THE INTERACTION OF RESTRICTED FEED INTAKE AND SEX ON SWINE PERFORMANCE AND CARCASS QUALITY

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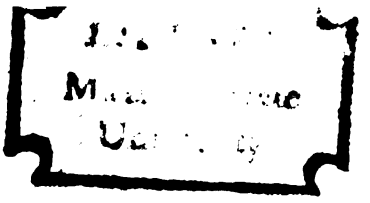

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ROBERT H. HINES

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ABSTRACT

THE INTERACTION OF RESTRICTED FEED INTAKE AND SEX ON SWINE PERFORMANCE AND CARCASS QUALITY

By Robert H. Hines

A total of four hundred and forty-nine pigs were used in seven experiments to study the effect of sex, level of feeding, and the interaction of sex and level of feeding upon the feedlot performance and carcass quality of finishing swine. In all trials except one, the sexes were fed separately. Six of the experiments compared barrows with gilts, while the other experiment compared barrows, gilts, boars, and spayed gilts. The methods used for limiting daily feed consumption were (1) feeding a constant level of feed daily per pig during the finishing period, (2) feeding a percentage of full feed, (3) feeding an appetite depressant, (4) ad libitum feeding every second day, and (5) ad libitum feeding every third day.

Restricting feed intake reduced daily gain on the average 0.15-0.20 pounds with each 10% restriction. This decreased growth rate resulted in an increased feeding time of 7 to 10 days to reach slaughter weight with each 10% restriction. The feed required per pound of gain generally favored the full-fed pigs. Restricting feed to a level of 70% or more resulted in an increased feed requirement per pound of gain. The optimum level of feed

restriction appears to be 75-80% of full feed. At this level superior carcasses are produced in terms of leanness and yield of preferred cuts, while the feed utilization ratio remains about the same as that of full-fed pigs.

Restricting feed intake improved carcass quality. Backfat measurements were reduced approximately 0.10 inches with each 10% restriction. Loin eye area significantly increased with restriction, whereas carcass length was only slightly increased. Percent of lean cuts always favored the restricted fed groups with improvements of 0.5% to 1% with each 10% restriction. Although a few carcasses in this study did appear pale, soft, and watery, the occurrence of this condition did not seem to be associated with levels of feeding.

The methods used for restricting daily feed consumption caused very similar responses in the variables studied, except the use of the appetite depressant (L-dichloramphetamine). The appetite depressant did not reduce daily feed intake; consequently, these pigs were similar in performance and carcass quality to the ad libitum-fed pigs.

Sex differences were apparent in daily feed intake under ad libitum feeding conditions. Full-fed boars consumed less feed per day than barrows, gilts, and spayed

gilts. Barrows ate on the average 3/4 of a pound more feed per day than gilts. Feed intake and growth rate were similar for full-fed gilts and spayed gilts. Barrows gained approximately 0.10 pounds faster per day than gilts which reduced their age at slaughter by 9 days. Feed per pound of gain was similar for barrows, gilts and spayed gilts, but boars were 10-15% more efficient. Boars gained faster than any of the other sexes. Boars and gilts yielded carcasses similar in percent of lean cuts. Spayed gilt carcasses were similar to those of barrows in backfat thickness, loin eye area, carcass length, and percent lean cuts. Gilts yielded carcasses with less backfat (0.11 in.), larger loin eye area (0.52 sq. in.) and greater length (0.2 in.) than barrows. In addition, gilts cut a higher percentage of ham and loin (1.7%) and lean cuts (1.8%) than the barrows. Dressing percentage usually favored the barrows which was consistent with their greater depth of backfat.

Some evidence of the interaction between sex and level of feeding was observed for the traits of rate of gain, backfat thickness, and percent lean fat. This observation was not consistent in each of the experiments. Therefore, it would appear that sex and limited feeding do not consistently interact to significantly impair or improve the carcass and performance parameters reported in the study.

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I. INTRODUCTION

In early life, swine utilize feed efficiently for growth; however, with increasing age efficiency decreases. The decline in efficiency is due to an increasing maintenance requirement and an increase in body fat deposition. The latter being high in energy, requires a large amount of feed energy per unit of gain. The consumer demand for lean pork products at minimum prices coupled with the econimic demand for efficiency of production requires the swine producer to manipulate the factors of his enterprise which maximize efficient growth and minimize body fat deposition. Great strides have been made in recent years through testing and selection to improve the genetic make-up of swine. This improvement has resulted in superior breeding animals with the capability of transmitting the characteristics of rapid and efficient growth and carcass excellence under present production practices.

An environmental factor known to influence the rate of growth and deposition of body fat is the level of feed consumption by growing-finishing swine. Restricted feeding during the latter portion of the growing-finishing period has been suggested as a means of improving the quality of carcass and increasing the efficiency of the conversion of feed to body weight gain.

The sex of the pig has also been reported as exerting an influence on carcass quality of swine as measured by leanness and development of muscle mass. Gilts usually yield carcasses of higher merit than barrows when slaughtered at similar weights.

Most of the research on restricted feeding has been conducted with mixed lots of barrows and gilts. In view of the known sex influence on carcass quality, this study was initiated in an attempt to determine the interaction of restricted feed intake on the performance and carcass quality of barrows and gilts fed separately. Later, the study was expanded to include boars and spayed gilts.

The objectives of this study were as follows:

1. To study the effect of various methods of limited feeding upon swine performance and carcass merit.
2. To study the influence of sex on swine performance and carcass merit.
3. To study the interaction of sex and limited feeding on swine performance and carcass merit.

II. REVIEW OF LITERATURE

A. Influence of limited feeding upon swine performance and carcass quality.

1. Feeding a percentage of a full-feed allowance.

The practical application of limited feeding to swine was first reported by Robison (1920). He restricted the concentrate allowance in dry lot and on pasture and found a lowered concentrate requirement per unit of gain as well as slower gains. Under similar experimental conditions Ferrin and McCarty (1928) compared pigs that were full-fed from a self-feeder to those receiving only one-half this amount for 90 days and then full-fed thereafter to market weight. Their results favor the continually full-fed pigs since gains were superior to the restricted-fed lots and feed conversion was slightly more efficient. Ellis & Zeller (1931), on the other hand, full-fed pigs and restricted other pigs to intakes equivalent to three-fourths and one-half of the intake of the full-fed pigs and observed a marked decrease in daily gain with substantial improvement in efficiency of feed utilization in the limited fed lots. They also reported a reduction in the percentage of fat in the carcass, but the carcass fat was softer and had a higher iodine number, particularly that from pigs restricted to 50 percent of full feed. St Pierre *et al*.

(1934) found that pigs receiving 75 percent of the amount eaten by those which were given all they could readily clean up twice daily made more economical gains, but that restriction to 50 percent was unsatisfactory. Pigs on both the limited levels tended to have softer carcasses with lower dressing percentages. They did observe a decrease in body fat with the pigs on restricted feed intake. Crampton (1935) obtained no advantage from restriction of 50 percent of full feed in either economy of feed conversion or in grading results, and Freeman (1935), limiting the ration of 60 pound pigs to the equivalent of 2 and 3 percent of live weight, obtained poorer feed conversion values as compared with those for self-fed pigs.

In addition to an improved economy of feed conversion, Edwards (1936) observed that pigs limited to 3/4 of full feed produced higher grading carcasses but required a slightly longer feeding period. Mansfield and Trehane (1936) made similar conclusions with pigs restricted to 3/4 full feeding from 65 to 100 pounds and to 2/3 of full feed from 100 to 200 pounds, as compared with full-fed controls. Economy of feed conversion and grading results were both improved by the lower level of feeding. Similarily, Crowther (1937) describes two experiments in which restriction to 90, 85, and 80 percent of the quantity allowed under full-feeding was initiated at 65, 85, and 100 pounds live weight. While no differences between the

effects of the various degrees of restriction or the times at which they were imposed were detected, restriction in general, resulted in better feed utilization and slightly thinner backfat.

Crampton (1937) compared pigs self-fed to appetite with pigs fed the amount they would clean up in fifteen minutes three times a day. He observed a reduction in daily gain and an improved feed efficiency in the hand-fed pigs. On the other hand, Burroughs and Carroll (1939), introducing a new technique for limited feeding, paired 24 pigs according to litter size, sex, and body weight. One member of each pair was full-fed by hand two times daily while the other pig received 3/4 of this amount. Using this technique they were unable to demonstrate an improvement in efficiency of feed utilization due to restriction of feed intake. They did observe a depression in daily gains and a decrease in fatness of the carcasses due to the restriction. The limited-fed pigs required 43 days longer to reach market weight than did the full-fed pigs.

Fishwick (1936) reported that the factor which exerts the greates influence on the quality of the carcass is the "type" of the pig. McMeekan and Hammond (1939) used genetically uniform pigs from a brother-sister mating and divided them into four groups which were made to conform to pre-determined growth curves. During the first sixteen weeks only a high (H) and low (L) plane of nutrition were

employed. After this, one-half of the high plane pigs continued as such (HH) and the other half were placed on a low plane (HL). Likewise, one-half the pigs on the low plane continued as such (LL) and the remainder were placed on the high plane (LH). One pig from each group was slaughtered at eight and sixteen weeks for comparison with the final results.

The results of this experiment (McMeeken and Hammond, 1939) have led to the following conclusion: bacon and lard pigs differ mainly in the intensification of the early skeletal and muscular phase of growth in the former and the intensification of the subcutaneous fatty phase of growth in the latter. This conclusion is based on the fact that muscle and fat have a different order of development. Muscle develops earlier, thus making a greater proportion of its growth early in life. During the growing and finishing period, fatty tissue is deposited in small amounts within the muscles (intramuscular depots) and around the kidneys (perinephric depots); however, larger amounts are laid down in the two main depots - the subcutaneous depots directly under the skin and the intermuscular depots between the muscles. Rapid early growth and slow growth later intensify the early-developing tissue (skeletal framework and muscle), and inhibits the later-developing tissue (subcutaneous fat), respectively. Slow early

growth and rapid later growth have exactly the opposite effect, thus producing a pig with an excess of fat.

Shorrock (1940) reported results obtained from twenty-two restricted feeding experiments (400 hogs) in various centers throughout Great Britain. He devised a high, medium, and low level of nutrition by restricting the daily allowance per unit of live weight. Results indicate more economical feed conversion and production of a slightly thinner and softer backfat. In addition, restricted-fed pigs required a longer feeding period, the increase being approximately 8-10 days to grow from 100 to 200 lbs. in live weight. He further noted a slight increase in length of body as well as length of leg; however, body depth and dressing percent were not affected. Hilditch (1939) verified that the plane of nutrition affected thickness of backfat by retarding fat deposition, but also found a softer fat with a higher proportion of linoleic and oleic acids.

Winters et al. (1949) subjected pigs to an experimental design similar to McMeekan and Hammonds (1939), employing a High-High (HH), High-Low (HL), Low-High (LH) and Low-Low (LL) level of nutrition. The low plane fed pigs were restricted to three percent of their body weight. The initial period ranged from the start of the experiment (about 44 lbs.) to 125 lbs. live weight, and the final period from 125 lbs. to the slaughter weight of

215 lbs., in contrast to the latter worker's sixteen-week periods. Feed-lot data indicate the HL lot as the most efficient feed converters; however, the LL pigs produced the leanest carcasses, but required a considerably longer feeding period. Brugman (1950) modified slightly the above technique to study further the effects of plane of nutrition. He divided the litters of two sows equally, and randomly assigned them to lots. One-half were self-fed for the entire time and the other one-half received 70 percent of full feed to 150 lbs. followed by full feeding to 220 lbs. He reported less backfat, greater body length, and more weight of lean cuts in favor of the restricted-fed pigs. He further observed a significant increase in the number of days required to reach market weight by the pigs on the low plane of nutrition.

Smith et al. (1950) studied the effect of restricting feed intake on pasture. He compared full-fed pigs in dry lot and on pasture with pigs on pasture receiving 80 and 60 percent of full feed, respectively. The restricted lots made more efficient gains; however, the daily gains were depressed with the feeding periods appreciably lengthened. The pigs restricted on pasture had a higher dressing percentage, yielded a higher percentage of primal cuts, and had less backfat thickness. Carcasses from the restricted-fed pigs had a greater tendency

toward softness. Carcass length was not affected by either treatment. Robison et al. (1952) also reported that carcasses from limited-fed hogs yielded approximately 6 percent more lean cuts and 6 percent less fat trim than full-fed hogs.

Gregory and Dickerson (1952) restricted feed intake of pigs to 80 percent of full-fed controls. Limited feeding did not affect the digestibility of protein, ether extract, nitrogen free extract, or dry matter. They did observe a decrease of 0.1 lb. in daily gain, an increased time to market weight of 14 days, a reduced feed required per 100 lb. of gain, a reduced dressing percentage, and a significantly increased percentage of lean cuts of the chilled carcass. Crampton et al. (1954) observed similar results with pigs limited-fed after they reached 110 lbs. In this study, rates of gain were reduced by 25 percent for the restricted-fed pigs which were accompanied by a corresponding longer feeding period of 17 days. However, more feed per hundred pounds of gain was required by the restricted-fed pigs. They did observe a significant increase in percentage of grade A carcasses, and size of loin eye muscle. Backfat thickness was significantly reduced.

Lucas and Calder (1956) conducted experiments to determine the effect of limiting feeding upon carcass

characteristics of swine developed to mature early and late. Pigs from within each maturing group were allotted to the following treatments: (1) very high plane (VH) of nutrition throughout the period from weaning to slaughter; (2) a very high plane to 100 lbs. (VH) and a restricted (R) plane during the finishing period; or (3) restricted throughout the growing-finishing period on a low energy diet (VL-VL). They observed that pigs of the VH-R group gained 15 percent less rapidly during the finishing period and 9 percent less rapidly than those from the VH-VH group for the entire growing-finishing period. Pigs from the VL-VL group gained 48 percent less rapidly after they reached 100 lbs. than did pigs from the VH-VH group. They found no differences in growth rate among breeds, sexes, or litters within breeds; hence, there were no breed x treatment or sex x treatment interactions. They did report that carcasses from the VL-VL pigs had significantly larger loin eyes and were significantly leaner. Subsequently, Lucas and Calder (1956) conducted another experiment in which they compared a lean type cross (Landrace x Large White) and a fat type cross (Essex x Large White). Planes of feeding were similar to those described previously. They reported that pigs on the VH-R and VL-VL sequences required 11 and 63 days longer, respectively, to reach slaughter weight than did pigs on the VH-VH sequence. There were no effects of plane of

feeding upon loin eye area, but a significant reduction in backfat did occur with the reduced level of feeding. A highly significant increase in percentage of ham resulted from the VL-VL plane of feeding. The authors did report a significant breed x feeding level interaction. They concluded from the study that restriction of feed intake during the finishing period from 100 - 200 lbs. live weight, unless it was severe enough to cause a delay of at least 40 days to reach slaughter weight, had no significant effect on feed conversion, backfat thickness, or area of loin eye muscle. In addition, they observed an increase in dressing percentage as a result of limited feed intake, an observation not confirmed by many investigators.

Jordan et al. (1956) reported the results of the limited feeding of corn on pasture. In a series of four trials they concluded that the feeding of 50 - 70 percent of a full feed of corn to be the most desirable level for the improvement of the leanness in the carcass without seriously reducing rate of gain. They further observed a slightly more efficient gain, a depressed daily gain, and a much longer feeding period when grain was limited or omitted from the ration of the pigs on pasture. The elimination of grain from the ration resulted in the production of inferior carcasses due to lack of finish. Wallace et al. (1955) had observed similar results with restriction of feed intake on pasture. They demonstrated

that restriction of feed produced carcasses which were much higher in percentage of lean cuts, possessed .4 in. less backfat, and a lower dressing percentage. They further observed that the full-fed lots had more economical gains than the limited-fed lots in one trial, but were approximately equal in another.

Braude et al. (1958) reported the results of a large scale study in which they compared several planes of feeding at a number of centers. They compared (1) ad libitum feeding until pigs reached market weight; (2) ad libitum feeding until pigs reached 120 lbs. and then restriction to 6.5 pounds of feed daily once that level of consumption was reached; (3) restriction on basis of a sliding scale which permitted 2.0 lb. of meal daily for 32-36 lb. pigs and allowed 0.1 lb. increase for each 3 lb. increase in body weight until pigs reached 6.5 lbs. daily intake (the maximum level of feed intake allowed) at weights of 169 lbs.; (4) severe restriction permitting only 1.3 lbs. meal daily for pigs weighing 42 lbs. and allowing 6.5 lbs. per pig daily when the pigs reached the weight of 198 lbs.; and (5) moderately restricted feed intake at a level intermediate between 3 and 4. Pigs were slaughtered when they reached weights of 210 lbs. The data from this trial indicate that those pigs which were moderately restricted (treatment 5) gained less rapidly and required 8 percent less feed per unit of gain than

pigs fed ad libitum. The slower gaining pigs were leaner, slightly longer, and possessed a greater depth of loin eye muscle. Carcasses of the restricted-fed pigs were softer than those of ad libitum fed pigs. The ad libitum fed pigs did have a higher dressing percentage and required fewer days to reach slaughter weight.

Hafez et al. (1958) demonstrated the effect of plane of nutrition on the carcass components of swine. They compared the feeding sequences of HH, LH, LL, HL, where the initial letter refers to the plane of nutrition up to 100 lbs. to slaughter weight. They reported an increase of 12 percent in lean cut yield of the LL group over the HH group. The percent of carcass bone averaged 8.5 percent for limited-fed and 5 percent for the full-fed. Swell and Carmon (1959), using the same feeding sequence, observed no significant difference between treatments with regard to carcass length, backfat thickness, or percent total lean cuts. This disagrees with the data of Hafez et al. (1958). Swell and Carmon (1959) did note that the HH group of pigs had a more economical gain and a higher dressing percentage.

Self et al. (1960) compared the influence of full-feed, two-thirds of full-feed, and one-third of full-feed on the carcass characteristics of swine. They observed a significant difference in lean cut yields with the medium and severely restricted groups excelling the full-fed groups by 1.0 percent and 2.7 percent, respectively. Loin eye

area and carcass length were not significantly affected by the level of feeding.

Salmela *et al.* (1960) demonstrated that pigs fed *ad libitum* had significantly more backfat and a lower percent of lean than did pigs being limited-fed to 85 percent of full feed or restricted by adding 20 percent of ground, low quality brome-alfalfa hay to the basal ration. Feed efficiency favored the restricted and fiber-fed lots over the full-fed lot. In this study, three kinds of single cross pigs were compared as to their response to limiting feeding. All breeding groups considered, ham weight and loin eye area differed significantly due to breeding group, but not due to level of feeding.

Lucas *et al.* (1960) also conducted a study to determine the influence of breed and season on performance of swine being fed a restricted ration. The pigs on the VH-VH plane of feeding were slaughtered at an average of 121 days from the start of the experiment. In comparison, the pigs restricted by 13 and 26 percent in feed intake caused growth to be slower by 13 and 22 percent, respectively. This also caused average delays of 18 and 34 days, respectively, to grow from 44 to 200 lbs. Reduction of the plane of feeding had no significant effect upon carcass length but did decrease all measurements of fat thickness and increase the area of loin eye. Severe reductions in plane of feeding caused 9 percent and 14 percent losses in

efficiency in two lots, but 11 and 15 percent improvements in two others.

