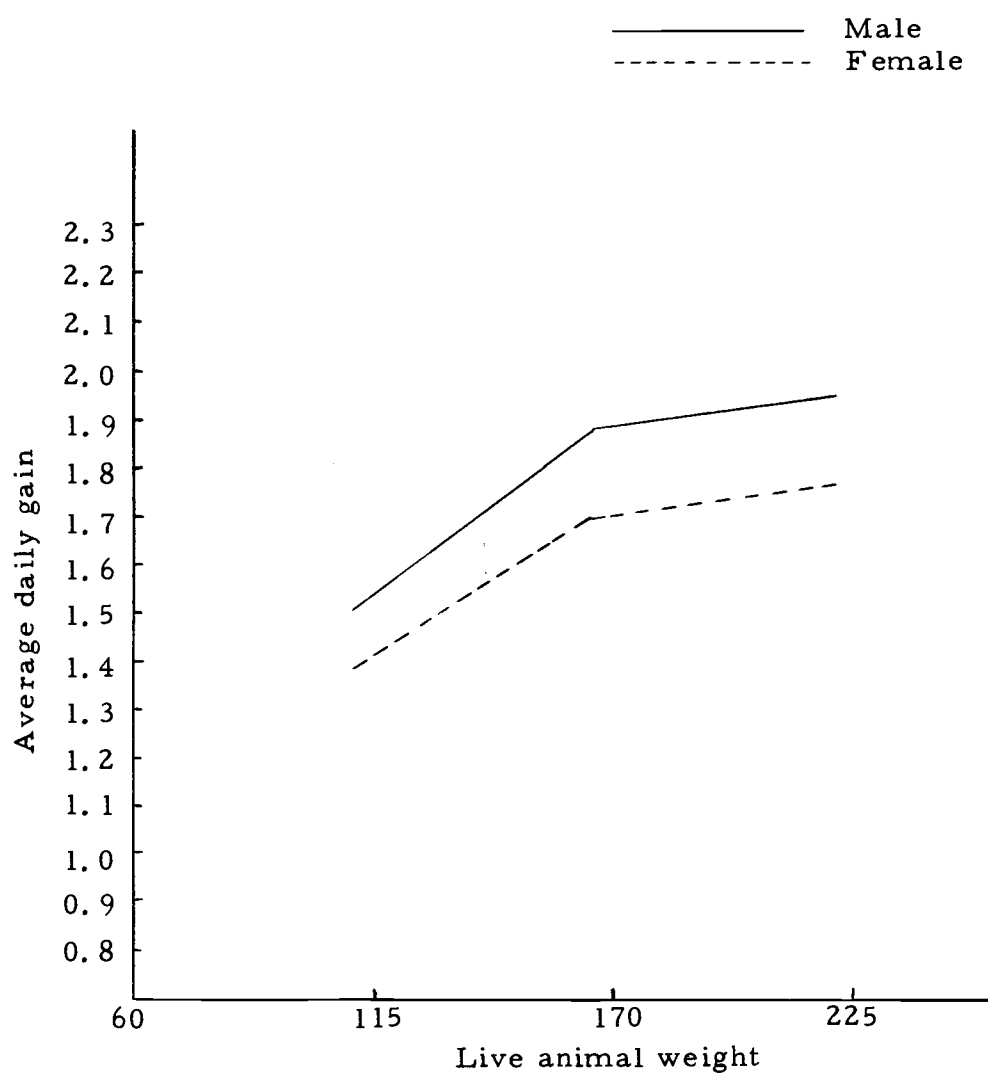


Figure 7. Average daily gain by sex.