Calloway et al. (1962) reported a very dramatic reduction in backfat thickness when a severe restriction of 50 percent of full-feed was imposed on miniature hogs fed to almost a year of age. The spread in average backfat thickness between the restricted-fed lot and full-fed lot was 1.6 inches.

Thrasher et al. (1962) limited the intake of a corn-soybean meal fortified ration to 85 and 90 percent of full feed. They reported, at both degrees of limitation, a reduced rate of gain, reduced backfat thickness, and an increased lean cut yield. The feed per unit of gain was higher for the limited-fed groups. Greer and co-workers (1963) also reported, with feed restrictions of 70 and 85 percent, a linear decrease in average daily gain and backfat thickness as levels of feeding decreased. They further reported a linear increase in percent of ham and loin of the chilled carcass weight. In comparing efficiency of feed utilization, there was no difference in feed efficiency in trial 1, but in trial 2 there was a linear decrease in feed per pound of gain with increasing level of feeding.

Plank and Berg (1963) compared: (1) limited feeding to a scale of 75 percent of the National Research Council's

recommended requirements for bacon hogs; (2) liberal feeding, wherein pigs were fed to appetite three times daily; and (3) ad libitum feeding. They observed that as the plane of nutrition increased, average daily gain, dressing percentage, and backfat thickness increased comparatively; whereas, loin eye area and feed efficiency became correspondingly inferior.

Wallace and co-workers (1963a; 1963b) reported the results of three experiments in which they showed the well established decreases in rate of gain and in backfat thickness. They were unable to show an improvement in efficiency of feed utilization in any of their studies. They did not obtain statistically significant increases in percentage of the four lean cuts and significant decreases in dressing percentage in two studies due to restriction of feed intake.

Becker et al. (1962) reported that hogs limited to 70 percent of full feed required 11 percent less feed per unit of gain than pigs full-fed. The limited-fed pigs exhibited a reduced gain of 20 percent, an increased lean cut yield of approximately 1 percent, and required 10 days longer to reach market weight. In a later study, Becker et al. (1963) reported results in which pigs fed restricted amounts of feed in dry form were no more efficient than full-fed pigs. Both of these reports disagree with Thrasher et al. (1963) in that he observed that full-fed

pigs required 7 percent less feed per pound of gain than those limited-fed. However, he found that those pigs being limited-fed gained only 78 percent as fast as the full-fed pigs, but produced significant improvements in average backfat thickness, percent lean cuts, and percent ham and loin on a carcass basis.

More recently, Orme et al. (1965) compared full-feeding with 70 and 85 percent restriction. The limited-fed lots showed highly significant increases in age at slaughter, decreases in daily rate of gain, and decreases in feed per pound of gain. No difference s were observed in backfat thickness of the 85 percent and FF lots; however, a significant decrease occurred at the 70 percent level. They further observed an increase in percent moisture in the ham of the limited-fed hogs. Similar results were reported by England et al. (1965) with pigs fed at 70, 80, and 90 percent of full-feed compared to ad libitum feeding. However, McCampbell and Baird (1965) observed non-significant differences in average daily gain, days on feed, and age at slaughter between energy levels of 1000 and 1200 productive calories per pound of ration. Feed efficiency was improved by 60.5 pounds per hundred pounds of gain with the higher energy ration.

Biswas et al. (1966) found that average daily gain was positively correlated with average daily feed consumption, but that feed consumption was negatively associated with

feed efficiency - expressed as the ratio of average daily gain to average daily feed consumption. Furthermore, feed efficiency was positively correlated with gain. Daily gain and feed consumption were negatively associated with percent lean cuts and positively correlated with carcass backfat. On the other hand, feed efficiency was positively correlated with percent lean cuts and negatively correlated with carcass backfat. Magee (1963) reported similar relationships between daily feed intake, feed efficiency, and daily gain.

2. Feeding a constant level of feed throughout the entire finishing period.

With this procedure a predetermined daily feed allowance is selected and adhered to throughout the finishing period. This method imposes an increasing level of restriction as the animal progresses toward the finishing weight.

Barber et al. (1957) reported results of a study in which they compared six different levels of feed intake. The pigs were fed on a sliding scale until they reached maximum daily feed intake levels of 7, 6-1/2, and 6 lbs. Differences in feed efficiencies were small, but those pigs fed to scale until they reached intake levels of 6-1/2 lbs. daily, required significantly less feed per unit of gain. All pigs restricted to scale tended to be leaner than ad libitum-fed pigs. Braude et al. (1959), following a similar plan, compared pigs fed ad libitum until they

reached daily levels of feed intake of 6-1/2, 6, 5-1/2, and 5 lbs. These workers observed that as the level of meal feeding was reduced, the growth rate of the pigs was significantly lowered; however, nonsignificant differences in efficiency of feed utilization were noted. There was a general trend for the layer of fat all along the back to be reduced in thickness, especially over the loin. Along with a lower level of feeding was an increase in loin eye area. No differences were noted in carcass length or dressing percentage. From their study, these workers concluded the maximum daily allowance should be 5-1/2 lbs. in order to obtain satisfactory performance.

Becker et al. (1963) compared limited-fed pigs at a level of 4 lbs. per pig daily with ad libitum-fed pigs. They further compared dry and wet feed (1:1 feed/H_2O). The results of this study indicated that wetting the ration increased the rate and efficiency of gain by the limited-fed pigs, but only the rate of gain of those full-fed. The differences noted in feed efficiency due to wetting were not in agreement with those reported by Thrasher et al. (1964), who reported non-significant effects on feed efficiency.

Shroder (1963) used a different technique to limit the daily intake of feed. He compared: (1) placing 15 lbs. of feed per hog in a self-feeder every three days; (2) increasing the feed allowance at three different body weights

from 15 to 18 lbs. in a self-feeder; (3) hand feeding 5 lb. per head per day; (4) hand feeding 5, 5-1/2, and 6 lbs. at three different weight intervals. Data from his trials indicated practically no differences in feed per pound of gain between treatments; however, the most efficient group was the group fed 15 lbs. of feed per hog in a self-feeder every third day. All lots fed on a limited basis showed improvement in backfat thickness and a decreased average daily gain.

Keese et al. (1964) compared full-feeding with feeding a constant 5 lb. level from 100 lbs. to slaughter weight. He reported a significant decrease in rate of gain and backfat thickness along with significant increases in loin eye area and percent of lean cuts. He noticed that full-fed pigs had firmer, less watery carcasses, and when subjected to palatability studies, scored higher in tenderness than did the limited-fed pigs. However, the limited-fed pigs scored higher on juiciness.

3. Dilution of the ration.

In this procedure the ration is diluted with low energy fibrous ingredients and self-fed. Interest in this method of limited feeding generates from trying to save labor needed to hand feed swine as required in the previously discussed methods.

Vestal (1921) reported that when fibrous feeds were added to a basal ration of corn and tankage, the rate of gain decreased as the fiber level increased.

Proctor and Wright (1927) stated that in the case of 40 to 80 lb. pigs, the bulk occupied by ration affected the quantity of feed taken in; however, the volume of the stomach did not appear to be the limiting factor. They hypothesized that the amount of feed eaten may be controlled by the requirement for nutrients rather than by the emptiness of the stomach.

Robinson (1928) studied the effect of high and low fiber rations on bacon and lard-type breeds of swine. Animals receiving a relatively high percentage of fiber in the ration gained more slowly and produced carcasses lower in fat content. These pigs also had a lower dressing percentage. The lean cuts from the pigs fed low fiber appeared fatter than those of the pigs fed the high fiber rations.

Ellis and Zeller (1938) obtained an increase in rate of gain when alfalfa hay was added to swine rations up to 10 percent. Even with the addition of up to 20 percent alfalfa hay, the gains were comparable to the controls receiving no alfalfa hay. The carcasses were not markedly affected, although slight decreases in fatness and firmness of fat were observed. The lots receiving no alfalfa required less feed per unit of gain and consumed less feed per day than the lots receiving the alfalfa hay. In another study,

Ellis and co-workers (1942) indicated that rations for growing-finishing swine should not contain more than 5 - 6 percent fiber for optimum growth. Later, Axelsson and Eriksson (1953) stated that for maximum gain of finishing pigs and optimum level of crude fiber in the rations averaged 6.57 percent, but 7.26 percent fiber was consistent with maximum efficiency of metabolizable energy. They further noted that daily feed consumption increased with increased crude fiber content.

Whatley et al. (1951) restricted twelve litters of two pigs in energy intake during the latter part of the finishing period by substituting ground hay for part of the corn. The pigs were all fed alike up to 140 pounds; however, from 140 lbs. to 225 lbs. one-half of the pigs were fed a ration containing only 1.43 therms per pound of feed as compared to 1.52 therms per pound of feed for the control group. The reduced energy level significantly depressed the rate of gain and increased the feed cost. It also resulted in a leaner carcass with a higher yield of lean cuts. Hillier et al. (1951) also noted a reduction in average backfat with hogs fed high fiber rations. In addition, they found that 20 percent ground prairie hay reduced rate of gain about 30 percent and increased the feed required per unit of gain by 60 percent.

Forbes and Hamilton (1952) stated that 125 pound pigs could digest 42.5 and 49.7 percent of the crude fiber and cellulose respective, in a ration containing 23.6 percent alfalfa. Bohman et al. (1953) fed levels of alfalfa to swine varying from 10 to 60 percent and noted only a slight depression in rate of gain up to the 30 percent level. Rates of gain of 1.3 to 1.7 lbs. daily were obtained for alfalfa levels up to 50 percent for the entire growing-finishing period. However, carcasses of the pigs grown on rations containing 30 to 60 percent alfalfa were graded medium, with a small proportion of choice #1. No significant differences were observed in the percent of primal cuts, backfat thickness, carcass length, or dressing percent. They did observe a marked enlargement of the stomach and intestines in the 30 and 50 percent alfalfa-fed groups. Later, Bohman et al. (1955) reported another study on the effect of alfalfa meal in swine rations. The results were similar, except that significant decreases were obtained in dressing percent, depth of backfat, and percent of belly as the level of alfalfa increased. This was accompanied by a significant increase in percent of ham, shoulder, and loin. Kidwell and Hunter (1956) also studied the influence of 50 percent alfalfa in a swine ration and observed the same response. Their results indicate that at the level of 50 percent alfalfa in the ration, 1 lb. of alfalfa will replace 0.5 lb. of grain and supplement.

Coey and Robinson (1954) reported little or no diminution in rate of gain as the crude fiber content of the rations was increased from 3.5 to 11 percent. A reduction in carcass fat, a decreased dressing percentage, and slightly more feed per pound of gain were noted with increasing levels of fiber in the rations. Crampton et al. (1954) obtained similar results in performance when the fiber content of the ration was increased. They further reported superior grading of carcasses as a result of significant decreases in shoulder and loin fat.

Teague and Hanson (1954) studied the level of fiber tolerated by growing and finishing pigs on a purified ration by replacing starch with 2.5, 5, 10, 15 and 20 percent ruffex (cellulose product). The 15 and 20 percent levels slightly depressed the rate of gain and daily feed consumption. Carcass studies revealed no marked differences which could be attributed to the rations fed.

Merkel et al. (1958a) found that restricting the TDN level by incorporating fibrous feeds into rations, decreased daily gain and increased the feed required to produce a pound of gain. However, the TDN consumed per 100 pounds of gain was essentially equal except when the ration contained approximately 52 percent "poor quality" alfalfa hay. They further reported that the level of crude fiber in the ration was more highly correlated with the results of growth and carcass data than either TDN or

protein level. Regardless of whether TDN or fiber level were employed as a measure of restricting the digestible nutrients of the ration, the length of the feeding period was significantly increased and dressing percentage, carcass backfat thickness, and leaf fat weights decreased (Merkel et al., 1956b).

Hochstetler et al. (1959) found no significant differences in feedlot performance or carcass characteristics between pigs fed rations containing 0, 20 and 40 percent oats. With alfalfa meal used as the source of fiber non-significant decreases in rate of gain and backfat thickness were observed. However, significant decreases in rate of gain, feed efficiency, dressing percentage, and percent of fat trim were reported for pigs fed a ration containing 40 percent wheat bran. This was accompanied by a similar increase in lean and primal cuts expressed as a percent of chilled carcass weight. In contrast, Jensen et al. (1959) reported a growth reduction caused by adding oats to a finishing ration. Jensen et al. (1959b) also reported a decrease in growth rate when oat hulls were added to a corn-soybean meal ration. This was overcome by the addition of corn oil to equate the ration for TDN. In this study, adding 30 percent oat hulls resulted in more feed required per pound of gain and a depression in daily feed intake. Bowland and Berg (1959) observed similar results with reference to average daily feed intake. They noted that pigs on high energy rations consumed more feed during the

growing period, but less feed during the finishing period than those on low energy rations. This agrees with Dinusson et al. (1961) who stated that hogs tend to eat on an energy basis rather than on pounds of feed and therefore, usually eat more total pounds of a higher fiber ration.

Larsen et al. (1960) compared the effects of different types of fiber. They found that barley hulls decreased backfat thickness on both corn and barley rations, while wood cellulose lowered backfat thickness only on the corn rations. They further observed no significant differences in dressing percent or in carcass length. Their studies indicate that crude fiber levels per se were not significantly correlated with either backfat ($r = .23$) or estimated fat content of the carcass ($r = -.20$). Anderson and Hanby (1961) also reported no significant reduction in backfat thickness in using barley to increase fiber content of the ration.

Hoefer et al. (1963) compared corn and cob meal, wheat bran, oats, and alfalfa meal as fiber sources in swine rations. They noted that wheat bran and alfalfa rations were the most effective in reducing the amount of fat on the carcasses. The corn and cob meal also improved leanness, whereas, oats tended to produce carcasses similar to the corn basal ration. Gross feed conversion favored the basal ration but on the basis of TDN, the corn and cob meal ration was equally as efficient as the high energy basal ration.

Hale et al. (1962) used ground corn cobs and stabilized tallow to alter the energy level of rations. Ground corn cobs decreased the rate of gain and efficiency of feed utilization, while the added tallow increased both. The addition of 30 percent cobs reduced backfat thickness, increased loin eye area, and increased lean cut yield as compared with those pigs fed added tallow. Dressing percent also decreased which agrees with the findings of Cunningham et al. (1961) when he compared adding purified cellulose to a swine ration. Cunningham et al. (1961) further observed no significant difference in the protein or fat content of the carcasses; however, the iodine number of the loin fat was significantly higher in the pigs fed solka-floc (purified cellulose).

Troelsen and Bell (1962) conducted a feeding experiment of 2 x 2 x 3 x 5 factorial design (two sexes, pellets vs. meal, three levels of fiber, and five sources of fiber) involving 60 gilts and 60 barrows. The basal ration of barley and soybean meal was diluted with three levels each of oat hulls, alfalfa meal, wheat bran, cellulose, and ground corn cobs so as to obtain estimated TDN levels in the rations of 62, 65 and 68 percent. Their results indicate that daily feed intakes varied depending upon the diluent used, thus revealing that factors other than TDN levels per se influence consumption of balanced self-fed rations. Certain bulk types led to increased feed

intake and others depressed feed intake. Pigs fed corn cob meal exhibited the highest gains and consumed the most feed. Increasing the level of bulk from low to high resulted in a lower dressing percent, but no significant differences were noted in percent of ham, loin eye area, or carcass length.

4. Effect of protein level.

In most limited feeding experiments, the basal ration is restricted which reduces the intake of not only energy but all other nutrients. Since the development of maximum muscle is one of the main goals of limited feeding, the influence of the level of protein on rate of gain and carcass leanness has received the attention of several investigators.

The effect of high level protein upon rate of gain and carcass leanness was reported by Woodman et al. (1936) and Woodman et al. (1939). They concluded that an intermediate level of protein is most economical; nevertheless, high protein presents no serious deleterious effects, except a tendency toward a slightly softer fat. Nitrogen retention from the high protein rations was no higher than from the normal ration. Most of the extra protein in the high protein rations could be accounted for by the extra urea eliminated in the urine of the pigs on these rations. They further noted that nitrogen retention remained similar throughout the period of growth from weaning to approximately

200 pounds. Woodman and Evans (1941), (1945), and (1948) conducted similar experiments in an attempt to establish the minimum protein level for hogs consistent with economical growth and desirable carcass characteristics. They observed more efficient feed utilization when the levels of protein were low, but gains, carcass leanness and nature of the fat were approximately equal for all of the levels studied.

Ellis and Hankins (1935) hand-fed three levels of protein (12.4, 15.4, and 18.9 percent) to hogs restricted to three pounds of feed per 100 pounds of body weight. Increased gains were accomplished by increases in protein level; however, feed efficiency significantly favored the lower level of protein. They found that the medium level of protein produced the maximum muscular development. Also, more desirable backfat thickness and longer carcasses were obtained on the medium level. The highest percentage of total fat in the carcass and ham occurred on the low level of protein. McMeekan (1940), using his earlier plan (HH, HL, LH, LL levels of nutrition), substituted two levels of protein in the place of the previous high and low levels of nutrition. Growth on the low protein level equalled that of the high level. In contrast with the work of Ellis and Hankins (1935), he found no appreciable increase in carcass fatness of the low level protein group. The high protein level tended to encourage the development of the

most valuable muscles (ham and loin); whereas, the LH and LL levels inhibited these muscle masses. The relative effect upon the measurement of the loin muscle was less than upon carcass fat.

Robinson (1940) fed 9.1, 17.3, 25.6, 34.2, and 51 percent protein rations to pigs in dry lot to study the effects of high protein. In an additional lot he alternated, at four week intervals, with and without ad libitum protein supplement. Maximum gains and feed efficiency were observed on the 17.3 percent protein supplement level. The low protein level produced a considerably fatter carcass and required much more feed per 100 pounds of gain. When alternating the protein supplement at four week intervals, the performance of this lot nearly approached that of the 17.3 percent level. The extreme high level of protein showed a depression in daily gains and a significant improvement in feed efficiency; however, this group oroduced the lowest percentage of fat cuts and was intermediate in the percent of lean cuts. Similar experimental results were obtained by Robinson et al. (1952) when approximately 10, 12, 15 and 20 percent protein levels were fed. Carcasses fed the higher percent of protein yielded more lean cuts and less fat trim than hogs on the lower level. Ashton et al. (1955) observed the same effect on carcass leanness in their protein level studies.

Tribble and Pfander (1955) compared 12 and 16 percent protein levels for hogs being full-fed and limited-fed. Their data indicated no differences in feed economy between protein levels; however, the pigs fed the high protein produced carcasses that contained 1.6 percent more lean cuts and 4.5 percent less fat than the low protein fed pigs. Bowland and Berg (1959) observed that live weight gain tended to be faster in pigs fed a high energy - high protein ration. In contrast, Mulholland et al. (1960) observed a decrease in daily gain when protein level increased from 14 to 28 percent. The higher protein ration resulted in leaner carcasses.