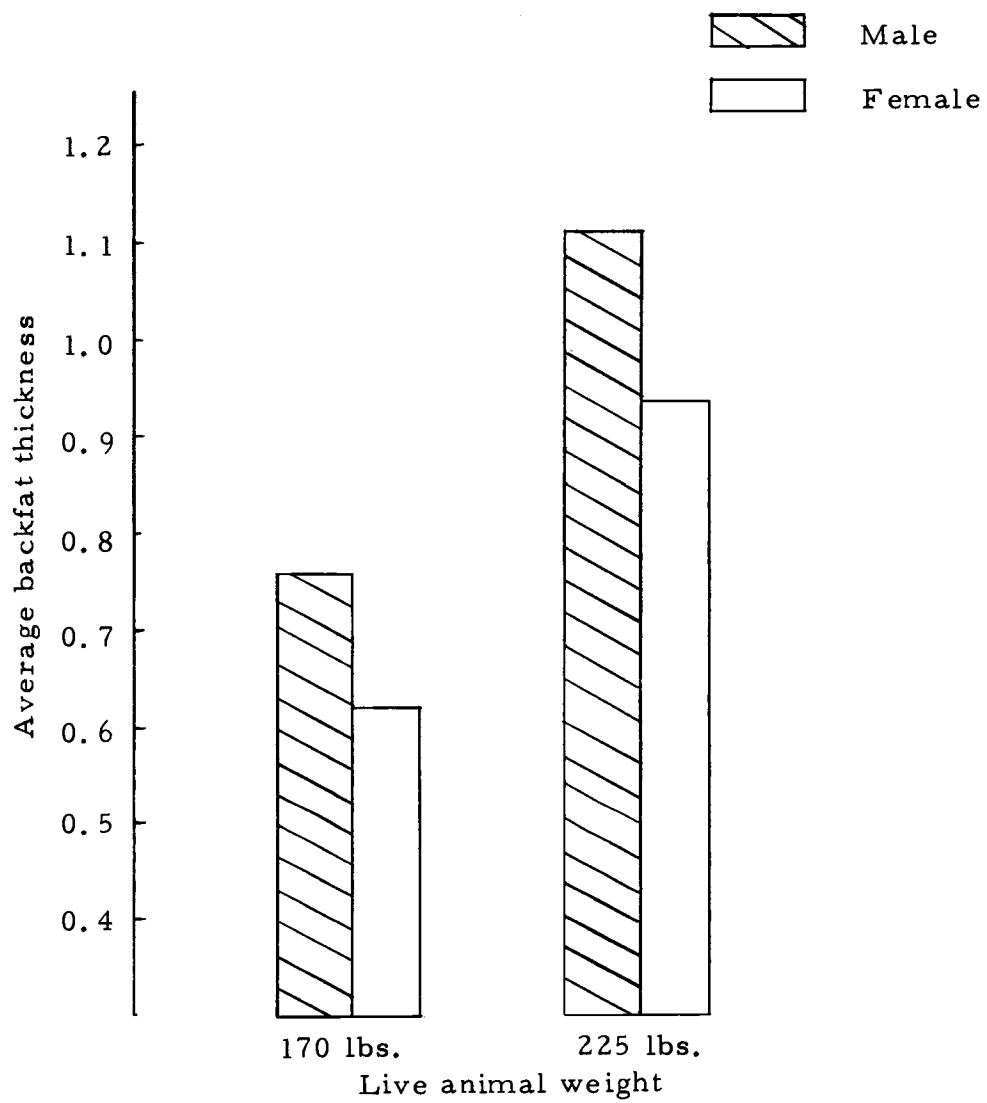


Figure 8. Average backfat thickness by sex.