Kropf et al. (1959) experimented on the influence of amino acid balance as well as the protein level. Providing a poor amino acid balance reduced rate of gain, daily feed intake, and feed efficiency significantly. Carcasses from pigs given the poor amino acid balance tended to be lower in protein with a higher fat content than those produced on a better balance of amino acids. Their results indicate that feeding a 12 percent protein diet of good amino acid balance did not lower rate or efficiency of gain, but tended to produce a fatter carcass than the 16 percent protein ration. Carcass muscle development was more severely hindered in early growth than in later growth by the low protein level and/or quality. Smolinsky et al. (1963) also studied the effect of adding protein, methionine,

and lysine to swine rations which were being limited-fed. The limited-fed pigs were fed added protein, methionine and lysine to equal the intake of the full-fed pigs. None of the treatments significantly affected rate or efficiency of gain.

Noland and Scott (1960) fed three levels of protein (12, 16, and 20 percent) at three levels of energy. Carcasses from pigs fed the 1200 calorie ration were fatter than pigs fed the 950 and 1050 calorie rations; however, pigs fed the 16 and 20 percent rations produced longer and leaner carcasses than those fed the 12 percent rations. Bellis and Taylor (1961) also reported an increase in the lean meat content of the carcasses from pigs fed a 17 percent protein versus a 14 percent protein ration, but further indicated a decrease in the feed required to produce more muscular carcasses. Nickelson et al. (1961), on the other hand, reported that feeding at 80 percent of full-feed improved the gain - feed ratio when 12 percent protein was fed, but that efficiency was impaired with the 18 percent protein ration.

Aumon et al. (1961) conducted four trials in which they compared low and high levels of protein feeding. They found that neither protein feeding sequence had a significant influence on any of the measures of carcass quality. They further state that protein level had no effect on rate of gain or efficiency of gain. In trial

#4 they compared feeding levels of 16, 14, and 12 percent protein up to 125 pounds and then 11 percent protein till slaughter weights were reached. This trial revealed no improvement in carcass traits, but did indicate a significant improvement in rate of gain of pigs up to 125 pounds in favor of the 16 and 14 percent protein lots. They felt the genotype of the animal fed was an important factor in carcass leanness, because significant differences were found between breeds. On the other hand, Baird and McCampbell (1962) reported that high protein levels showed an improvement in average daily gain, feed economy, backfat thickness, loin eye area and percentage of lean cuts. Gillett et al. (1962) reported similar carcass improvements in a comparison of four protein treatments. The low protein levels fed during the finishing phase had significantly fatter carcasses; whereas, the high protein fed ration resulted in .89 percent more trimmed ham and .98 percent more trimmed loin, with both being significant.

Clawson et al. (1962) used rations containing graded levels of 10 to 18 percent protein formulated so that a similar ratio of amino acids was maintained in all diets. They observed that feed efficiency was more closely associated with energy level of the ration than with the calorie-protein ratio. As the energy and protein levels increased in the rations (with a constant calorie-protein ratio), the feed per pound of gain was consistently decreased. The

carcass measurements were not significantly influenced by the ration treatments, although there was a tendency for both higher energy and lower protein levels to produce fatter carcasses.

Cunningham et al. (1962) self-fed pigs a 12 percent protein ration (HB); fed 1600 grams per pig daily of the same diet (LB); or fed 1600 grams of a 20 percent protein diet (HP) during the finishing period. They noted that feed requirements were increased 32 percent by restricting intake of the high protein (HP) ration. Loin eye areas tended to increase with restriction of either ration and backfat thickness tended to be reduced. Carcasses of pigs fed limited amounts of the basal ration contained 7 percent more protein and 3.9 percent less fat than did those from self-fed pigs. Restricting the amount of the HP ration further increased protein content by 3.1 percent and reduced fat by 1.8 percent.

Young et al. (1962) individually hand fed thirty pigs so as to give each pig approximately equal total consumption of protein, vitamins and minerals during the feeding period as they reduced energy consumption to approximately 80 percent of full feed. The reduced energy intake resulted in slower daily gains and the production of more lean cuts, but neither of the differences were significant. The ratios of feed/gain, energy/gain, and energy/total lean cuts were more favorable for pigs consuming the energy

restricted rations. When two levels of protein consumption were studied, they observed no significant differences between levels as measured by rate of gain, feed/gain ratio, or carcass merit.

Wagner et al. (1963) fed rations containing from 950 to 1640 calories per pound in combination with protein levels of 13, 19, and 25 percent. They reported that increased protein levels resulted in decreased backfat thickness. Their data indicated that this may be partially due to decreased feed consumption of the higher energy rations. No significant interactions of prtein and energy were observed in any of the measurements taken. Feed per pound of gain increased as the protein level increased above the 13 percent level.

In more recent studies, those characteristics of improvement due to higher protein levels have been reemphasized by the studies of Seerley et al. (1964), Meade et al. (1964), Waldern (1964), and Hale and Southwell (1966). In general, pigs fed high protein rations produced carcasses with a significantly higher percentage of lean cuts, less backfat thickness, and more loin eye area. However, Seerly et al. (1964) noted that protein did not significantly affect rate of gain or feed utilization. He did indicate that an interaction existed between protein and energy whereby advance effects on carcass quality of the high level of energy were modified by the high level

of protein. This resulted in an increased loin eye area and a higher percentage of Grade A carcasses.

5. Additional methods designed to limite the daily feed intake.

Various feed additives have been used to improve the carcass leanness of swine. The purpose of some additives is to curb appetite while others may act as enzyme inhibitors which affect metabolic pathways.

Friend et al. (1962) studied the effect of acetozolamide (2 acetylamino-1, 3, 4-thiadiazole 5 sulfonamide) on weight gain, feed consumption, and carcass characteristics of swine. Acetozolamide (which inhibits the enzyme, carbonic anhydrase) delayed marketing of gilts and barrows by 26 and 7 days, respectively. Feed consumption per day was significantly reduced; however, feed conversion, carcass length, loin eye area, and backfat thickness were not significantly affected by the treatment. They did observe that acetozolamide appeared to have a differential sex effect since the rate of gain by gilts was reduced more than that of barrows.

Schmoll (1966) reported the effect of selected citrus bioflavonoids and celery oil on the performance of growing-finishing swine. He concluded that performance of growing-finishing swine was not affected by the addition of either pure or crude naringin. He did note that lemon-orange flavonate glycoside reduced feed intake by 0.8 lbs. per day.

No significant differences in carcass characteristics were noted for any of his treatments.

Skjervold et al. (1963) forced pigs to stand on their hind legs to eat trying to facilitate a self-limiting type of feed restriction. They used a paired feeding test and showed there was no change in ham or muscle development. However, daily feed intake was reduced approximately 0.4 lbs.

Heeney et al. (1964) used a method of restriction similar to that of Skjervold et al. (1963) in that feeders were located on a raised platform with stairs built on a 56° angle up to the platform. They reported that feed intake was restricted to approximately 80 percent of full feed by this method. Those pigs which were limited-fed gained at a significantly slower rate, but utilized their feed more efficiently. Percent lean cuts, loin eye area, and specific gravity of the carcass were significantly increased and backfat thickness was significantly decreased by this method of limited feeding.

6. Influence of frequency of feeding.

Limited feeding either by hand or mechanical means poses a problem of how often the pig should be fed in order to obtain maximum performance.

Braude and Rowell (1957) studied the effect of the omission of one feed per week, or reducing the number of feedings from 14 to 13 per week. They reported no significant effect on growth rate, efficiency of feed utilization, or carcass quality if the amount of meal normally allocated to the missing feed was distributed between the remaining feeds of the week. Later, Braude and Townsend (1963) compared the feeding of once a day versus twice a day at 17 centers in Great Britain. They noted that pigs fed once daily had slightly poorer growth rate and feed utilization; however, neither of these were significant. The pigs fed once a day were significantly lower in dressing percentage, but the researchers indicated the significance was probably due to the problem of obtaining an accurate weight off test. Neither carcass grade nor carcass length were significantly different for the treatments.

Friend and Cunningham (1965) used 14 pairs of Yorkshire barrows in a paired-feeding experiment to compare pigs fed once a day all they would eat in 30 minutes (single feeders) with pigs fed the same amount of total feed but consumed in five equal feedings (multiple feeders). The live weight gain of the single feeders was slightly greater than multiple feeders with corresponding differences in feed conversion of 3.86 and 3.97, respectively. The

single feeders had significantly larger loin eyes and less backfat thickness; however, the moisture content of the carcasses was greater.

Cromwell et al. (1965) reported that self-fed pigs gained significantly faster and more efficiently than pigs fed 1 or 8-12 times per day and slightly faster and more efficiently than pigs fed two times a day. The twice-daily fed pigs gained significantly faster than pigs fed once daily. Carcass characteristics were similar for pigs on the various feeding systems; however, one-daily fed pigs were slightly longer with less backfat thickness. In this experiment the pigs were allowed to consume all the feed they could in 1/2 the time to their next feeding. The average daily feed intake was 5.41, 5.57, 5.54 and 5.35 for once, twice, 8-12, and ad libitum methods of feeding, respectively.

7. Brief summary of the literature on the influence of limited feeding on swine performance and carcass characteristics.

In general, the literature would indicate that limited feeding reduces rate of gain, lengthens feeding period, and improves the acceptability of the pork carcass from the consumer's point of view. The most variation in the literature centers around the issue of feed required per pound of gain. Many investigators have reported improvements in feed conversion of 5-15 percent, others have reported

no apparent effect, while still others have reported inferior feed conversion ratios of 5-15 percent. In view of all this variation, one wonders as to the significance of feed wastage in these numerous trials. Horvath and Elliot (1962) reported work which indicates that with well-adjusted self-feeders, 1 to 3 percent feed wastage was normal; while as much as 7 percent feed wastage was routine on certain feeders, even when adjusted as carefully as possible. They noted at times, when using a poorly adjusted self-feeder, that feed wastage could amount to 4-17 percent.

B. Influence of pig sex on performance and carcass quality.

Although Woodman et al. (1936) reported a slightly, but significantly faster growth rate in gilts than in barrows, the majority of investigators have found that barrows grow faster than gilts (e.g. Comstock et al., 1944; Bruner et al., 1958; Bowland and Berg, 1959; Cameron, 1960; Wallace et al., 1960; Mulholland et al., 1960; Wagner et al., 1963; Waldern, 1964; Hale and Southwell, 1966). Comstock et al. (1944) also stated that the sex differences in growth rate increases with age. Plank and Berg (1963) reported that gilts outgained barrows when fed an equalized limited amount of feed; whereas, barrows outgained gilts when fed ad libitum. They further noted that barrows ate more feed per day than gilts when fed ad libitum.

Wagner et al. (1963) reported very little difference between rate of gain between boars and gilts; however, Winters et al. (1942) observed an increased growth rate in favor of boars as compared with barrows. Winters et al. (1942) inferred that the difference in growth between boars and barrows can be explained largely by differences in skeletal growth and the deposition of fat; the former being in favor of the boars and the latter in favor of the barrows. Thus, the cited literature would indicate that boars gain faster than barrows which in turn gain faster than gilts.

Bell et al. (1958) and Cameron (1960) both report that barrows consume more feed per day than gilts. On the other hand, Charette (1961) found that boars consumed less feed daily than either barrows or gilts. Charette (1961) and Wagner et al. (1963) observed that boars were more efficient in feed utilization than gilts and barrows. Bowland and Berg (1959) found that gilts required less feed per pound of gain than barrows. Lucas and Calder (1956) also observed that barrows were less efficient than gilts, but these differences were non-significant.

Hammond and Murray (1937) found that castrated males and females had thicker backfat measurements than corresponding intact males and females; while the intact females had more backfat than the intact males. McMeekan (1940) reported similar results in that intact females were characterized by less fat, more bone, and more muscle development than were barrows.

Somewhat later, Bruner et al. (1958) published data obtained on barrow and gilt littermate pairs at the Ohio Swine Evaluation Station which were in agreement with the work of Hammond and Murray (1937) and McMeekan (1940). Data were obtained on 385 full sibs which were slaughtered at an average weight of 206 lbs. They reported an advantage of 0.1 inch in backfat thickness, 0.51 sq. in. larger loin eye, and 2.3 percent greater yield of lean cuts of carcass weight in favor of the littermate gilts over the barrows.

Self et al. (1957) obtained cut-out data on 584 gilt and barrow carcasses which indicated that gilt carcasses contain more muscle and less fat than carcasses from barrows. The gilt carcasses appeared meatier than barrows; consequently, more gilt carcasses were selected for the meatier U.S. No. 1 grade, while more barrow than gilt carcasses were selected for the U.S. No. 3 grade.

Zobrisky et al. (1959) compared the carcass characteristics of littermate boars, barrows, gilts, and spayed gilts. Their data indicate that boars had larger loin eyes, yielded a higher percentage of bone and the four lean cuts than did littermate barrows, gilts or spayed gilts. The barrows were the most highly finished followed by spayed gilts, gilts, and boars. In another study, Zobrisky et al. (1960) noted that for each unit of increase in backfat thickness, the percent of trimmed fat was twice

as great for barrows as for boars and gilts. Later, Zobrisky et al. (1961) reported no difference in dressing percentage among barrows, gilts and boars. They still observed a higher percentage of lean in the order of boars gilts barrows. However, in this study, significant differences in backfat thickness were not observed.

Kropf et al. (1959) reported that carcasses from barrows contained 3.1 percent more fat, and 0.7 percent less protein than the carcasses from similar weight gilts. Handlin et al. (1961) also found that gilt carcasses were leaner, had greater loin eye area, higher specific gravity of the ham, were longer, and yielded a higher percentage of lean cuts than barrow carcasses. Wallace et al. (1960) reported similar results in that gilts yielded 0.14 inches less backfat, had 0.48 sq. in. more loin eye area and 1.5 percent more lean cuts than barrows. They further stated that in terms of lean cuts as a percentage of live weight, the 180 lb. barrows were about equivalent to 210 lbs. gilts, or 210 lb. barrows equivalent to 240 lb. gilts.

Bruner and VanStavern (1961) studied the influence of age on carcass characteristics of swine. They found that age differences when rather small are relatively unimportant on carcass characteristics; such as backfat, when hogs were slaughtered at an equal final weight.

This study which involved 1174 barrows and 1259 gilts established that as gilts mature the loin eye area tends to become larger and the percent of lean cuts greater. Elson et al. (1961) reported similar results in reference to loin eye area with increasing age. They found as age increased the fiber size and fat content of the longissimus dorsi muscle also increased. They estimated that the longissimus dorsi fibers had completed 70 percent of their growth by 180 days of age.

Fletcher et al. (1963) compared 79 barrow and gilt carcasses as to wholesale cuts, edible portion, fat, and bone. Their data showed that gilts have a significantly greater edible portion in the ham and loin, and significiantly greater percent of bone. Judge (1964) also found the mean weight of edible portion of hams and loins from gilts was greater than from barrows. He further stated that the data obtained from gilts were less variable than that of barrows, especially the loin eye area.

Plank and Berg (1963) reported that gilt carcasses were superior to those of barrows with a tendency for the differences to be greater in an equalized limited feeding system. They suggested that sex differences in carcass quality probably arise from metabolic differences which influence the relative production of fat and lean tissue. Using a chromic oxide technique they found non-significant differences between sexes in apparent dry matter

digestibility. Therefore, the differential utilization of these nutrients by the body occurs after digestion rather than from differential digestion in the alimentary tract.

Charette (1961) and Wagner et al. (1963) both report that boars yielded superior carcasses when compared to gilts and barrows as measured by less backfat thickness, greater percentage of lean cuts, larger loin eye area, and more length of side. The latter also reported that gilts had a higher dressing percent than either barrows or boars which agrees with the data of Hale and Southwell (1966).

Cox (1963) obtained data on 3898 Durocs and 3744 Hampshires to study the effect of sex on carcass leanness. They found a significant decrease in fat thickness over the shoulder, back, and loin in favor of the gilts over the barrows. The study of Salmela et al. (1963) further points out the significant influence of sex on carcass characteristics in that they found gilts to yield carcasses which were superior to barrows in all attributes of carcass leanness.

In more recent studies, Rahnefeld (1965) reported the effect of breed and sex upon 1596 pigs of Lacombe and Yorkshire breeding and their reciprocal crosses. Interestingly, in view of all the literature cited as to the superiority of gilts over barrows, this group found no breed or sex differences in proportion of fat as

measured at the shoulder, last rib, and loin. However, McCampbell and Baird (1965) did observe the more commonly reported differences. They observed that boars and barrows had significantly faster rates of gain when compared to gilts. Feed efficiency was similar for barrows and boars, while gilts were approximately 4.5 percent more efficient. Dressing percentage was significantly higher for barrows than boars and gilts; furthermore, average backfat was significantly higher for barrows than boars and gilts. Loin eye area was significantly higher for boars and gilts than barrows. The same was true for percent ham and loin.

Because of the known difference in carcass characteristics of barrows, gilts, and boars, several scientists have endeavored to try and duplicate this difference by use of estrogens and androgens administered orally or injected.

Woehling et al. (1951) observed no significant differences in growing-finishing swine treated with either testosterone or stilbestrol on average daily gain, feed per 100 lbs. of gain, daily feed consumption, dressing percentage, length of carcass, loin eye area, or backfat thickness. On the other hand, Dinusson et al. (1951) observed no consistent stimulus to daily gain, but did note an improvement in feed efficiency of 5 to 13 percent. Side effects of hormone treatment were also observed; namely, teat development in both barrows and gilts,

a mild nymphomaniac response and extreme swelling of external genitalia of gilts, and a restored ability for erection and renewal of sex desire in barrows.

Similar results were reported by both Sleeth et al. (1953) and Pearson et al. (1952) in that neither testosterone, estradiol, the combination of the two, or stilbestrol appeared to influence significantly feedlot performance or carcass merit of barrows and gilts. The latter group did observe that stilbestrol depressed the growth rate of the young boars.

Beeson et al. (1955) found, with chemical analysis of carcasses, that testosterone fed pigs had approximately 5 percent less fat and 5 percent more lean than control pigs. The testosterone feeding produced significantly heavier hams, picnics, and loins than the controls. Stilbestrol did not exert this effect. Neither of the orally administered hormones caused a significant increase in growth rate, feed efficiency, or feed consumption. Noland and Burris (1956) also reported leaner carcasses from pigs fed methyl testosterone as evidenced by a higher percent of primal cuts. In this study, they compared the effect of methyl testosterone on intact males, castrated males, intact females, and castrate females. They observed statistically significant differences between castrates and intact males and females; however, castrate males gained appreciably faster than intact females.

Tribble et al. (1958) also used intact and castrate males and females to determine the effect of added hormones. Their data indicate that neither sex nor added hormones caused significant differences in rate of gain. There was a sex stilbestrol interaction in that the males increased and the females decreased in rate of gain when stilbestrol was fed. Non-significant differences were noted between controls and stilbestrol treatments; however, boars yielded less fat and a higher percent of lean cuts than the other groups. The carcasses of the gilts ranked second on percent of fat and lean cuts with barrows and spayed gilts having about the same. Likewise, Cahill et al. (1960) observed non-significant differences in carcasses of barrows and gilts treated with stilbestrol as compared with untreated pigs.

Bratzler et al. (1954) used 24 boar pigs to determine the effect of testosterone and castration on growing-finishing swine. Treatments involved castrating at 70 lbs., 100 lbs., 140 lbs., 180 lbs., with a control lot of boars, and a group of boars castrated at 70 lbs. fed methyl testosterone. When the carcasses of the various treatments were compared, the boars and the 180 lb. castrates had a higher percent of lean in the rough loin, less backfat thickness, greater body length and a higher yield of preferred cuts. The performance of the castrates implanted with testosterone was not significantly improved over the

other castrates. Perry et al. (1956) reported similar results when testosterone was added to swine finishing rations. They did observe at a high level of methyl testosterone intake (27 mg.) a significant growth depression. It was in this range that decreased fat deposition was apparent as indicated by significantly less backfat.

Thrasher et al. (1959) conducted three trials involving 180 weaning pigs to determine the effects of various testosterone analogs, combination of testosterone and stilbestrol, and late castration. The oral administration of several testosterone analogs showed no effect upon growth rate or carcass quality. Similar results were found for combinations of feeding and implanting stilbestrol and testosterone.

More recently, Beacom (1963) reported on the effect of diethyl-stilbestrol and estradiol-testosterone implantations which showed no overall effect of hormone treatments on rate of gain. A reduction in feed consumption of 0.4 pound per day per pig was obtained which was reflected in an overall improvement in feed efficiency. He did observe a protein x hormone interaction which indicated that the major improvement due to implantation occurred when additional protein was fed. Also, a highly significant hormone x sex interaction showed clearly that the hormone implanted into gilts had no beneficial effect on feed efficiency, but the hormone implanted into the barrows did

improve feed efficiency. The hormone implantation had no effect on the carcass grades of gilts, but implanting the barrows increased the percentage of grade A carcasses.

C. Interaction of sex and limited feeding upon the performance of swine.

Lucas and Calder (1956) reported that restricting the plane of feeding after 100 lbs. live weight, had a marked effect in reducing the shoulder-fat measurements of females, but did not effect the depth of shoulder-fat of the barrows. This report agrees with the early report of McMeekan (1940) in which he obtained a 20 percent reduction in total fat of females by HL plane of feeding as compared with HH, but the HL growth curve reduced the total fat in the carcasses of males by less than 2 percent. The interaction was not evident in the shoulder-fat measurements on the carcasses of McMeekan's pigs, but it was shown by the reduced last rib and loin fat measurements.

Baird et al. (1959) compared tallow feeding initiated at various weight intervals, stilbestrol implantation, and tranquilizers for growing finishing swine. The only source of variation found to be significant for average daily gain was sex (barrows > gilts) and the interaction of sex x treatment. The same interaction (sex x treatment) was highly significant for dressing percentage and backfat thickness.

Kropf et al. (1959) noted that the composition of gilt carcasses seemed to be affected more by the balance of amino acids fed than did barrow carcasses; however, this difference was non-significant. They suggested that since gilt carcasses were more muscular, carcass composition of gilts may be more sensitive to changes in quality and quantity of protein in the ration.

Troelsen and Bell (1962) found no important statistically significant interaction between sexes and treatment of varying types of fiber, levels of fiber, or meal and pellets. Stothers (1963) reported similar results on the interaction of sex and meal vs. pellets. In all lots, regardless of sex the best feed efficiency was observed in the hand-fed pellet lots as compared with hand-fed or self-fed mash. However, he did report that differences in backfat thickness, carcass length, and loin eye area were non-significant.

On the other hand, Robinson (1964) observed a greater response by gilts to a change in plane of nutrition during a period of compensatory growth which had been preceded by a limited plane of nutrition as compared to barrows. He further observed, as suggested by Kropf et al. (1959), that gilts made a greater growth response than barrows to the supplementation of amino acids (lysine and methionine) when fed an amino acid deficient barley ration.

In the absence of amino acid supplementation, the performance of the gilts was inferior to barrows. He also reported that boars respond to high protein levels more than castrates. This suggests that even under normal feeding conditions, boars and possibly gilts, may suffer some disadvantages owing to their apparently higher requirements for protein than the more rapidly maturing and therefore, fattening castrate. In his study, Robinson (1964) found a non-significant sex x restricted feed intake interaction.

Beacom (1964) reported the rate of gain of barrows was reduced to a greater degree by ration dilution than was that of the gilts. At the level of 50 percent fiber in the ration, gains of barrows were reduced 44 percent and those of gilts by 26 percent compared with their respective control groups. His data suggests that barrows were more efficient when fed undiluted rations, but less efficient when fed the highly diluted ration. He did observe the characteristic differences in carcass quality of barrows and gilts in that gilts were .5 in. longer, had .15 in. less shoulder-fat, and .25 to .44 more sq. inches of loin eye area.

III. EXPERIMENTAL PROCEDURE

A. Introduction

Seven feeding experiments were conducted involving a total of 449 pigs. The objectives of these experiments were to study and evaluate the effects of various methods of limiting feeding, the influence of the sex of the pig, and the interaction of sex and limited feeding on the feedlot performance and carcass characteristics of swine.

The criteria for comparison of feedlot performance were average daily gain, feed consumption per pig per day, pounds of feed reauired per pound of gain, and experimental days required to reach a slaughter weight of approximately 200 - 220 lbs.

The criteria for comparison of carcass quality were dressing percentage, carcass length, backfat thickness, loin eye area, and the individual percentages of the wholesale cuts. In addition, percent ham and loin, percent lean cuts, percent primal cuts, and percent fat trim were calculated. All carcass measurements were taken after the carcasses had been chilled for 40 to 48 hrs. at 34° to 36° F. Thickness of backfat was measured at the first rib, seventh rib, last rib, and last lumbar vertebra and the average of the four measurements used for comparison. Carcass length was measured from the anterior edge of the first rib to the anterior edge of the aitch bone. The

carcasses were cut according to standard packing house procedure with a 2-1/2 rib shoulder. Percentage of lean cuts was calculated by relating the combined weights of skinned hams, trimmed shoulders, and trimmed loins to chilled carcass weight. Percentage of primal cuts was calculated by adding the pounds of lean cuts to belly weights and expressed as a percentage of chilled carcass weight. The hams were faced leaving one-fourth inch of fat on the front of the face with the facing running back to skin thickness about one-third of the way back to where the bulge of the ham meets the hock. Excess fat was trimmed from the shoulder leaving one-fourth inch of fat covering. Loin eye area measurements were taken by cutting the loin at the 10th rib and making acetate paper tracings of the longissimus dorsi muscle. The area of the loin eye muscle was then determined by use of a compensating polar planimeter.

In all trials except experiment 4, the sexes were fed separately. The general procedure for lotting was essentially the same in every trial. Pigs were randomized to experimental treatments taking into account weight, sex, breed, litter, and thriftiness.

In all experiments the pigs were housed in an open-fronted building with concrete floors. The pens were 10 ft. x 15 ft. and were separated by 40 inch high solid partitions. Manure was removed from each pen by a shuttle-stroke gutter

cleaner which traversed across the center of the pen. Automatic water fountains were located in each pen to permit continual access to water.

All feed offered in each trial was in dry meal form. Full-fed pigs, unless mentioned otherwise, ate from self-feeders which were constantly checked for adjustments in order to minimize feed wastage. The limited-fed lots were fed on the floor in the rear of the pen. This feeding area was set apart by a 10-compartment stanchion across the pen, 12 inches from the back wall. Feed was placed on the floor behind the stanchion in equal amounts so that each pig received an equal share. Fighting during feeding was negligible because of the stanchion.

Feed and growth data were collected at 2 week intervals. However, near the end of the trial as the pigs approached slaughter weight, they were weighed weekly. The pigs were individually removed from the experiments as they reached 200 - 215 lbs. live weight, held off-feed for 15 to 18 hrs. and then slaughtered at the University Meat Laboratory. During the fasting period the pigs did have access to water.

The seven experiments involved in this investigation were as follows:

Experiment 1. Comparison of barrows and gilts fed 5 lbs. of feed per day and ad libitum feeding.

Experiment 2. Comparison of barrows and gilts fed 5 lbs. of feed per day by hand and by auger with ad libitum feeding.

Experiment 3. Comparison of barrows and gilts fed 60, 70, 80, and 90 percent of ad libitum fed barrows and gilts.

Experiment 4. Study of various methods of restricting feed intake.

Experiment 5. Study of rate and efficiency of gain of full sib pigs.

Experiment 6. Varying energy level study using barrows and gilts fed an equal protein, mineral, and vitamin intake each day.

Experiment 7. Comparison of limited and ad libitum feeding of boars, barrows, gilts, and spayed gilts.

All data were treated statistically by analysis of variance (Snedecor, 1956). Treatment means were compared by the multiple range test of Duncan (1955). Correlations were developed between and within the parameters of growth and carcass characteristics.

B. Experiment 1. - Comparison of barrows and gilts fed 5 lbs. of feed per day and ad libitum feeding.

The purpose of this experiment was to determine the effect of a constant level of restriction upon the performance and carcass merit of barrows and gilts. The composition of the basal ration used is shown in Table 1.

Thirty-six finishing pigs were allotted to the following four treatments: gilts versus barrows limited-fed 5 lbs. of feed per day, and gilts versus barrows ad libitum-fed. The pigs were started on trial at an average weight of 145 and 158 lbs. for gilts and barrows, respectively.

The limited-fed pigs were fed by an auger three times a day: 8:00 a.m., 12:00 noon, and 5:00 p.m. To check the amount of feed the auger was delivering to each lot, feed was continually weighed into the hopper of the mechanical feeder.

C. Experiment 2. - Comparison of barrows and gilts fed 5 lbs. of feed per day by hand and by auger with ad libitum feeding.

The purpose of this investigation was to confirm, or to refute, the results obtained in the preceding trial. With that objective in mind, trial 2 was essentially a repeat of trial 1 except an additional lot of both barrows and gilts were added. The purpose of the added lots was to compare restriction by hand and by auger. This comparison

Table 1.-Ingredient Composition of Rations

Ingredient	Finisher Expt. 1&2	Finisher Expt. 3,4, 5&7	Grower Expt. 5&7	Basal Expt. 6
	%	%	%	%
Corn	84.8	86.8	77.7	52.8
Soybean Meal (50%)	10.0	6.5	15.0	40.0
Meat & Bone Scraps (50%)	--	2.5	2.5	5.0
Alfalfa Meal (17%)	2.5	2.5	2.5	--
Limestone	0.9	0.5	0.6	0.3
Dicalcium Phosphate	0.8	0.2	0.2	0.4
Trace Mineral Salt (hi-Zn)	0.5	0.5	0.5	0.5
VATM - premix	0.5[a]	0.5[a]	0.5[a]	1.0[b]
Calculated analysis:				
% Protein	12.9	12.4	16.1	27.0
% Ca	.60	.56	.67	.89
% P	.48	.43	.48	.77

[a]The pounds of VATM - premix consists of 0.6 lbs. of MSU A & D mix[c]; 1.0 lb. of B vitamin mix[d]; 1.0 lb. of Vitamin B_{12} conc.[e]; 2.0 lbs. of pro-strep "20"; 0.1 lb. zinc oxide; and 5.3 lbs. of ground yellow corn.

[b]Ten pounds of VATM - premix consists of 0.3 lb. MSU A & D mix[c]; 0.5 lb. of B vitamin mix[d]; 1.75 lbs. of Vit. B_{12} conc.[e]; 1.5 lbs. of pro-strep "20"; 0.15 lb. of zinc oxide; and 5.80 lbs. of ground yellow corn.

[c]MSU A & D mix contains 8000,000 IU of Vit. D per lb. and 3,628,720 IU of Vit. A per lb.

[d]Merck 1231 contains 8,000 mg. of riboflavin per lb., 14,720 mg. of pantothenic acid per lb., 36,000 mg. of niacin per lb., and 40,000 mg. of choline per lb.

[e]Dawes B_{12} contains 6 mg. of Vit. B_{12} per lb.

was necessary because of the observed separation of nutrients in the ration as it moved down the auger in trial 1. Data are presented in Table 2.

Sixty pigs, weighing approximately 135 lbs., were allotted into 6 uniform lots. The pigs were of Yorkshire, Hampshire, and crossbred breeding. The treatments used in this experiment were as follows: gilts versus barrows limited-fed 5 lbs. of feed per day by hand; and gilts versus barrows ad libitum-fed. The ration fed was the same as experiment 1 and is listed in Table 1. The limited-fed lots were fed three equal feedings a day.

D. Experiment 3. - Comparison of barrows and gilts fed 60, 70, 80, and 90 percent of ad libitum fed barrows and gilts.

In the two previous experiments a difference in daily intake was noted between barrows and gilts. Consequently, when a constant level of feed is offered to both sexes, the level of restriction on a percentage basis is not equal. This study was initiated to compare the performance and carcass quality of barrows and gilts restricted to the same percentage of full-feed. An additional purpose was to determine the optimum level of restriction for each sex.

With these objectives in mind, one hundred Yorkshire, Hampshire, and crossbred pigs were allotted to the following ten treatments: gilts versus barrows with each sex fed 4

Table 2.-Summary of Feedlot Performance and Carcass Data by Main Treatment Variables (Exp. 1)

Variable	Sex		Level of Feeding	
	Barrows	Gilts	Ad Lib	Limited[1]
No. pigs	18	18	18	18
Initial wt., lbs.	158.1	145.5	152.3	151.3
Final wt., lbs.	214.3	211.8	217.1	208.9
Da. gain, lbs.	1.53	1.44	1.75**	1.22
Da. feed, lbs.	6.33	5.64	6.95	5.01
Feed/gain,	4.12	3.94	4.02	4.04
Exp. days	38.2*	46.8	38.5*	46.4
Slaughter age, da.	177.1*	185.7	177.4*	185.3
Dress, %	73.2	73.6	73.1	73.7
Carc. length, in.	29.8	30.4**	30.1	30.1
Backfat, in.	1.62	1.50	1.59	1.52
Loin area, sq.in.	4.08	4.41*	4.16	4.34
Ham, %	18.6	19.4	18.9	19.1
Loin, %	16.9	17.6	17.7	17.4
Shoulder, %	17.0	17.1	17.0	17.1
Belly, %	12.3*	11.5	12.0	11.8
Fat trim, %	23.6	21.8	23.0	22.4
Leaf fat, %	3.2	3.3	3.2	3.3
Ham & loin, %	35.5	37.0*	36.0	36.5
Lean cuts, %	52.6	54.1	53.0	53.7
Primal cuts, %	64.9	65.6	65.0	65.5

[1]Limited-fed pigs were fed 5 lbs. of feed per day.
*Significant at 5% level.
**Significant at 1% level.

levels of restricted feed intake (60, 70, 80 and 90 percent) and ad libitum.

The daily feed intake of the restricted lots was based upon the feed intake of the full-fed (ad libitum) lots. Feed adjustments were made each week. Feed consumption, during the last week in which the ad libitum-fed lots were intact, determined the level of feed intake of the limited-fed lots for the remainder of the trial. This experiment was initiated when the pigs averaged 105 lbs. All limited-fed lots were hand-fed two equal feedings of the finisher ration listed in Table 1. The pigs were fed at 8:00 a.m. and 5:00 p.m.

E. Experiment 4. - Study of various methods of restricting feed intake.

The purpose of this investigation was to determine the influence of an appetite depressant and intermittent feeding upon swine performance and carcass acceptability.

In this experiment the barrows and gilts were not fed separately, but in mixed lots. Each lot was balanced as evenly as possible for sex. Four lots of ten head each were lotted from forty Yorkshire and crossbred pigs. The treatments were as follows: lot 1, ad libitum fed basal ration; lot 2, ad libitum fed basal ration plus 10 mg./lb. of MK 541 (L-dichloroamphetamine) an appetite depressant;

lot 3, ad libitum feeding of basal ration every second 24 hr. period; lot 4, ad libitum feeding of basal ration every third 24 hr. period.

The basal ration used in this experiment was the same as Experiment 3, and is listed in Table 1. Lot 3 had access to a self-feeder from noon one day till noon the next, followed by a 24 hr. of fasting period before self-feeders were again placed in the pen. Lot 4 received similar treatment; however, the fasting period was lengthened to 48 hrs. In order to obtain comparable final weights, the slaughter weights were used in this trial to determine the parameters of feedlot performance.

F. Experiment 5. - Study of rate and efficiency of gain of full sib pigs.

The objectives of this trial were to determine differences in ad libitum-fed littermates (barrows and gilts) in terms of daily gain, daily feed intake, and efficiency of feed conversion.

The trial consisted of 33 barrows and 33 gilts allotted to 6 lots of 11 head each. Special care was taken to have full sibs in each of three replicates. The pigs were ad libitum fed throughout the trial. From 60 to 125 lbs., the pigs were fed a 16 percent protein grower ration (ingredients listed in Table 1). During the remainder of the trial, the pigs were fed the finisher ration used in

Experiment 3 and 4 (Table 1). The duration of the trial was 84 days. Only feedlot performance data were obtained in this experiment.

G. Experiment 6. - Varying energy level study using barrows and gilts fed an equal protein, mineral, and vitamin intake per day.

In all trials previously conducted in this study, the basal rations were restricted. This not only limited energy, but also protein, mineral, and vitamin intake. Therefore, the purpose of this experiment was to determine the influence of restricting only energy to finishing swine.

To obtain a constant protein, mineral, and vitamin intake, a high protein-fortified basal ration was used. The basal ration was fed at a rate of 3 lbs. per head per day to each of the seven lots. The composition of the basal ration is listed in Table 1. The energy levels were varied by adding different levels of corn starch to the basal ration.

Forty barrows and thirty gilts of Yorkshire breeding were used in this study. These pigs were allotted to the following seven treatments: gilts versus barrows fed 3 lbs. of basal ration (B); gilts versus barrows fed 3 lbs. of basal ration plus 1 lb. of corn starch (B + 1); gilts versus barrows fed 3 lbs. of basal ration plus 2 lbs. of corn starch (B + 2); and barrows fed 3 lbs. of basal ration plus 3 lbs. of corn starch.

Since the rations with the added corn starch were extremely fine in texture, the pigs were placed on pre-trial rations containing starch to determine the level of feed they would consume. No problems in feed intake were noted. The pigs were started on experiment when they reached approximately 100 lbs. When each lot averaged 125, 150, and 175 lbs. of live weight, respectively, the starch portion of the ration was increased by 0.5 lb. increments, respectively.

The highest levels of daily feed intake for each sex were very similar to full-fed lots in previous experiments. Therefore, these lots were considered to be full-fed in order that the percentage of restriction could be determined for the other lots. Gross energy of all experimental rations was determined by bomb calorimetry.

H. Experiment 7. - Comparison of limited and ad libitum feeding of boars, barrows, gilts, and spayed gilts.

The purpose of this experiment was to determine the effect of limited feeding upon the various sexes of swine.

Initially, 6 litters of York x Hamp crossbred (Yorkshire sire) pigs and 6 litters of Hamp x York crossbred (Hampshire sire) pigs were selected for this trial. Each of these litters contained 4 boars and 4 gilts. Two weeks after weaning, the pigs were randomly assigned to four sex groups: boars, barrows, gilts, and spayed gilts. Each litter was

represented in each sex group by 2 pigs. Those boar pigs designated to be barrows were then castrated. The gilts designated to be spayed were anesthetized to permit a posterior mid-line belly incision to be made. A hysterectomy was then performed by removing the uterine body and horns plus the oviducts and ovaries. Throughout the operation, surgical aseptic techniques were used; however, 3 pigs died from the combination of surgery and anesthesia.