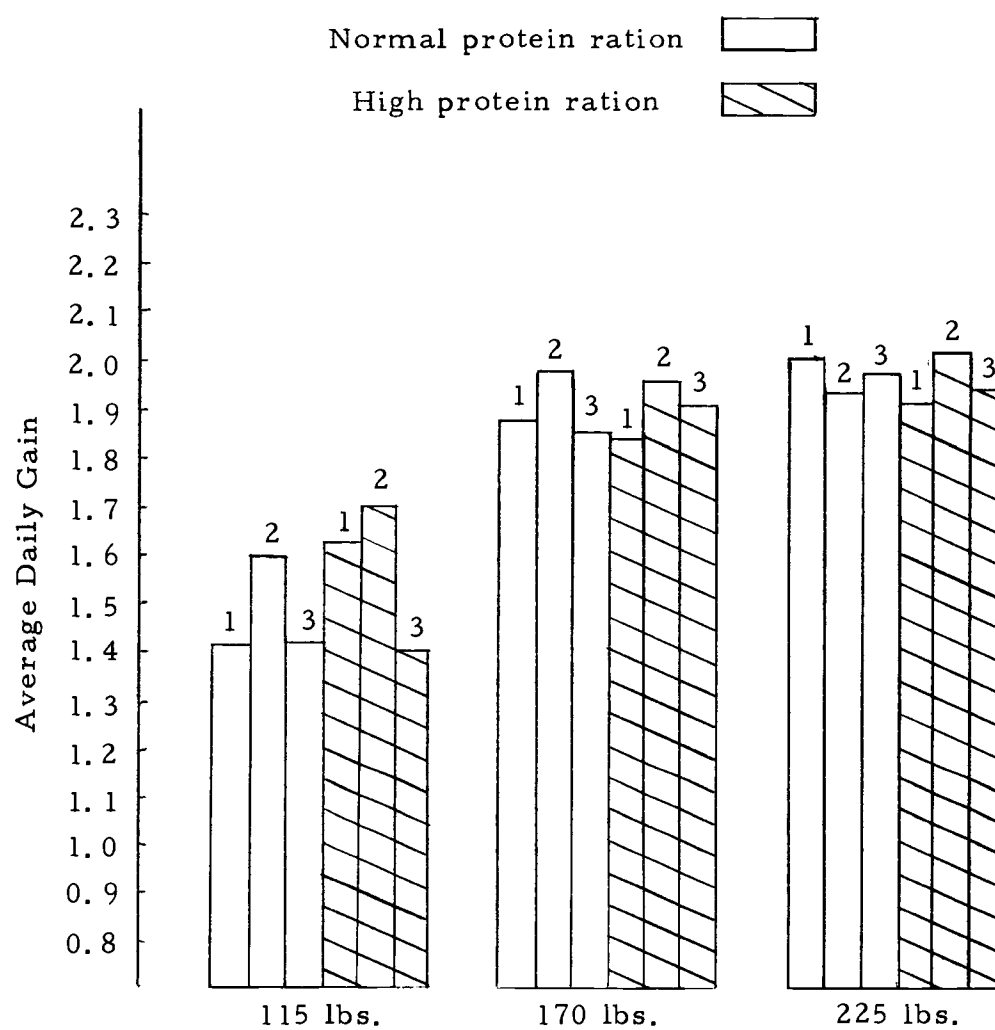


Figure 9. Sire by ration interaction.  
Sire 1 - 1; Sire 2 - 2; Sire 3 - 3

Correlation and regression values were calculated for selected performance traits in males and appear in Table 12.

### Carcass Data

Although protein level did not have any significant effects on the measured carcass traits there were many slight nonsignificant ration effects all in favor of the high protein ration. Ration effect on carcass backfat approached significance as the animals fed the high protein ration were slightly leaner. Table 13 summarizes the ration effects on carcass data.

When the carcass data were analyzed by sire groups, significant differences were found between sires for loin eye area and ham weight. The rest of the parameters showed no significant sire effect. Table 14 summarizes sire effects.

No significant interactions occurred between sires and rations for any of the measured carcass traits although an unexpected interaction between sire and ration for carcass length approached significance at the .05 level of probability. Even though this relationship was nearly significant, the biological relationship between ration and carcass length is such that it is very unlikely that this interaction could occur. Limited numbers may have by chance resulted in this nearly significant interaction.