Prior to being placed on experiment and throughout the trial, each sex group was fed the grower ration (Table 1). One litter was discarded because the pigs were considerably larger than the other litters. The remaining 11 litters were divided into 8 lots of ten head each, except for the lack of one spayed gilt. Seven of the 11 litters had a pig in each of the 9 treatments. The treatments for this trial were as follows: 4 sex conditions (boars, barrows, gilts, and spayed gilts), with one lot within each sex group fed ad libitum and the other lot limited to 80 percent of the full-fed group. The daily feed intake of each of the restricted lots was based on the feed consumption of their respective sex ad libitum fed lot. The feed intake data for the ad libitum lots were determined in the same manner as in Experiment 3.

IV. RESULTS AND DISCUSSION

A. Experiment 1. Comparison of barrows and gilts fed 5 lbs. of feed per day with ad libitum feeding.

Table 2 summarizes the feedlot performance and carcass data by sex and level of feeding. Individual lot performance and carcass data are summarized in Table 3.

Pigs full-fed gained an average of 1.75 pounds per head per day compared to 1.22 for the pigs limited to 5 pounds of feed per day. This difference was highly significant ($P<.01$). Approximately 8 days more feeding time was required by the restricted-fed pigs to reach slaughter weight. This difference was significant ($P<.05$). The feed required per unit of gain was approximately the same for the restricted and full-fed pigs (4.04 vs. 4.02). The feed efficiency data disagrees with Thrasher et al. (1962), who reported a higher requirement per pound of gain, and Becker et al. (1963) who reported a lower requirement per pound of gain for restricted-fed pigs. Both these groups of researchers reported similar depressions in growth rate of the restricted-fed pigs.

Carcass data showed there were no differences between ad libitum and restricted-fed pigs for any of the parameters studied. The lack of improved leanness in the restricted-fed pigs was surprising; however, the pigs were averaging over 150 lbs. when the trial was initiated.

TABLE 3.-Summary of Feedlot Performance and Carcass Data for Individual Lots (Exp. 1)

Sex	Barrows		Gilts			Stt.Sign.
Type of Feeding[1]	Limited	Ad Lib	Limited	Ad Lib	S.E.[2]	Sex X Trt.
No. pigs	9	9	9	9	---	-
Initial wt., lbs.	156.9	159.3	145.8	148.2	-	-
Final wt. lbs.	208.8	219.8	209.1	214.4	2.79	-
Da. gain, lbs.	1.14[c]	1.92[a]	1.31[c]	1.57[b]	.06	.00
Da. feed, lbs.	4.97	7.69	5.05	6.22	-	-
Feed/gain lbs.	4.27	3.97	3.81	4.07	-	-
Exp. days	44.9	31.4	48.0	45.6	3.74	.15
Slaughter, age da.	183.7	170.4	186.9	184.4	4.01	.19
Dress, %	73.6	72.8	73.8	73.5	.42	.77
Carc. length, in.	29.6	30.0	30.6	30.3	.21	.16
Backfat, in.	1.59	1.65	1.45	1.54	.09	.86
Loin area, sq.in.	4.09	4.07	4.58	4.24	.13	.24
Ham, %	18.8	18.4	19.4	19.3	.35	.61
Loin, %	17.1	16.6	17.7	17.5	.37	.75
Shoulder, %	17.0	17.1	17.3	17.0	.34	.58
Belly, %	12.2	12.4	11.4	11.6	.37	.89
Fat trim, %	23.3	23.9	21.5	22.2	1.11	.91
Leaf fat, %	3.3	3.0	3.3	3.3	.21	.49
Ham & loin, %	35.9	35.1	37.1	36.8	.57	.61
Lean cuts, %	53.0	52.2	54.4	53.8	.84	.87
Primal cuts, %	65.1	64.5	65.8	65.4	.83	.84
No. carc. PSW[3]	0	0	1	0	-	-

[1]Limited-fed lots received 5 lbs. of feed per pig per day.
[2]Standard error of means.
[3]Pale, soft, and watery carcass.
[a,b,c] Means on the same line bearing different superscript letters differ significantly ($P < .05$).

McMeekan (1940) suggested that pigs should be limited-fed from 125 lbs. to slaughter weight in order to produce superior grading carcasses. The 60 lbs. of gain during the feeding period may have been too small to permit significant improvements in carcass quality. Early investigations on the effect of limited feeding on swine carcasses indicated a tendency toward softer fat (Ellis and Zeller, 1931; St. Pierre et al., 1934; Hilditch, 1939). Of the thirty-six pigs in this trial only 1 pig yielded a carcass which was classified as pale, soft and watery (PSW).

In this experiment, gilts gained slower than barrows (1.44 vs. 1.53) and required less feed per pound of gain (3.94 vs. 4.12), but neither of these differences were significant. Barrows required significantly fewer days to reach slaughter weight ($P<.05$). The reason the difference in time to reach slaughter weight is significant and the difference in daily rate of gain is not significant is that the barrows were on the average 13 lbs. heavier than the gilts when the experiment was initiated. The terminal weight was similar for both sexes; therefore, the barrows had fewer lbs. to gain during the experimental period than the gilts. Gilts yielded carcasses which were significantly longer ($P<.01$), had larger loin eye areas ($P<.05$), and a greater percentage of ham and loin ($P<.05$). Barrows yielded a higher percentage of belly ($P<.05$). Although gilts yielded less backfat thickness and greater percentage

of lean and primal cuts than barrows, the differences were non-significant.

A significant interaction between sex and level of feeding was observed for rate of gain, indicating that barrows gained significantly faster than gilts on ad libitum feeding ($P<.05$). A difference of .17 lbs. in rate of gain favoring the gilts was noted on the restricted level of feeding; however, this difference was non-significant. The ad libitum-fed gilts consumed 6.22 lbs. of feed per day and the ad libitum-fed barrows consumed 7.69 lbs. per day. Thus, the limited-fed gilts and barrows fed a constant level of 5 lbs. per day were restricted to a level of 80.4 and 65.0 percent, respectively.

B. Experiment 2. Comparison of barrows and gilts fed 5 lbs. of feed per day by hand and by auger with ad libitum feeding.

Feedlot performance and carcass data of pigs fed 5 lbs. per head per day by hand and by auger were compared to determine the effect of the ration separation noted in Experiment 1. Table 5 shows the results of this comparison as well as the influence of sex and level of feeding on feedlot performance and carcass measurements. Table 6 presents the means of the individual lots for feedlot performance and carcass traits.

TABLE 4.-Proximate Analysis of the Experimental Ration at Various Points Along a 20 ft. Horizontal Auger

	Percentages Expressed as fed basis							
Sample Designation	H_2O	Protein	Crude Fiber	Ether Extract	NFE	Ash	Ca	P
At Hopper	8.97	12.94	2.73	3.44	68.27	3.65	.60	.48
5' from Hopper	8.94	13.56	2.66	3.41	67.44	3.99	.74	.50
10' from Hopper	8.92	13.19	2.68	3.47	68.13	3.61	.66	.47
15' from Hopper	8.82	13.31	2.60	4.03	67.83	3.41	.52	.47
20' from Hopper	8.81	10.81	3.11	4.74	70.18	2.35	.31	.39

Table 4 shows the variation in proximate analysis of the finisher ration along the 20 ft. horizontal auger which was used to feed the two restricted-fed lots. The proximate analysis of the experimental ration indicates that as the ration moved down the horizontal auger the smaller particles tended to separate-out. This separation of ration nutritional components created differences in the composition of the ration at various intervals down the auger. The restricted-fed lot neares the auger hopper, which was gilts, received a ration higher in percent protein, calcium, phosphorus and total ash than the other restricted-fed lot. The restricted-fed barrows, fed by the last 10 ft. of auger, received a higher percentage of crude fiber and ether extract. How the changing composition of the experimental ration affected the performance of the restricted-fed pigs is a matter for speculation.

TABLE 5.-Summary of Feedlot Performance and Carcass Data by Main Treatment Variables (Exp. 2)

Variable	Sex		Level and method of Feeding		
	Barrows	Gilts	Ad-Lib	A-LF[1]	H-LF[2]
No. pigs	30	30	20	20	20
Initial wt., lbs.	137.9	130.6	134.0	133.4	135.3
Final wt., lbs.	205.5	204.1	208.8	202.2	203.4
Da. gain, lbs.	1.39	1.39	1.87[a]	1.12[b]	1.18[b]
Da. feed, lbs.	5.53	5.34	7.08	4.44	4.78
Feed/gain, lbs.	4.08	3.97	3.82	4.08	4.18
Exp. days	52.3	56.3	40.4[a]	63.2[b]	59.3[b]
Slaughter, age,da.	173.3	179.1	162.0[a]	184.6[b]	182.0[b]
Dress, %	71.8	72.8*	72.1	72.2	72.4
Carc.length, in.	29.9	29.7	29.9	29.9	29.6
Backfat, in.	1.41	1.33	1.44[a]	1.28[b]	1.38[ab]
Loin area, sq.in.	3.66	4.21**	3.81	4.15	3.85
Ham, %	19.0	19.8**	18.6[a]	19.9[b]	19.5[b]
Loin, %	15.9	16.8**	16.0[b]	16.9[a]	16.2[b]
Shoulder, %	17.2	17.2	17.0	17.6	17.0
Belly, %	13.0	12.6	12.9	12.7	12.9
Fat trim, %	24.9	24.3	26.3[b]	22.8[a]	24.8[ab]
Leaf fat, %	3.2	2.9	3.1	3.8	3.2
Ham & loin, %	34.9	36.6**	34.6[a]	36.8[b]	35.7[c]
Lean cuts, %	52.1	53.8**	51.6[b]	54.5[a]	52.8[b]
Primal cuts, %	65.2	66.4**	64.6[a]	67.2[b]	65.6[c]

[1]Limited-fed 5 lbs. per pig per day using an auger. (A-LF).
[2]Limited-fed 5 lbs. per pig per day by hand. (H-LF).
[a,b,c]Means on the same line bearing different superscript letters differ significantly ($P < .05$).
*$P < .05$.
**$P < .01$.

TABLE 6.-Summary of Feedlot Performance and Carcass Data for Individual Lots (Exp. 2)

Sex	Barrows			Gilts				Stt. Sign.
Type of Feeding[1]	Ad-Lib	A-LF	H-LF	Ad-Lib	A-LF	H-LF	S.E.[2]	Sex X Trt.
No. pigs	10	10	10	10	10	10	-	-
Initial wt., lbs.	137.6	133.4	142.8	130.4	133.5	127.8	-	-
Final wt., lbs.	209.7	202.0	204.8	207.9	202.4	201.9	2.04	-
Da. gain, lbs.	1.91	1.10	1.16	1.84	1.13	1.21	.06	.60
Da. feed, lbs.	7.41	4.40	4.75	6.74	4.49	4.80	-	-
Feed/gain, lbs.	3.93	4.07	4.24	3.70	4.09	4.11	-	-
Exp. days	38.3	63.5	55.1	42.5	62.8	63.5	4.52	.61
Slaughter age, da.	159.2	183.9	176.8	164.8	185.2	187.2	4.07	.54
Dress, %	72.0	71.7	71.5	72.2	72.6	73.2	.47	.30
Carc. length, in.	30.0	30.0	29.8	29.9	29.8	29.4	.29	.95
Backfat, in.	1.51	1.28	1.42	1.36	1.27	1.34	.05	.42
Loin area, sq.in.	3.54	3.83	3.62	4.07	4.47	4.08	.16	.86
Ham, %	17.8	19.9	19.2	19.4	20.0	19.8	.34	.07
Loin, %	15.4	16.6	15.7	16.6	17.2	16.7	.26	.50
Shoulder, %	16.9	17.6	17.2	17.0	17.7	16.9	.31	.71
Belly, %	13.3	12.8	13.0	12.6	12.6	12.7	.32	.71
Fat trim, %	26.6	23.0	25.0	25.9	22.5	24.5	1.16	.98
Leaf fat, %	3.1	3.1	3.4	3.2	2.5	3.1	.20	.24
Ham & loin, %	33.2	26.5	34.9	36.1	37.2	36.5	.48	.09
Lean cuts, %	50.1	54.1	52.1	53.1	54.9	53.4	.64	.21
Primal cuts, %	63.4	66.9	65.2	65.7	67.6	66.1	.47	.18
No. carc. PSW[3]	0	0	0	0	0	0	-	-

[1]A-LF refers to lots limited-fed 5 lbs. per pig per day using an auger.
H-LF refers to lots limited-fed 5 lbs. per pig per day by hand.
[2]Standard error of means.
[3]Pale, soft, and watery carcass.

Small differences were noted between pigs fed 5 lbs. per pig per day by hand and those fed 5 lbs. per head per day by auger. Differences in rate of gain, age at slaughter, backfat thickness, carcass length and loin eye area were all non-significant. Similar results were obtained for the following percentages: shoulder, fat trim, leaf fat, and belly. Significant increases in percent loin ($P<.05$), ham and loin ($P<.05$), lean cuts ($P<.05$), and primal cuts ($P<.05$) were observed in favor of the auger-fed group. These differences may be partially explained by the slightly reduced rate of daily feed intake of the auger-fed pigs causing a slower rate of gain. The difference in daily feed intake was due to a periodic malfunctioning of the automatic auger feeder.

Full-fed pigs gained significantly faster than those restricted-fed ($P<.05$). As a result of the slower gains made by the restricted-fed pigs, an average of approximately 21 days additional time was required to reach slaughter weight ($P<.05$). Full-fed pigs required 7 percent less feed per pound of gain than the average of the restricted-fed groups. Thrasher et al. (1964) also reported less feed required per pound of gain in favor of full-fed pigs over pigs restricted-fed to a constant level of feed intake from 100 lbs. to slaughter weight.

Backfat thickness was significantly lower for the pigs restricted-fed by auger ($P<.05$) as compared with full-fed pigs. Carcass length, dressing percentage, and loin eye area were similar for all treatments. Limited auger-fed pigs yielded a significantly higher percentage of loin ($P<.05$) than either limited hand-fed or full-fed pigs which were similar. Carcasses from full-fed pigs were significantly inferior to both limited-fed lots as measured by percent ham and loin ($P<.05$) and percent primal cuts ($P<.05$). They were inferior to the hand-fed restricted lots in percent lean cuts, and percent loin; however, these differences were not significant. The limited auger-fed pigs yielded significantly more percent loin ($P<.05$) and percent lean cuts ($P<.05$) than the full-fed pigs. Keese et al. (1964) reported similar carcass improvements with respect to leanness and cutability of restricted-fed pigs as compared with pigs full-fed.

It is generally accepted that gilts gain slower but more efficiently than barrows. In this experiment, barrows and gilts gained at the same rate. Feed efficiency slightly favored the gilts (3.97 vs. 4.08). The major differences between barrows and gilts were observed in the carcass traits. Gilts yielded carcasses with significantly greater percent of each of the following: ham, loin, ham and loin, lean cuts, and primal cuts ($P<.01$). In addition, gilt carcasses possessed 0.55 sq. in. more loin eye area

($P<.05$) and dressed 1 percent higher ($P<.05$). Gilts yielded carcasses which were 0.2 in. longer and carried approximately 0.1 in. less backfat than barrows; however, these differences were not significant. Zobrisky et al. (1961) reported similar data from one study with respect to sex effect upon backfat thickness; however, in two earlier studies Zobrisky et al. (1959, 1960) reported barrows to be significantly leaner.

In this experiment no significant sex x treatment interactions were observed. The data presented in Table 6 indicates that both sexes were influenced in a similar manner by feed restriction. The backfat thickness and percent ham and loin seemed to be improved more in the barrows, but still remained inferior to the gilts in this respect. Ad libitum-fed barrows ate approximately .7 pounds more feed per day than ad libitum-fed gilts. This resulted in the restricted-fed barrows and gilts being fed approximately 62% and 69% of full-feed, respectively. The differences in percentage of restriction observed in this trial compared with trial 1, arises primarily from the increased consumption of feed by the ad libitum-fed gilts. The full-fed gilts in this trial consumed approximately 0.55 pounds more feed per day than in the previous trials. This difference resulted in an increased daily gain of the full-fed gilts which was more comparable to the full-fed barrows. Therefore, no interaction between sex x

treatment was observed for rate of gain in this trial as noted in the previous trial.

C. Experiment 3. Comparison of barrows and gilts fed 60, 70, 80 and 90 percent of ad libitum-fed barrows and gilts.

The data for this experiment are summarized by sex and level of feeding in Table 7. Individual lot means are given in Table 8.

Table 7 shows that as the level of daily feed intake was decreased from full feeding to 60% of full feed the rate of gain decreases linearly at an average of .18 pounds per day for each reduction of 10% in feed intake. Each level of feeding was significantly different from the other in regards to rate of gain ($P<.05$). The most efficient group of pigs was the group restricted to 90% of full feed. The least efficient was the 60% restricted group. Only slight differences were found in feed required per pound of gain for the full-fed, 90%, 80%, and 70% groups; however, the 60% group required approximately 11% more feed per pound of gain than the most efficient group. Age at slaughter obviously was affected by rate of gain with each 10% restriction increasing the age at slaughter by an average of 12 days. Greer et al. (1963), Thrasher et al. (1962) and Orme et al. (1963) reported similar linear decreases in rate of gain with decreasing percentage of full feed intake. Feed efficiency data appears

TABLE 7.-Summary of Feedlot Performance and Carcass Data by Main Treatment Variables (Exp. 3)

Variable	Sex		Level of Feeding				
	Barrows	Gilts	Ad-Lib	90%	80%	70%	60%
No. pigs	50	50	20	20	20	20	20
Initial wt., lbs.	106.4	104.6	106.4	104.0	105.8	105.6	105.6
Final wt., lbs.	216.2	217.1	214.4	216.9	218.4	216.6	216.9
Da. gain, lbs.	1.45**	1.24	1.71[a]	1.55[b]	1.34[c]	1.17[d]	.98[e]
Da. feed, lbs.	5.91	5.14**	6.90	6.10	5.51	4.86	4.26
Feed/gain, lbs.	4.15	4.18	4.08	3.99	4.13	4.16	4.46
Exp. days	79.3**	94.8	64.4[a]	74.2[b]	85.0[c]	95.6[d]	116.1[e]
Slaughter age, da.	192.3**	210.3	178.3[a]	189.4[b]	197.8[c]	209.6[d]	231.3[e]
Dress, %	74.1	73.6	74.2	73.6	74.2	73.8	73.4
Carc. length, in.	29.8	30.5**	29.8[b]	29.9[b]	30.0[b]	30.3[ab]	30.8[a]
Backfat, in.	1.52	1.36**	1.57[a]	1.51[ab]	1.47[b]	1.37[c]	1.29[c]
Loin area, sq.in.	4.14	4.62**	4.01[c]	4.11[bc]	4.45[ab]	4.61[a]	4.73[a]
Ham, %	18.9	20.2**	18.7[b]	19.2[b]	19.1[b]	20.2[a]	20.6[a]
Loin, %	16.4	17.2**	16.2[c]	16.5[bc]	16.5[bc]	17.0[b]	17.8[a]
Shoulder, %	17.8	18.0	17.5[c]	17.5[c]	17.5[c]	18.5[a]	18.2[ab]
Belly, %	13.5**	12.9	13.5[a]	13.6[a]	13.6[b]	13.1[b]	12.4[c]
Fat trim, %	23.5	21.0**	24.8[a]	23.3[b]	23.0[b]	20.4[c]	19.8[c]
Leaf fat, %	3.5	3.1**	3.4	3.5	3.2	3.0	3.3
Ham & loin, %	35.3	37.5**	34.9[b]	35.7[b]	35.6[b]	37.2[a]	38.4[a]
Lean cuts, %	53.0	55.4**	52.4[b]	53.2[b]	53.2[b]	55.7[a]	56.6[a]
Primal cuts, %	66.5	68.3**	66.0[b]	66.8[b]	66.5[b]	68.8[a]	69.1[a]

a,b,c,d,e Means on the same line bearing different superscript letters differ significantly ($P < .05$).