Since only males were slaughtered, with slight exception, it was

Table 12. Live animal correlations and regressions.

Pd.	Trait		Pd.	Trait	d. f.	r	r <sup>2</sup>	b
2	ADG <sup>1</sup>	on	1	ADG	84	.195	.0380	.1816**
3	ADG	on	1	ADG	84	.145	.0210	.0608
3	ADG	on	2	ADG	84	.393**	.1544	.2653**
3	ADG	on	1+2	ADG	84	.352**	.1239	.1459**
2	ABF <sup>2</sup>	on	1	ADG	84	.194	.0376	.3619**
2	ABF	on	2	ADG	84	.237*	.0562	.3414**
2	ABF	on	1+2	ADG	84	.279*	.0778	.3668**
3	ABF	on	1	ADG	84	.334**	.1118	.3615**
3	ABF	on	2	ADG	84	.331**	.1096	.3443**
3	ABF	on	3	ADG	84	.301**	.0906	.1503
3	ABF	on	2+3	ADG	84	.305**	.0930	.2666**
3	ABF	on	1+2+3	ADG	84	.394**	.1552	.3039**
3	ABF	on	2	ABF	84	.441**	.1945	.4003**

<sup>1</sup> Average daily gain.

<sup>2</sup> Average backfat thickness.

\*P < .05

\*\*P < .01

Table 13. Effect of protein level on carcass data.<sup>1</sup>

Ration	C. L. <sup>2</sup>	C. B. F. <sup>3</sup>	L. E. A. <sup>4</sup>	L. Wt <sup>5</sup>	H. Wt <sup>6</sup>
No. 1	30.2	1.55	3.64	24.8	31.3
No. 2	30.4	1.49	3.78	25.1	31.8

<sup>1</sup>No significant differences existed.<sup>2</sup>Carcass length in inches.<sup>3</sup>Carcass backfat in inches.<sup>4</sup>Loin eye area in square inches.<sup>5</sup>Loin weight in pounds.<sup>6</sup>Ham weight in pounds.Table 14. Sire effects on carcass data.<sup>1</sup>

Sire	C. L. <sup>2</sup>	C. B. F. <sup>2</sup>	L. E. A. <sup>2</sup>	L. Wt <sup>2</sup>	H. Wt <sup>2</sup>
No. 1	30.5 <sup>a</sup>	1.52 <sup>a</sup>	3.53 <sup>a</sup>	24.7 <sup>a</sup>	31.9 <sup>a</sup>
No. 2	30.2 <sup>a</sup>	1.56 <sup>a</sup>	3.72 <sup>b</sup>	24.7 <sup>a</sup>	30.6 <sup>a</sup>
No. 3	30.4 <sup>a</sup>	1.49 <sup>a</sup>	3.94 <sup>c</sup>	25.2 <sup>a</sup>	32.2 <sup>b</sup>

<sup>1</sup>Different adjacent superscripts within a column indicate  $P < .01$ .<sup>2</sup>Abbreviations and units are same as Table 13.



not possible to test sex effects or sex interactions on the carcass data. It was necessary to slaughter a few female offspring from sire three to obtain adequate numbers. These carcass data, however, were adjusted to the male carcass data means and treated as males during the analysis. Therefore, any correlations relating carcass traits or live animal data to carcass data involves males or adjusted female data only.

Live backfat probing is an attempt to predict carcass leanness; it is useful, therefore, to know the relationships between backfat depth and various carcass traits. Table 15 shows the correlation between live backfat depth at 170 pounds, 225 pounds and selected carcass traits.

Table 15. Correlations of live backfat thickness and carcass traits at two weights.<sup>1</sup>

Trait	170 lbs		225 lbs	
	r	r <sup>2</sup>	r	r <sup>2</sup>
Loin eye area	-0.103	.0106	-0.150	.0225
Ham weight	-0.185	.0342	-0.308**	.0949
Loin weight	-0.186	.0346	-0.273**	.0745
Ham + loin weight	-0.199	.0396	-0.316**	.0999
Dressing percent	0.145	.0210	0.065	.0042
Carcass length	-0.132	.0174	-0.385**	.1281
Carcass backfat	0.424**	.1797	0.631**	.3981

<sup>1</sup>Correlations involve males only.

\*\*P < .01.

### Cost Analysis

Ration costs varied from \$76.06 per ton for the normal protein ration (ration 1) to \$83.36 per ton for the high protein ration (ration 2). Analysis of the results shows that even though the high protein ration improved growth rate, feed efficiency and carcass leanness, there was not enough of an increase in any of the traits to pay for the extra protein costs. The results of the cost analysis are summarized in Tables 16, 17, and 18.

The results show that possibly higher protein levels may be feasible to use during early feeding periods for the increased average daily gains but no further advantage is gained by keeping the animals on the high protein ration past 115 pounds. The added expense of the extra protein in the final feeding periods more than offsets any further improvement in average daily gains or feed efficiency.

Table 16. Ration 1 cost analysis for ADG during various growth periods.

	60-115 lbs.	115-170 lbs.	170-225 lbs.
ADG (lbs)	1.49	1.90	1.96
Feed used/lb of gain (lbs)	3.28	3.52	4.00
Feed cost/lb of gain (\$)	0.1246	0.1338	0.1520

Table 17. Ration 2 cost analysis for ADG during three growth periods.

	60-115 lbs.	115-170 lbs.	170-225 lbs.
ADG (lbs)	1.60	1.89	1.96
Feed used/lb of gain (lbs)	3.01	3.45	3.76
Feed cost/lb of gain (\$)	0.1264	0.1449	0.1579

Table 18. Cost per pound of selected carcass yields for two protein levels.

	Ration 1	Ration 2
Ham + loin wt (lbs)	56.11	56.89
Feed used/lb ham + loin (lbs) <sup>1</sup>	10.30	9.91
Feed cost/lb ham + loin (\$)	0.3914	0.4162
Cold carcass weight (lbs)	167.7	167.6
Feed used/lb carcass wt (lbs) <sup>1</sup>	3.45	3.37
Feed cost/lb carcass wt (\$)	0.1311	0.1415

<sup>1</sup>Based on feed consumption from 60 to 225 pounds.

## DISCUSSION

The ration effect on average daily gain and feed efficiency during the first period (60 to 115 pounds) confirms studies reported by Wilson et al. (1953), Jensen et al. (1955), and Lee et al. (1967). The data in this experiment indicate that high protein levels significantly improve ( $P < .025$ ) average daily gain during the early period of growth but no further significant differences are noted during the later periods of growth. Apparently the animals had a greater need for protein during the early growth period and a decline in protein need as they approached market weight. Feed efficiency on both rations roughly paralleled average daily gains as expected (England et al. , 1968) with the exception of the final finishing period. Feed requirements rose higher than was expected for the normal protein ration and may reflect some feed wastage during the third period.

There are conflicting reports in the literature regarding feed efficiency and ration protein levels. Jensen et al. (1955) reported no improvements in feed efficiency with high protein rations while Kropf et al. (1969) found improved feed efficiency to approach significance with a high protein ration. Lee et al. (1967) and Cookie et al. (1972) both found significant improvements in feed efficiency with higher protein rations. The trend indicates that higher ration protein levels result in increased feed efficiencies. That hypothesis is supported by the data from this research.

Sire effect showed a significant difference ( $P < .01$ ) in average daily gains during the first period but showed no significant differences during the second or third period. Feed efficiency roughly paralleled the average daily gains and, as expected, the groups of offspring with the highest average daily gains were also the most efficient. These data support research performed by McGloughlin (1968) who also found significant sire effects on weight gains as well as carcass length, carcass grade, and shoulder fat thickness.