** $P < .01$.

TABLE 8.-Summary of Feedlot Performance and Carcass Data for Individual Lots (Exp. 3)

Sex	Barrows					Gilts						Stt. Sign.
Level of Feeding	Ad-Lib	90%	80%	70%	60%	Ad-Lib	90%	80%	70%	60%	S.E.[2]	Sex X Trt.
No. pigs	10	10	10	10	10	10	10	10	10	10	-	-
Initial wt., lbs.	110.4	101.8	104.5	108.5	106.9	102.5	106.1	107.2	102.7	104.4	-	-
Final wt., lbs.	216.5	216.7	217.2	215.8	214.9	212.4	217.1	219.6	217.4	218.9	1.99	-
Da. gain, lbs.	1.85	1.71	1.48	1.21	1.04	1.58	1.39	1.21	1.13	0.92	.05	.07
Da. feed, lbs.	7.39	6.56	5.90	5.19	4.51	6.40	5.65	5.12	4.52	4.01	-	-
Feed/gain, lbs.	4.05	3.88	3.99	4.30	4.53	4.12	4.10	4.27	4.03	4.38	-	-
Exp. days	58.1	67.9	76.3	88.9	105.5	70.7	80.5	93.8	102.2	126.7	3.81	.74
Slaughter age, da.	169.2	181.2	188.4	202.0	220.7	187.7	197.5	207.2	217.3	242.0	4.18	.96
Dress, %	74.4	73.5	74.7	73.7	74.2	74.0	73.8	73.6	73.6	72.6	.50	.20
Carc. length, in.	29.8	29.6	29.8	30.0	30.0	39.9	30.2	30.2	30.6	31.6	.30	.10
Backfat, in.	1.73[a]	1.60[ab]	1.53[bc]	1.40[cd]	1.34[de]	1.41[cd]	1.41[cd]	1.41[cd]	1.33[de]	1.24[e]	.05	.05*
Loin area, sq.in.	3.68	3.81	4.34	4.41	4.46	4.33	4.42	4.55	4.82	4.99	.18	.76
Ham, %	18.0	18.4	18.5	19.8	19.7	19.5	20.0	19.6	20.6	21.5	.30	.49
Loin, %	15.9	16.0	16.2	16.6	17.1	16.5	17.0	16.8	17.3	18.5	.28	.60
Shoulder, %	17.3	17.3	17.6	18.7	17.8	17.6	17.7	17.6	18.3	18.6	.29	.40
Belly, %	13.4	14.1	13.5	13.5	13.0	13.7	13.1	13.1	12.8	11.8	.10	.12
Fat trim, %	26.3	24.9	23.7	21.0	21.6	23.2	21.7	22.3	19.8	18.0	.69	.29
Leaf fat, %	3.4[abc]	3.7[ab]	3.2[bcd]	3.1[cd]	3.8[a]	3.4[abc]	3.3[bc]	3.2[bcd]	2.9[d]	2.7[d]	.19	.01**
Ham & loin, %	33.9	34.4	34.7	36.4	36.9	36.0	37.0	36.4	37.9	40.0	.48	.42
Lean cuts, %	51.2	51.7	52.4	55.1	54.7	53.6	54.7	54.0	56.2	58.6	.64	.23
Primal cuts, %	64.6	65.8	65.9	68.6	67.8	67.4	67.9	67.1	69.0	70.4	.55	.16
No. carc. PSW[1]	0	1	0	0	0	0	1	0	0	0		

[1]Pale, soft and watery carcass.
[2]Standard error of means.
a,b,c,d,e Means on the same line bearing different superscript letters differ significantly ($P < .05$).

more controversial in that Thrasher et al. (1962) reported a higher requirement of feed per pound of gain by the restricted-fed pigs; whereas, Orme et al. (1965) found the restricted-fed pigs to require less feed per pound of gain. Becker et al. (1962) reported that pigs limited-fed were 11 percent more efficient than full-fed. On the other hand, Greer et al. (1963) found no difference in feed efficiency in one trial, but an improvement in feed efficiency in favor of increasing levels of feeding in another.

Level of feeding did not significantly affect dressing percent or percent leaf fat. Meade et al. (1964) and Braude et al. (1959) also reported no effect on dressing percent with changing levels of feeding. Backfat thickness was not significantly reduced in the 90% restricted-fed pigs as compared with the full-fed pigs. Restriction to 80% of full feed did significantly reduce average backfat ($P<.05$). Both the 70% and 60% restricted groups were significantly lower ($P<.05$) than the higher levels of feeding with respect to backfat thickness. Loin eye area followed a similar trend with the larger loin eye areas observed in the two most severely restricted groups ($P<.05$). Although the pigs fed 90% of full feed yielded a slightly larger loin eye area than the full-fed pigs, the difference was not significant. Carcass length increased slightly with increasing level of restriction,

but the only level with a significant difference was the 60% group ($P<.05$). Percent ham and loin, lean cuts, and primal cuts were increased significantly ($P<.05$) in the 60% and 70% restricted groups. Improved yield of percent ham and loin, lean cuts and primal cuts were noted in favor of the 80% and 90% restricted-fed pigs as compared with those full-fed; however, these differences were non-significant.

Sex differences were observed for most of the traits studied. Barrows gained significantly faster ($P<.01$) than gilts. Feed required per pound of gain was about the same (4.15 vs. 4.18). Gilts had significantly longer carcasses, less backfat, larger loin eye area, and a greater percentage of ham and loin, lean cuts, and primal cuts. All these measurements were significant at the 1% level. No sex difference was noted for dressing percent.

In this experiment, a significant sex x treatment interaction was found for average backfat thickness ($P<.05$) and percent leaf fat ($P<.01$). Backfat thickness declined somewhat linearly with increasing severity of restriction in the barrows; however, no difference was observed among the full-fed, 90% and 80% groups in the gilts. The most severe restriction resulted in an improvement of only .17 inches in the gilts; whereas, in the barrows the same restriction reduced backfat thickness by .32 inches. On the other hand, percent leaf fat in the

gilts declined with increasing restriction of feed intake, but no trend was apparent for the barrows. The most severely restricted group of barrows yielded the highest percent of leaf fat with the full-fed group being intermediate. The approximate significance of sex x treatment interaction for rate of gain was 7%. In general, barrows restricted to 70% of the daily feed intake of full-fed barrows, produced carcasses similar to gilts fed ad libitum. It is interesting to note that barrows were more efficient in feed utilization than gilts when full-fed, and restricted to 80% and 90% of full feed; however, at 60% and 70% restriction the gilts were more efficient in feed conversion than barrows. Barrows restricted to a daily feed intake of 70% of the feed consumed by full-fed barrows required 6% more feed per pound of gain. With an additional 10% reduction in daily feed intake, the feed utilization ratio was increased 11% above the full-fed lot. This suggests that restricting feed intake of barrows to 70% of full feed is too severe to be a practical feeding recommendation, even though leaner carcasses are produced.

Gilts, on the other hand, seemed to tolerate the 70% restriction of daily feed intake better than the barrows. This observation is based on the similarity of feed required per pound of gain among gilts full-fed, and restricted to levels of 90, 80, and 70 percent of full feed. As noted in the two most severely restricted groups of barrows, the feed required per pound of gain increased

as the level of restriction became too severe for the gilts. Gilts restricted to 60% of full feed required approximately 6% more feed per pound of gain than the full-fed lot. The increased feed requirement observed in the severely restricted groups suggests that the amount of energy available above the maintenance requirements was minimal. Therefore, with the lengthened feeding period of the severely restricted groups the total maintenance requirement was greater. When the difference between gross energy consumed and maintenance requirement per day becomes too small, the feed required per pound of gain increases suggesting a level of restriction which is not compatible with efficient gains.

D. Experiment 4. Study of various methods of restricting feed intake.

The results of experiment 4 are presented in Table 9. One of the most interesting observations in this experiment concerns the daily feed intake data. The pigs fed the appetite depressant (L-dichloramphetamine) consumed more feed per pig per day than the full-fed pigs (7.32 vs. 7.16). The ad libitum feeding of pigs every second day decreased daily feed intake by 24.6% as compared with the full-fed lot. The ad libitum feeding of pigs every third day reduced daily feed intake by 38.7%. These differences in daily feed intake resulted in a non-significant difference in growth rate between full-fed and appetite

TABLE 9.-Summary of Feedlot Performance and Carcass Data by Main Treatment Variables (Exp. 4)

Variable	Sex		Type of Feeding					Stt. Sign.
	Barrows	Gilts	Ad-Lib	A.D.[1]	A-L-2[2]	A-L-3[3]	S.E.[4]	Sex x Trt.
No. pigs	19	21	10	10	10	10	-	-
Initial wt., lbs.	135.9	127.8	131.5	132.4	132.7	130.8	-	-
Final wt., lbs.	218.3	214.9	217.4	216.4	219.6	213.1	2.09	-
Da. feed, lbs.	1.51*	1.37	1.72^{a}	1.75^{a}	1.31^{b}	.98^{c}	.06	.94
Da. feed, lbs.	-	-	7.16	7.32	5.47	4.36	-	-
Feed/gain, lbs.	-	-	4.18	4.29	4.23	4.51	-	-
Exp. days	58.5**	67.3	50.4^{a}	48.7^{a}	67.2^{b}	85.4^{c}	2.82	.91
Slaughter age, da.	175.8**	187.3	169.0^{a}	168.8^{a}	185.3^{b}	203.1^{c}	3.22	.83
Dress, %	71.2	73.6*	72.7^{ab}	73.9^{a}	73.4^{a}	71.6^{b}	.54	.46
Carc. length, in.	30.6	30.2	30.3	30.1	30.7	30.6	.24	.24
Backfat, in.	1.44	1.41	1.47^{a}	1.56^{a}	1.42^{a}	1.26^{b}	.05	.70
Loin area, sq.in.	4.08	4.68**	4.31	4.36	4.51	4.33	.20	.75
Ham, %	19.4	19.7	19.1^{bc}	18.6^{c}	19.9^{ab}	20.4^{a}	.37	.75
Loin, %	16.6	17.2*	16.7	17.0	16.8	17.2	.26	.78
Shoulder, %	18.2	18.0	18.0	17.9	17.9	18.6	.21	.34
Belly, %	12.7	12.6	12.8	12.8	12.6	12.4	.29	.69
Fat trim, %	22.0	21.7	23.1^{a}	23.4^{a}	21.4^{ab}	19.4^{b}	.86	.94
Leaf fat, %	3.3	3.0	3.2	3.4	2.9	3.0	.17	.91
Ham & Loin, %	36.0	36.9	35.8	35.7	36.7	37.6	.54	.68
Lean cuts, %	54.2	55.0	53.8^{b}	53.6^{b}	54.6^{ab}	56.2^{a}	.66	.77
Primal cuts, %	66.9	67.5	66.6	66.4	67.2	68.6	.66	.85
No. carc. PSW[5]	0	0	0	0	0	0	-	-

[1] Pigs were ad libitum-fed the basal ration plus 10 mg./lb. of MD 541 (L-dichloroamphetamine), an appetite depressant.
[2] Ad libitum feeding of basal ration every second 24 hr. period.
[3] Ad libitum feeding of basal ration every third 24 hr. period.
[4] Standard error of means. *P< .05.
[5] Pale, soft, and watery carcass. **P< .01.
[a,b,c] Means on the same line bearing different superscript letters differ significantly (P < .05).

depressant fed pigs, but a significant reduction in rate of gain of both restricted-fed lots as compared with the full-fed lot ($P<.05$). Ad libitum feeding of pigs every third day also caused a significant depression in growth rate as compared with the ad libitum-fed pigs every second day ($P<.05$). Feed efficiency data were very similar for all lots except the lot which was ad libitum-fed every third day. This lot required approximately 7% more feed per pound of gain. Shroder (1963) reported non-significant differences in feed utilization per pound of gain when pigs were fed 15 lbs. of feed per hog in a self-feeder every three days which agrees with the data obtained in this trial. The slower rates of gain for the restricted-fed lots resulted in longer feeding periods for both lots ($P<.05$) as compared with the full-fed lots.

Pigs restricted in daily feed intake by ad libitum feeding every third day produced leaner carcasses as indicated by significantly less backfat ($P<.05$). Both groups of pigs fed ad libitum and the pigs fed ad libitum every second day yielded carcasses similar in fat depth. Lean cut percentages were higher in both restricted-fed lots; however, only those carcasses produced by ad libitum feeding every third day were significantly greater ($P<.05$). Percent ham was significantly greater ($P<.05$) in both limited-fed groups over the pigs ad libitum-fed the basal ration plus the appetite depressant. A non-significant difference was observed between the full-fed control group full-fed every second day.

Sex differences noted in this trial were similar to those of the previous trials. The barrows gained significantly faster ($P<.05$) than gilts. Gilts yielded a significantly higher percent loin ($P<.05$) with a larger loin eye ($P<.01$). In this trial, gilts dressed a higher percentage ($P<.05$) than the barrows. Higher dressing percent in favor of gilts over barrows was also reported by Wagner et al. (1963), but Zobrisky et al. (1961) reported no difference in the yield of barrows and gilts. None of the other traits showed significant differences due to sex effects.

No sex x treatment interactions were noted in this experiment.

E. Experiment 5. Study of rate and efficiency of gain of full sib pigs.

This experiment was designed primarily to obtain information on feedlot performance of littermate barrows and gilts. Data from this trial are summarized in Table 10. Many investigators, Bruner et al. (1958), Wallace et al. (1960), Wagner et al. (1963), Waldern (1964) and Hale and Southwell (1966) have reported that barrows gained faster than gilts. This agrees with the data obtained in this trial in that barrows gained significantly faster ($P .01$) than the gilts (1.66 vs. 1.54). Barrows consumed .73 lbs. more feed per day than the gilts, which is similar to the difference reported by Plank and Berg (1963). This

TABLE 10.-Summary of Performance Data of Full Sib Barrows and Gilts (Exp.5)

Variable	Sex		Statistical Significance
	Barrows	Gilts	
No. pigs	33	33	-
Initial wt., lbs.	64.8	62.1	-
Final wt., lbs.	204.2	191.6	-
Da. gain, lbs.	1.66**	1.54	.00
Da. feed, lbs.	6.27	5.54	.06
Feed/gain, lbs.	3.78	3.60	.15
Exp. days	84	84	-

** P < .01.

TABLE 11.-Summary of Performance Data for Individual Lots of Full Sibs (Exp.5)

Variable	Replicates					
	I		II		III	
Sex	Barrows	Gilts	Barrows	Gilts	Barrows	Gilts
No. pigs	11	11	11	11	11	11
Initial wt., lbs.	64.7	62.9	65.8	61.2	63.8	62.3
Final wt., lbs.	204.9	193.0	196.8	193.1	210.8	188.7
Da. gain, lbs.	1.67	1.55	1.55	1.57	1.75	1.51
Da. feed, lbs.	6.17	5.56	5.94	5.46	6.69	5.61
Feed/gain, lbs.	3.70	3.59	3.81	3.48	3.82	3.73
Exp. days	84	84	84	84	84	84

difference in daily feed intake between barrows and gilts approached significance ($P<.06$). The feed/gain ratio favored the gilts over the barrows (3.60 vs. 3.78); however, this difference was non-significant. Bowland and Berg (1959) and Lucas and Calder (1959) also reported that gilts were more efficient than barrows, but the difference was not statistically significant.

Table 11 presents a summary of performance data for the individual lots of full sibs.

F. Experiment 6. Varying energy level study using barrows and gilts fed an equal protein, mineral, and vitamin intake each day.

The purpose of this experiment was to determine the effect of restricting only energy to barrows and gilts. Knowing that barrows will consume more feed per day than gilts when full-fed, an additional lot of barrows were used to permit the comparison of two methods of restricted feeding of finishing hogs. The first comparison was the effect of feeding barrows and gilts three different levels of energy. The energy levels compared in this analysis were based on feeding equal amounts of energy to each sex with no regard as to the percentage of restriction. This comparison involved the grouping of data for barrows and gilts fed 3 pounds of basal ration (B); barrows and gilts fed the basal ration plus 1 pound of cornstarch (B + 1); and barrows and gilts fed the basal ration plus 2 pounds

of cornstarch (B + 2). The second comparison was the effect of feeding barrows and gilts a percentage of full feed. In this comparison, the data from the barrows fed the basal ration plus 3 pounds of cornstarch were grouped with the data from the gilts fed the basal ration plus 2 pounds of cornstarch. Both these lots approximated 100% full-fed for their respective sexes. Likewise, the data of barrows fed the basal ration plus 2 pounds of cornstarch were grouped with the data from gilts fed the basal ration plus 1 pound of cornstarch (85% of full feed); and the data of barrows fed the basal ration plus 1 pound of cornstarch were grouped with data from gilts fed the basal ration (70% of full feed).