Backfat thickness showed a rather surprising sire effect. Sire two, whose offspring were most efficient and showed the highest average daily gains, also showed the greatest backfat depth at both 170 and 225 pounds. Although this difference was not statistically significant, it is contradictory to several other reports which show that the most efficient and fastest gaining animals are the leanest animals (DePape et al., 1956; Hetzer et al., 1956; King et al., 1962; Seymour et al., 1964).

Ration effect on backfat thickness was nonsignificant although the differences that did occur generally agree with other reported work. Wilson et al. (1953), Ashton et al. (1955), Wahlstrom et al. (1971), and Cookie et al. (1971) all showed decreasing backfat depth with increasing dietary protein levels up to the 21% level. By increasing the protein content from 21 to 24%, Cookie et al. (1972) showed a decrease in growth rate and an increase in backfat thickness. Data in

the present experiment show that the animals on the high protein ration were slightly, but not significantly, leaner at both 170 and 225 pounds.

Sex effect was significant for average daily gain during all three periods and for backfat at both 170 and 225 pounds. Barrows gained faster ( $P < .01$ ) than gilts and this agrees with work reported by Geary et al. (1972), Wahlstrom et al. (1971), and several others who have all shown that barrows gain significantly faster than gilts. Present data indicate that from 60 to 170 pounds the average daily gain for the barrows increased faster than it did for the gilts. From 170 to 225 pounds the rate of increase in average daily gain for both sexes paralleled each other with the barrows being at the higher level. This is illustrated graphically in Figure 7. Backfat depth was significantly greater ( $P < .01$ ) for barrows at both 170 and 225 pounds with the average difference between the two sexes increasing between the two probings. Hetzer et al. (1956) and many other workers have shown the same relationship between sexes and backfat thickness.

No significant interactions occurred during the feeding trial. Berg et al. (1959) found a ration by strain interaction for live weight gain as well as a sex by ration interaction for the same trait. Berg used strains from different breeds and could thus be expected to find greater differences between strains due to more widely separated genetic backgrounds. The animals used in the present research came from a more restricted gene pool within a breed. All had a common

genetic background among the dams and some common within-breed background among the sires. This genetic structure would be expected to reduce variation and the chance of occurrence of significant interactions.

The correlations in Table 12 indicate that probes at the heavier weights (period 3) are more closely associated with average daily gain than are probes at the lighter weights. At 170 pounds the live backfat probe proved to be relatively accurate for prediction of the final backfat thickness which makes it a good predictor of carcass leanness. This hypothesis is supported by King et al. (1962). It could thus be used to objectively decide which males should be castrated before reaching market weight.

There were no significant ration effects on the carcass data. However, there were slight differences in the carcasses between rations and in each case the difference favored the high protein ration. Lee et al. (1967) and Holme et al. (1965) also noted that irrespective of growth patterns, there is a favorable carcass response to level of protein. McConnell et al. (1971) found no improvement in carcass leanness when high protein diets were fed to fat-type hogs, but also found that higher protein levels substantially improved carcass leanness in lean-type hogs. Carcass data in this experiment show only a slight mean difference due to ration. Presumably the lower protein ration was adequate as it was formulated according to N. R. C.

standards and apparently it met muscle growth requirements adequately in the later two growth periods during which muscle growth is a lower proportion of total weight gain than in the earlier growth phases. In view of the heritability estimate of carcass leanness (0.50 to 0.70) it is reasonable to expect that a ration adequate for muscle growth in the later two growth periods would permit a relatively adequate expansion of genotypic capacity for leanness even if the previous ration were slightly inadequate. It is possible that a wider range between protein levels, especially if it included rations with lower protein levels, would have resulted in greater carcass differences. Support for this hypothesis is given by Ashton et al. (1955) who showed carcass differences by feeding rations with protein contents ranging from 10 to 20% in 2% increments. He found significant differences in carcass data between the high and low protein levels but only slight nonsignificant differences between adjacent rations.