Table 12 summarizes the results of the first comparison. The B + 2 group gained significantly faster ($P<.05$) than the B + 1 group, which in turn gained significantly faster ($P<.05$) than the B group. The reduced growth rates of the B and B + 1 groups resulted in an increased age at slaughter of 41 and 12 days, respectively. Gross energy per pound of gain was similar for the B + 2 and the B + 1 groups; however, the B group required 16% more gross energy per pound of gain. The increased requirement for energy per unit of gain with increasing restriction was consistent with data reported in the preceding trials. The B group yielded significantly leaner carcasses ($P<.05$) with a larger loin eye area ($P<.05$) and a greater percent of ham

TABLE 12.-Summary of Feedlot Performance and Carcass Data by Main Treatment Variables (Exp. 6). I. Equal Level of Energy Intake

Variable	Sex		Level of Feeding[1]			Stt. Sign.
	Barrows	Gilts	B	B+1	B+2	Sex x Trt.
No. pigs	30	30	20	20	20	-
Initial wt., lbs.	100.2	101.9	101.9	100.5	100.8	-
Final wt., lbs.	214.8	216.8	213.0	216.6	217.9	-
Da. gain, lbs.	1.40	1.46	1.08^{a}	1.48^{b}	1.75^{c}	.75
Da. energy, therms	8.48	8.30	6.84	8.42	9.87	-
Therms/lb. gain	6.30	5.84	6.65	5.72	5.71	-
Exp. days	87.0	82.8	108.0^{a}	79.0^{b}	67.8^{c}	.40
Slaughter age, da.	191.8	188.6	213.9^{a}	184.4^{b}	172.3^{c}	.26
Dress, %	74.3	75.2*	74.3	74.6	75.3	.59
Carc. length, in.	30.8	31.1	31.2	31.0	30.7	.64
Backfat, in.	1.31	1.25	1.13^{b}	1.30^{a}	1.40^{a}	.95
Loin area, sq.in.	4.37	4.92**	4.93^{b}	4.55^{a}	4.45^{a}	.92
Ham, %	20.0	21.1**	21.6^{a}	20.5^{b}	19.5^{c}	.21
Loin, %	17.5	17.9	18.3^{a}	17.9^{a}	17.0^{b}	.92
Shoulder, %	17.9	18.0	18.8^{a}	18.0^{b}	17.1^{c}	.58
Belly, %	11.9	11.5	11.0^{a}	11.7^{b}	12.4^{c}	.63
Fat trim, %	21.1	19.5*	17.1^{b}	21.1^{a}	22.7^{a}	.84
Leaf fat, %	2.7	2.3*	2.2	2.5	2.7	.46
Ham & loin, %	37.5	39.0**	39.9^{a}	38.3^{b}	36.6^{c}	.71
Lean cuts, %	55.4	57.0*	58.8^{a}	56.3^{b}	53.6^{c}	.60
Primal cuts, %	67.4	68.5**	69.8^{a}	68.0^{b}	66.1^{c}	.71

[1]Basal ration plus pounds of starch fed each pig.

a,b,c Means on the same line bearing different superscript letters differ significantly ($P < .05$).

*$P < .05$.

**$P < .01$.

and loin ($P<.05$) and lean cuts ($P<.05$) than either the B + 1 or B + 2 groups. Backfat thickness and percent fat trim were slightly improved in the B + 1 group as compared with the B + 2 group. These improvements were not significant. Linear increases in percentages of ham, shoulder, ham and loin, lean cuts and primal cuts were obtained with decreased energy intake. A reverse trend was observed for the trait of dressing percentage, but this decline was not significant. Although longer carcasses were produced by reducing energy consumption, the differences were not significant.

In this comparison, the sex effects were somewhat different from those observed in previous trials. Barrows normally gain faster than gilts; however, in this comparison where barrows and gilts were fed similar amounts of feed the gilts gained slightly faster than the barrows (1.46 vs. 1.40). The amount of gross energy required per pound of gain slightly favored the gilts. The most marked differences due to sex were noted in the carcass parameters. Gilts dressed significantly better ($P<.05$) and yielded carcasses with a larger loin eye area ($P<.01$). Furthermore, gilt carcasses were superior in percent ham and loin ($P<.01$) and percent lean cuts ($P<.05$). They were also 0.3 inches longer and carried 0.06 inches less backfat than barrows, but these advantages were not significant. The statistical significance of the sex x treatment interactions

were non-significant for all parameters studied. Table 14 presents the means of the individual lots. It is interesting to note that at each level of feeding the gilts slightly outperformed the barrows and yielded carcasses which were superior in leanness and the percentages of the preferred cuts. Comparatively, the response at each level was approximately the same for the barrows and gilts resulting in no apparent level of feeding x sex interaction.

Table 13 presents the results of the second comparison. With the data grouped as mentioned previously, the pigs receiving approximately 100% full feed gained significantly faster ($P<.05$) than the 85% restricted group. Significantly slower gains ($P<.05$) were noted in the 70% restricted group as compared with either of the higher levels. These differences in rates of gain resulted in an increased age at slaughter of approximately 9 and 26 days for the 85% and 70% restricted groups, respectively. The group fed 70% of full feed required the greatest amount of gross energy per pound of gain; whereas, the other two groups were approximately the same.

Restricting daily energy intake by increments of 15% resulted in a reduced backfat thickness of approximately 0.15 inches per increment. These differences were significant at the 5% level. Since the restricted-fed groups yielded significantly less total fat, improvements in carcass yield were noted for the traits of ham and loin, lean

TABLE 13.-Summary of Feedlot Performance and Carcass Data by Main Treatment Variables (Exp. 6). II. Percentage of Full Feed

Variable	Sex		Level of Feeding[1]			Stt. Sign.
	Barrows	Gilts	100%	85%	70%	Sex x Trt.
No. pigs	30	30	20	20	20	-
Initial wt., lbs.	100.5	101.9	101.6	100.4	100.6	-
Final wt., lbs.	216.8	216.8	219.0	216.6	214.7	-
Da. gain, lbs.	1.70*	1.46	1.84^{a}	1.60^{b}	1.29^{c}	.08
Da. energy, therms	9.96	8.30	10.55	9.21	7.62	-
Therms/lb. gain	5.90	5.84	5.79	5.78	6.04	-
Exp. days	69.7**	82.8	64.6^{a}	73.4^{b}	90.8^{c}	.06
Slaughter age, da.	173.5**	188.6	168.9^{a}	178.6^{b}	195.8^{c}	.13
Dress, %	75.0	75.2	75.6	75.0	74.6	.59
Carc. length, in.	30.5	31.1**	30.6	30.7	31.1	.76
Backfat, in.	1.46	1.25**	1.50^{a}	1.34^{b}	1.22^{c}	.68
Loin area, sq. in.	4.10	4.92**	4.32^{a}	4.48^{ab}	4.73^{b}	.70
Ham, %	19.1	21.1	19.1^{a}	20.3^{b}	20.9^{b}	.21
Loin, %	16.9	17.9**	16.8^{a}	17.4^{ab}	18.1^{b}	.74
Shoulder, %	17.0	18.0**	16.6^{a}	17.7^{b}	18.3^{b}	.86
Belly, %	12.4	11.5**	12.6^{a}	12.0^{ab}	11.4^{b}	.25
Fat trim, %	24.0	19.5**	24.4^{a}	21.6^{b}	19.2^{c}	.43
Leaf fat, %	2.6	2.3*	2.5	2.5	2.5	.06
Ham & loin, %	36.0	39.0**	35.9^{a}	37.7^{b}	39.0^{c}	.66
Lean cuts, %	53.1	57.0**	52.5^{a}	55.4^{b}	57.3^{c}	.68
Primal cuts, %	65.5	68.5**	65.0^{a}	67.3^{b}	68.7^{c}	.93

[1]Percentage of full feed.

^{a,b,c}Means on the same line bearing different superscript letters differ significantly ($P < .05$).

* $P < .05$.

** $P < .01$.

TABLE 14.-Summary of Feedlot Performance and Carcass Data for Individual Lots (Exp. 6)

	Barrows				Gilts			
Level of Feeding[1]	B+3	B+2	B+1	B	B+2	B+1	B	S.E.[3]
No. of pigs	10	10	10	10	10	10	10	-
Initial wt., lbs.	101.6	99.8	100.1	100.8	101.7	100.9	103.0	
Final wt., lbs.	218.3	216.1	215.9	212.4	219.7	217.2	213.5	2.18
Da. gain, lbs.	1.89	1.72	1.46	0.98	1.75	1.48	1.08	.05
Da. energy, therms[2]	11.40	10.03	8.45	6.88	9.71	8.40	6.80	-
Therms/lb. gain	6.04	5.88	5.78	7.00	5.55	5.67	6.30	-
Exp. days	61.8	68.1	79.3	113.6	67.4	78.6	102.4	4.16
Slaughter age, da.	165.1	171.9	183.6	219.9	172.7	185.3	207.9	4.39
Dress, %	75.7	75.1	74.2	73.6	75.4	74.9	75.0	.50
Carc. length, in.	30.2	30.4	31.0	31.1	31.0	31.1	31.4	.26
Backfat, in.	1.62	1.42	1.34	1.16	1.38	1.27	1.10	.06
Loin area, sq. in.	3.87	4.14	4.28	4.68	4.77	4.82	5.18	.15
Ham, %	18.5	19.3	19.6	21.2	19.8	21.3	22.1	.34
Loin, %	16.3	16.7	17.6	18.1	17.3	18.1	18.4	.36
Shoulder, %	16.2	17.2	17.8	18.8	16.9	18.2	18.9	.30
Belly, %	12.7	12.5	12.0	11.2	12.4	11.4	10.8	.30
Fat trim, %	26.7	23.3	22.1	17.8	22.?	20.?	16.4	.90
Leaf fat, %	2.4	2.8	2.7	2.5	2.7	2.3	2.0	.19
Ham & loin, %	34.7	36.0	37.3	39.3	37.1	39.3	40.6	.60
Lean cuts, %	50.9	53.2	55.0	58.0	54.0	57.5	59.4	.80
Primal cuts, %	63.6	65.6	67.1	69.3	66.4	68.9	70.2	.66
No. carc. PSW[4]	0	0	0	0	0	0	0	-

[1]Please refer to "procedure" for levels of feeding.
[2]Gross energy of the starch and basal ration were determined by bomb calorimetry. Starch - 1.716 therms/lb.; Basal ration 1.905 therms/lb.
[3]Standard error of means.
[4]Pale, soft, and watery carcass.

cut, and primal cut percentages as compared with the full-fed group. Although slightly longer carcasses were produced with increasing percentage of restriction, the differences were not significant.

In contrast to the other comparison, barrows gained significantly faster ($P<.01$) than the gilts. The faster rate of gain resulted in significantly fewer days to reach market weight ($P<.01$). Therms of gross energy per pound of gain were about the same for the barrows and gilts (5.90 vs. 5.84). Highly significant increases ($P<.01$) in carcass length, loin eye area, percentages of the individual wholesale cuts, ham and loin, and lean cuts were observed in favor of the gilts over the barrows. These differences seemed more pronounced in this trial as compared with earlier trials. Kropf (1959) suggested that the composition of gilt carcasses seemed to be affected more by the balance of amino acids than did barrow carcasses. The superior performance of gilts in this trial as compared with earlier trials indicates a trend toward this hypothesis. Although no statistically significant interactions were obtained in this comparison, three parameters were approaching significance. These parameters were daily gain ($P<.08$), experimental days ($P<.06$), and percent of leaf fat ($P<.06$. The sex x treatment interaction for rate of gain resulted from the superior performance of the barrows at each percentage

of restriction. Experimental days followed the same pattern as rate of gain. On the other hand, percentage of leaf fat seemed to vary considerably within the barrow lots since the full-fed barrows yielded the lowest percentage. Percentage of leaf fat in the gilts declined linearly with increasing restriction.

Analysis of the data presented in Table 12 and Table 13 shows that both methods of restriction resulted in an improvement in carcass quality. Feedlot performance was about the same in that the higher levels of energy intake resulted in the faster gains. Energy utilization was similar in both comparisons as shown by an inferior energy per pound of gain ratio in the most restricted groups. The most striking differences were noted between the sexes in each comparison. The data shown in Table 13 indicate a marked increase in yield of wholesale cuts of gilts over barrows; whereas, in Table 12 the differences are smaller for the same carcass traits. This difference in sex effects suggests that barrows and gilts fed equal amounts of energy will produce carcasses with smaller differences than if restricted on a percentage basis of full feed. This observation disagrees with the findings of Plank and Berg (1963) who reported that the sexes tended to show greater carcass differences in an equalized limited feeding system. The rate of gain of gilts and barrows were about the same when fed equal amounts of

energy; however, when gilts and barrows were fed a percentage of full feed the barrows gained significantly faster. The difference in growth rate between the two comparisons comes from the difference in daily feed intake between the barrows and gilts.

Throughout this trial, special note was made of the fact that the fat on these pork carcasses was harder than from pigs fed the normal finishing ration. Because of this increased firmness, considerable difficulty was encountered in removing the fat from the wholesale cuts. None of the carcasses in this trial appeared pale, soft, or watery. The effect of dietary cornstarch on the composition of carcass fat is not known.

In summary, feeding an equal amount of protein, minerals and vitamins with a varying energy level produced results similar to those observed in earlier trials. Therefore, energy would appear to be the limiting factor in the earlier trials and not protein, minerals or vitamins.

G. Experiment 7. Comparison of limited and ad libitum feeding of boars, barrows, gilts and spayed gilts.

The literature on the influence of restricted feeding of boars and spayed gilts is very fragmentary, particularly so in the case of the latter. In view of the sex differences observed previously between barrows and gilts, this trial was initiated to determine possible interactions

between level of feeding and the four sex conditions. Table 15 summarizes the feedlot performance and carcass data.

The ad libitum-fed pigs gained significantly faster ($P<.01$) and required approximately 20 days less time to reach slaughter weight ($P<.01$). They also required approximately 7% less feed per pound of gain than the restricted-fed pigs. Trasher et al. (1962) and Wallace et al. (1963a) reported similar advantages in favor of full-fed pigs. Restricted-fed pigs yielded carcasses carrying significantly less backfat ($P<.01$), a higher percent of ham and loin ($P<.05$), and primal cuts ($P<.05$). Restricted-fed pigs also yielded slightly longer carcasses with larger loin eye areas and greater percent of lean cuts; however, these differences were not statistically significant. Wallace et al. (1963b) also reported no improvement in loin eye area due to restricted feed intake, but did find significant increases in percentage of lean cuts.

Boars and barrows gained significantly faster ($P<.05$) than gilts and spayed gilts. Growth rate of boars and barrows were similar (1.51 vs. 1.49). Winters et al. (1942) observed an increased rate of gain in favor of boars as compared with barrows. Growth rate of gilts and spayed gilts were the same (1.36 vs. 1.36). Boars were the most efficient in the conversion of feed to live weight gain

TABLE 15.-Summary of Feedlot Performance and Carcass Data by Main Treatment Variables (Exp. 7)

Variable	Sex				Level of Feeding[1]	
	Barrows	Gilts	Boars	Sp. Gilts	Ad-Lib	LF
No. pigs	20	19[y]	20	18[z]	39	38
Initial wt., lbs.	103.6	101.5	103.6	99.9	101.8	102.5
Final wt., lbs.	225.6	224.7	226.0	233.0	225.8	223.8
Da. gain, lbs.	1.49[a]	1.36[b]	1.52[a]	1.36[b]	1.61**	1.25
Da. feed, lbs.	6.00	5.64	5.35	5.77	6.21	5.17
Feed/gain, lbs.	4.07	4.23	3.57	4.37	3.92	4.20
Exp. days.	83.5[bc]	92.3[ab]	82.1[c]	92.8[a]	78.1**	97.3
Slaughter age, da.	188.4[b]	197.5[a]	187.0[b]	198.0[a]	183.2**	202.3
Carc. length, in.	30.6[b]	30.7[a]	31.3[a]	30.5[b]	30.7	30.8
Backfat, in.	1.31[a]	1.16[b]	1.04[c]	1.28[a]	1.25	1.15**
Loin area, sq.in.	5.15[b]	5.70[a]	5.50[ab]	5.13[b]	5.35	5.39
Ham, %	19.9[b]	21.6[a]	21.5[a]	20.5[b]	20.6	21.2*
Loin, %	18.5[b]	19.0[b]	19.9[a]	18.4[b]	18.8	19.1
Shoulder, %	18.4[b]	19.0[ab]	19.4[a]	18.4[b]	18.8	18.8
Belly, %	12.8[a]	11.6[b]	11.8[b]	12.3[ab]	12.2	12.2
Fat trim, %	18.8[a]	16.8[b]	14.2[c]	19.7[a]	18.2	16.6**
Leaf fat, %	2.4[ab]	2.2[b]	1.6[c]	2.7[a]	2.2	2.2
Ham & loin, %	38.4[b]	40.6[a]	41.4[a]	38.9[b]	39.4	40.3**
Lean cuts, %	56.8[b]	59.6[a]	60.8[a]	57.3[b]	58.2	59.1
Primal cuts, %	69.6[c]	71.3[b]	72.6[a]	69.6[c]	70.3	71.3*

[1]Limited-fed pigs were fed approximately 80% of the ad libitum-fed lot.
*P < .05.
**P < .01.
[y]One gilt was removed from the group because of crippling.
[z]One gilt died during the trial because of a bowel infection
[a,b,c]Means on the same line bearing different superscript letters differ significantly (P < .05).

followed by barrows, gilts, and spayed gilts in that order. This agrees with the data of Charette (1961) and Wagner et al. (1963), who observed that boars were more efficient in feed utilization than gilts and barrows. Boars yielded significantly longer carcasses ($P<.05$) than gilts, barrows, and spayed gilts which were similar. Boars yielded significantly leaner carcasses ($P<.05$) than gilts. The gilt carcasses carried significantly less backfat ($P<.05$) than either barrows and spayed gilt carcasses. The latter two were similar in backfat thickness. Loin eye area of gilts was significantly greater ($P<.05$) than barrows and spayed gilts which were similar. Even though the loin eye area of boars was greater than barrows and spayed gilts the difference was not significant. Loin eye area of gilts and boars were not significantly different. Barrows and spayed gilts were similar in all respects of carcass cutout as measured by the following percentages: ham and loin, lean cuts, primal cuts, and the individual wholesale cuts. Boars and gilts yielded carcasses similar in percent ham, percent ham and loin, and percent lean cuts. The boar and gilt carcasses cut higher percentages of ham and loin, lean cuts, and primal cuts than barrows and spayed gilts. These differences were all statistically significant at the 5% level. Zobrisky et al. (1961) reported the same findings with respect to yield of lean and backfat thickness for boars, barrows and gilts. However, their

data did indicate that boar carcasses yielded greater loin eye areas than gilts, which was not consistent with the data found in this experiment. McCampbell and Baird (1965) reported no significant differences in loin eye area between boars and gilts while other parameters of carcass leanness were consistent with the data reported in this experiment.