Sire effect showed greater differences in the carcass data than did the ration effect. This is not surprising as Hale et al. (1967) showed that differences in carcass characteristics due to breed were greater than differences due to increases in dietary protein. Offspring of sire three showed the largest loin eye area, heaviest ham weight and the least carcass backfat. This sire produced offspring with the best overall carcasses but his offspring were intermediate in average daily gain, feed efficiency and live backfat thickness.



No significant sire by ration interactions occurred for any of the reported carcass data. However, a ration by sire interaction for carcass length approached significance at the .05 level of probability. This near interaction can probably be explained by sample size. However, Norland et al. (1960) found that pigs fed a 16 or 20% protein ration produced longer carcasses ( $P < .01$ ) with a greater yield of primal cuts than pigs fed a 12% protein ration.

Correlations of live backfat thickness at 170 and 225 pounds with various carcass traits show that live probes can be used as a predictor of carcass merit. Probes at the heavier weight show significant correlations with the ham + loin weight ( $r = -.32$ ), carcass length ( $r = -.36$ ) and carcass backfat ( $r = .63$ ). Hetzer et al. (1956) also found probes at heavier weights to be a more accurate measure of carcass merit than probes at a lighter weight. This group of workers suggested that live hog measurements have greater accuracy for measuring carcass fatness than for measuring percentage preferred cuts or trimmed ham weights. From the correlations in Table 15 we can arrive at this same conclusion. Hazel et al. (1952) also found significant correlations between live backfat probes and carcass backfat depth. Their correlations were considerably higher than the ones found in this research.

The cost analysis shows the extra protein in the high protein ration did not produce enough favorable live animal or carcass results

to pay for the extra protein cost. It may be feasible to feed higher protein levels during the early stages of growth and then substitute a lower protein content ration for the later finishing periods. Even with the increased growth rate during the early period of growth it costs more per pound of gain to use the high protein ration. The advantage may be in the fact that with the increased gain the total feeding period is shortened and savings may be made on labor and interest. Rickaby (1967) found similar results and concluded that it may be economically sound to sacrifice carcass quality for a greater net profit by feeding a lower protein ration and producing slightly fatter, less efficient pigs.

## SUMMARY

Progeny from three sires were divided within litters by sex and placed on either a 15 or 19% protein ration. Pen feed consumption was recorded and weekly weighings were made from which average daily gain and feed efficiency were calculated. The test period began when the experimental animals weighed 60 pounds and continued until they were slaughtered at 225 pounds. This test period was divided into three growth periods; 60 to 115 pounds, 115 to 170 pounds; and 170 to 225 pounds. Carcass data were collected only on the males, with a few exceptions, and consisted of loin eye area, ham weight, loin weight, carcass length, carcass backfat, and a color and marbling index score.

Live animal data showed that a high protein ration gave additional growth ( $P < .025$ ) and feed efficiency only in the early stages of growth. Sire effects also were most evident in the early growth period ( $P < .01$ ) while sex effects showed males gained faster ( $P < .01$ ) and deposited more backfat ( $P < .01$ ) during all three growth periods when compared to the females. Backfat thickness measured at 170 and 225 pounds showed no differences due to sire or ration. No interactions were observed for average daily gain, feed efficiency, or backfat thickness regardless of the feeding period studied.

Carcass data showed the higher protein ration produced no

significant effects but did cause minor improvements in loin eye area, carcass backfat depth, ham weight and loin weight. Sire effects were significant for loin eye area ( $P < .01$ ) and ham weight ( $P < .01$ ) but were not significant for the other carcass traits measured. No interactions were found between sire and ration for any of the carcass traits studied. Cost analysis showed that the higher protein ration did not produce enough favorable live animal and carcass results to pay for the extra protein costs even during the early growth phase.

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