Table 16 summarizes the feedlot performance and carcass data of the individual lots. Sex x treatment interactions were non-significant for all parameters observed. It was interesting to note that in each sex the limited-fed pigs required more feed per pound of gain than full-fed pigs, except in the case of the boars. The ad libitum-fed boars ate less feed per day than any of the other sex conditions. This observation agrees with data reported by Charette (1961). Even though the boars did consume less feed per day, their daily rate of gain was the fastest. Barrows consumed the greatest amount of feed per day followed by spayed gilts and gilts. The ad libitum-fed boars yielded leaner carcasses than the limited-fed barrows. Likewise, ad libitum-fed gilts carried less backfat than the limited-fed spayed gilts. Percent ham and loin, and percent lean cuts followed a similar pattern in that full-fed boars yielded a greater percent of these wholesale cuts than barrows, and gilts yielded a greater percent than spayed gilts. In this experiment, 8 carcasses

TABLE 16.-Summary of Feedlot Performance and Carcass Data for Individual Lots (Exp. 7)

Sex	Boars		Barrows		Gilts		Sprayed Gilts			Stt. Sign.
Level of Feeding[1]	Ad-Lib	LF	Ad-Lib	LF	Ad-Lib	LF	Ad-Lib	LF	S.E.[2]	Sex X Trt.
No. pigs	10	10	10	10	10	9[y]	9	9[z]	-	-
Initial wt., lbs.	103.2	103.9	104.0	103.3	100.2	101.4	99.8	98.2	-	-
Final wt., lbs.	227.1	224.9	226.6	224.6	225.9	223.6	223.7	222.2	2.36	-
Da. gain, lbs.	1.67	1.34	1.64	1.31	1.53	1.15	1.52	1.14	.04	.97
Da. feed, lbs.	5.97	4.80	6.60	5.41	6.13	5.15	6.22	5.32	-	-
Feed/gain, lbs.	3.57	3.57	4.01	4.13	4.00	4.46	4.10	4.65	-	-
Exp. days	74.4	89.8	74.4	92.6	82.1	102.6	81.6	104.1	4.47	.88
Slaughter age, da.	178.8	195.2	179.8	196.9	187.5	207.6	186.6	209.4	3.95	.85
Carc. length, in.	31.2	31.3	30.4	30.8	30.9	30.5	30.4	30.5	.21	.26
Backfat, in.	1.12	.96	1.39	1.24	1.18	1.14	1.31	1.25	.05	.54
Loin area, sq. in.	5.43	5.58	5.14	5.16	5.56	5.86	5.30	4.96	.19	.44
Ham, %	21.2	21.7	19.3	20.5	21.4	21.7	20.3	20.7	.42	.73
Loin, %	19.7	20.0	18.4	18.7	18.9	19.2	18.3	18.5	.33	.99
Shoulder, %	19.1	19.7	18.3	18.5	19.0	19.0	18.6	18.2	.32	.47
Belly, %	11.9	11.7	12.8	12.8	11.5	11.8	12.4	12.3	.32	.92
Fat trim, %	15.3	13.1	20.0	17.6	17.6	16.1	19.8	19.6	.90	.61
Leaf fat, %	1.7	1.4	2.4	2.5	2.2	2.2	2.6	2.8	.17	.63
Ham & loin, %	41.0	41.7	37.7	39.2	40.2	40.9	38.6	39.2	.65	.90
Lean cuts, %	60.1	61.4	56.0	57.6	59.3	59.9	57.2	57.4	.84	.85
Primal cuts, %	72.0	73.2	68.8	70.4	70.8	71.7	69.5	69.6	.65	.73
No. carc. PSW[3]	2	3	1	0	1	1	0	0	-	-

[1]Limited-fed pigs were fed approximately 80% of the ad-libitum fed lots.
[2]Standard error of the means.
[3]Pale, soft, and watery carcass.
[y]One gilt was removed from the lot because of crippling.
[z]One gilt died during the trial because of a bowel infection.

were observed as being pale, soft, and watery. Five of these eight carcasses were littermates and six of the eight carcasses were sired by the same boar. Since the cause of this condition still remains unknown, speculation that heredity may play a role cannot be overlooked.

H. Correlation coefficients between and within carcass and performance parameters.

Data from 383 pigs were used to develop correlation coefficients between and within the feedlot performance and carcass traits. Table 17 presents the correlation coefficients among the 16 variables studied.

Within the performance traits, daily feed intake was highly correlated with daily gain (.76). Daily feed consumption was not correlated with feed per pound of gain (.04). Feed per gain was negatively correlated with daily gain (-.43). The association of these three variables observed in this series of experiments suggests that restricting feed intake will not improve feed conversion to liveweight gain. The negative correlation of daily gain and feed per gain indicates that as rate of gain decreases as observed with restriction of feed intake, the feed required per pound of gain becomes greater. Biswas et al. (1966) and Magee (1962) reported similar correlation coefficients with respect to daily gain - feed consumption, and feed efficiency - daily gain.

TABLE 17.-Correlation Coefficients Between and Within Carcass and Performance Parameters[1,2]

Traits	Da. feed	Da. gain	Feed/ gain	Sl. age	Back fat	Carc. length	Loin area	Ham %	Loin %	Shoulder %	Belly %	Fat trim %	Leaf fat %	Ham loin %	Lean cuts %
Da. gain	.76	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Feed/gain	.04	-.43	-	-	-	-	-	-	-	-	-	-	-	-	-
Slaughter age	-.66	-.77	.26	-	-	-	-	-	-	-	-	-	-	-	-
Backfat, in.	.52	.37	.18	-.37	-	-	-	-	-	-	-	-	-	-	-
Carc. lenght, in.	-.16	-.04	-.30	.14	-.33	-	-	-	-	-	-	-	-	-	-
Loin area, sq.in.	-.47	-.20	-.19	.38	-.56	.20	-	-	-	-	-	-	-	-	-
Ham, %	-.65	-.44	-.20	.50	-.74	.36	.61	-	-	-	-	-	-	-	-
Loin, %	-.42	-.22	-.30	.35	-.63	.44	.72	.63	-	-	-	-	-	-	-
Shoulder, %	-.52	-.27	-.16	.35	-.58	.28	.55	.61	.52	-	-	-	-	-	-
Belly, %	.15	.20	.40	-.20	.32	-.36	-.55	-.56	-.36	-	-	-	-	-	-
Fat trim, %	.57	.37	.08	-.47	.74	-.41	-.72	-.76	-.72	-.66	.39	-	-	-	-
Leaf fat, %	.38	.03	.10	-.08	.48	-.25	-.52	-.46	-.45	-.36	.30	.56	-	-	-
Ham & loin, %	-.60	-.37	-.28	.47	-.76	.44	.74	.91	.90	.63	-.61	-.82	-.51	-	-
Lean cuts, %	-.61	-.37	-.26	.47	-.77	.42	.74	.89	.85	.81	-.58	-.84	-.50	.96	-
Primal cuts, %	-.62	-.36	-.09	.48	-.78	.36	.73	.83	.78	.81	-.29	-.84	-.48	.89	.94

[1]All correlations coefficients above .102 are significant at the 5% level.
All correlation coefficients above .132 are significant at the 1% level.
[2]Data from 383 pigs were used to develop these correlation coefficients.

However, they reported a greater relationship between average daily feed consumption and feed efficiency. In their studies all pigs were ad libitum-fed in mixed lots which probably accounts for the difference in the correlation.

Within the carcass traits, backfat thickness was negatively correlated with the more desired wholesale cuts of the carcass. Backfat thickness was negatively correlated with loin eye area (-.56), percent ham and loin (-.76) and percent lean cuts (-.77). Carcass length was positively correlated with percent ham and loin (.44) and percent lean cuts (.42). Loin eye area was also positively correlated with percent ham and loin (.74) and percent lean cuts (.74). Based on these correlations, backfat thickness was a better indication of preferred cut yield than either loin eye area or carcass length.

Between carcass and performance traits, daily feed intake appears to be more highly correlated with backfat thickness, loin eye area, and percentages of the preferred cuts than either daily gain or feed efficiency. Feed efficiency was poorly correlated with all other variables studied.

V. SUMMARY

Seven experiments were conducted to study and evaluate the effect of restricted feed intake, sex, and the interaction of sex and level of feeding on feedlot performance and carcass quality of finishing swine. In all trials except one (experiment 4), the sexes were separately fed. Four hundred and forty-nine pigs were used in this study.

A. Effect of restricted feed intake on feedlot performance and carcass quality of swine.

Restricting feed intake reduced daily gain on the average 0.15 - 0.20 pounds with each 10% restriction. This decreased growth rate resulted in an increased feeding time of 7 to 10 days to reach slaughter weight with each 10% restriction. The feed required per pound of gain generally favored the full-fed pigs. Restricting feed to a level of 70% or more resulted in an increased feed requirement per pound of gain, which indicates a level of restriction too severe to be compatible with economic pork production. The optimum level of feed restriction appears to be about 75-80% of full feed. At this level of feeding superior carcasses are produced in terms of leanness and yield of preferred cuts, while the feed utilization ration remains about the same as that of full-fed pigs.

Restricting feed intake improved carcass quality. Backfat measurements were reduced approximately 0.10 inches with each 10% restriction. Loin eye area significantly increased with restriction; whereas, carcass length was only slightly increased. Percent of lean cuts always favored the restricted-fed groups with improvements of 0.5% to 1% with each 10% restriction. The number of pale, soft, and watery carcasses were somewhat negligible in all trials except experiment 7. In this experiment, 10% of the carcasses were noted as exhibiting this condition. The occurrence of pale, soft, and watery carcasses did not seem to be associated with levels of feeding.

B. Effect of sex on feedlot performance and carcass quality of swine.

Table 18 summarizes the performance and carcass data of 168 gilts and 177 barrows used in this study. Barrows gained approximately 0.10 pound faster per day than gilts which reduced their age at slaughter by 9 days. Feed per pound of gain was practically identical for each sex with barrows and gilts requiring 3.93 and 3.92 pounds of feed per pound of gain, respectively. Gilts yielded carcasses with less backfat (0.11 in.), larger loin eye area (0.52 sq. in.) and greater length (0.2 in.) when slaughtered at similar weights. In addition, gilts cut a higher percentage of ham and loin (1.7%) and lean cuts (1.8%) than

TABLE 18.-Grand Summary of Feedlot Performance and Carcass Data of Gilts versus Barrows

Sex	Barrows	Gilts
Feedlot performance:		
No. pigs	177	168
Final wt., lbs.	215.3	214.8
Da. gain, lbs.	1.46	1.37
Feed/gain, lbs.	3.93	3.92
Slaughter age, da.	184.6	193.4
Carcass data:		
Backfat, in.	1.44	1.33
Carc. length, in.	30.2	30.4
Loin area, sq. in.	4.19	4.71
Ham & loin, %	36.1	37.8
Lean cuts, %	53.8	55.6

the barrows. Dressing percentage usually favored the barrows which was consistent with the greater depth of backfat on the barrows.

Sex differences were apparent in daily feed intake under ad libitum feeding conditions. Full-fed boars consumed less feed per day than barrows, gilts, and spayed gilts. Barrows ate on the average 3/4 of a pound more feed per day than gilts. Feed intake and growth rate were similar for full-fed gilts and spayed gilts. Boars gained faster and more efficiently than any of the other sexes. Boars yielded significantly longer and leaner carcasses. Boars and gilts yielded carcasses similar in percent of lean cuts. Spayed gilt carcasses were similar to those of the barrows in backfat thickness, loin eye area, carcass length, and percent lean cuts.

C. Interaction of sex and level of feeding on swine performance and carcass quality.

In experiment 1, a significant interaction was observed for the trait of daily gain. This interaction developed from the fact that barrows gained significantly faster than gilts on full-feed; whereas, the gilts gained faster than the barrows when restricted to 5 lbs. of feed per day during the finishing period. This interaction was not substantiated in experiment 2, which was a repeat of the initial experiment. In experiment 3, a significant interaction resulted in backfat thickness, and percent leaf

fat. The interaction of sex x level of feeding for the trait of backfat thickness stemmed from the fact that backfat on the barrows declined linearly with increasing restriction of feed consumption; whereas, gilts fed ad libitum 90% and 80% of full feed carried the same amount of backfat. In all trials, barrows generally responded more to restricted feed intake than gilts as evidenced by a greater reduction in backfat thickness as compared with the full-fed lots; however, the interaction of sex x treatment was not significant in the other trials. Percent leaf fat declined with increasing restriction in the gilts, but no trend was apparent for the barrows. The most severely restricted group of barrows yielded the highest percent of leaf fat with the full-fed group being intermediate. This interaction was highly significant. Similar effects were noted in experiment 6 with respect to percent leaf fat.

On the basis of this research, it appears that sex and limited feeding do not consistently interact to significantly impair or improve the carcass and performance parameters reported in this study.

VI. CONCLUSIONS

The overall results of the seven experiments presented in this study have led the author to make the following conclusions:

1. Restricting feed intake reduced daily gains of finishing swine which resulted in a longer feeding period for the restricted-fed pigs to reach slaughter weight.

2. Restricting feed intake will not improve efficiency of gain of finishing swine. Full-fed pigs were generally more efficient than restricted-fed lots.

3. Restricting feed intake resulted in substantial improvements in carcass desirability as measured by backfat thickness, loin eye area, and percent of lean cuts.

4. Optimum level of restricting feed intake of finishing swine was 75-80% of full feed. At this level, superior carcasses were produced in terms of leanness with very little change in feed required per pound of gain. Restricting feed intake beyond 70% of full feed caused an increased requirement for feed per pound of gain.

5. Restricting feed intake exerted a greater influence on carcass cut-out of barrows than gilts. Backfat thickness was reduced comparatively more in the restricted-fed barrows than the restricted-fed gilts when compared to the full-fed lots.

6. Gilts yielded longer, leaner carcasses with larger loin eye areas than barrows. Furthermore, gilts yielded a greater percentage of ham and loin and lean cuts than the barrows.

7. Boars gained significantly faster than barrows, gilts, and spayed gilts. Boars were more efficient in converting feed to liveweight gain than the other three sexes. Boar carcasses were longer and leaner than gilt carcasses and yielded a greater percentage of lean cuts.

8. Barrows gained significantly faster and consumed more feed per day than gilts. Feed efficiency of barrows and gilts was approximately the same.

9. Barrows and spayed gilts yielded carcasses similar in backfat thickness, loin eye area, and percentages of the individual wholesale cuts.

10. The interaction of sex and level of feeding was not consistently significant for any of the parameters of performance and carcass quality.

VII. BIBLIOGRAPHY

Anderson, S. E. and R. Hanby. 1961. Comparison of milo, corn, and barley for growing and finishing hogs. J. Animal Sci. 20:923. (Abstr.).

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

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

Axelsson, Joel and Sture Eriksson. 1953. The optimum crude fiber level in rations of growing pigs. J. Animal Sci. 12:881.

Baird, D. M. and H. C. McCampbell. 1962. Influence of lysine, protein, and energy levels on growth and carcasses of hogs. J. Animal Sci. 21:987. (Abstr.).

Baird, D. M., H. C. McCampbell and W. E. Neville, Jr. 1959. Tallow feeding at weight intervals, stilbestrol implantation, and tranquilizer for growing-fattening swine. J. Animal Sci. 18:1160. (Abstr.).

Barber, R. S., R. Braude and K. G. Mitchell. 1957. Comparison of six different levels of feeding for fattening pigs. J. Agr. Sci. 48:347.

Beacom, S. E. 1963. The effect of diethylstilbestrol and estradiol-estosterone implantations on rate and efficiency of gain and on carcass quality of market pigs fed different finishing diets. Can. J. Animal Sci. 43:374.

Beacom, S. E. 1964. The influence of sex on the response of self-fed pigs to ration dilution during the finishing period. Can. J. Animal Sci. 44:281.

Becker, D. E., B. C. Breidenstein, A. H. Jensen and B. G. Harmon. 1963. Methods of limiting the feed intake of finishing pigs. Univ. of Ill. Mimeo A. S. 591.

Becker, D. E., A. H. Jensen and B. C. Breidenstein. 1962. Limited feeding of sinishing pigs. Univ. of Ill. Mimeo A. S. 571.

Becker, D. E., A. H. Jensen, B. G. Harmon, H. W. Norton and B. C. Breidenstein. 1963. Effect of restricted diet on the performance of finishing pigs. J. Animal Sci. 22:1116. (Abstr.).

Beeson, W. M., F. N. Andrews, T. W. Perry and M. Stob. 1955. The effect of orally administered stilbestrol and testosterone on growth and carcass composition of swine. J. Animal Sci. 14:475.

Bell, J. M., J. P. Bowland, C. D. T. Cameron, E. W. Crampton, L. E. Lloyd, M. E. Seale and F. Whiting. 1958. Nutrient requirements for Canadian Yorkshire swine. II. The effects of barley and oat finishing rations on rate of gain, feed utilization and carcass quality of pigs marketed at 185 and 200 lbs. live-weight. Can. J. Animal Sci. 38:73.

Bellis, D. B. and J. Taylor. 1961. Nutritional factors affecting lean meat production in cutting pigs. An. Prod. 3:209.

Biswas, D. K., P. V. Hurt, A. B. Chapman, N. L. First and H. L. Self. 1966. Feed efficiency and carcass desirability in swine. J. Animal Sci. 25:342.

Bohman, V. R., J. E. Hunter and J. A. McCormick. 1955. The effect of graded levels of alfalfa and aureomycin upon growing-fattening swine. J. Animal Sci. 14:499.

Bohman, V. R., J. F. Kidwell and J. A. McCormick. 1953. High levels of alfalfa in the rations of growing-fattening swine. J. Animal Sci. 12:876.

Bowland, J. P. and R. T. Berg. 1959. Influence of strain and sex on the relationship of protein to energy in the rations of growing and finishing bacon pigs. Can. J. Animal Sci. 39:102.

Bratzler, L. J., R. P. Soule, Jr., E. P. Reineke and Pauline Paul. 1954. The effect of testosterone and castration on the growth and carcass characteristics of swine. J. Animal Sci. 13:171.

Braude, R., K. G. Mitchell, A. S. Cray, A. Franke and P. H. Sedgewick. 1959. Comparison of different levels of all-meal feeding of fattening pigs. J. Agr. Sci. 52:408.

Braude, R., and J. G. Rowell. 1957. Labor saving in feeding of fattening pigs. J. Agr. Sci. 48:322.

Braude, R. and M. J. Townsend. 1963. A comparison of feeding growing pigs once or twice daily. J. Agr. Sci. 51:208.

Braude, R., M. J. Townsend, G. Harrington and J. G. Rowell. 1958. A large-scale test of the effects of food restriction on the performance of fattening pigs. J. Agr. Sci. 51:208.

Brugman, H. H. 1950. Effect of plane of nutrition on carcass quality of a line of swine based on Chester White and Danish Landrace Cross. J. Animal Sci. 9:602.

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

Bruner, W. H. and B. D. Van Stavern. 1961. Influence of age on the carcass characteristics of barrows and gilts. J. Animal Sci. 20:913. (Abstr.).

Burroughs, W. and W. E. Carroll. 1939. A new technique for limited feeding experiments. Am. Soc. An. Prod., pp. 407.

Cahill, V. R., H. S. Teague, L. E. Kunkle, A. L. Moxon and E. A. Rutledge. 1960. Measurement of and ways of affecting sex-influenced performance of growing finishing swine. J. Animal Sci. 19:1036.

Calloway, D. H., R. Hilf and A. H. Munson. 1962. Effects of chronic food restriction in swine. J. Nutr. 76:365.

Cameron, C. D. T. 1960. Effects of high fibre and pelleted and nonpelleted high fibre-high fat rations on performance and carcass characteristics of bacon pigs. Can. J. Animal Sci. 40:126.

Charette, L. A. 1961. The effects of sex and age of males at castration on growth and carcass quality of Yorkshire Swine. Can. J. Animal Sci. 41:30.

Clawson, A. J., T. N. Bloomer, W. W. G. Smart, Jr. and E. R. Barrick. 1962. Influence of energy-protein ratio on performance and carcass characteristics of swine. J. Animal Sci. 21:62.

Coey, W. E. and K. L. Robinson. 1954. Some effects of dietary crude fibre on liveweight gains and carcass conformation of pigs. J. Agr. Sci. 45:41.

Comstock, R. E., L. M. Winters and J. N. Cummings. 1944. Effect of sex on the development of the pig. III. Differences in the growth between gilts and barrows by breeding. J. Animal Sci. 3:120.

Comwell, G. L., R. A. Pickett and J. R. Foster. 1965. Effect of frequency of feeding on performance and carcass characteristics of swine. Purdue Res. Prog. Rot. 202.

Cox, D. F. 1963. Breed and sex effects on the relationship between weight and fatness measured at a constant age in swine. J. Animal Sci. 22:1091.

Crampton, E. W. 1935. The effect of full vs. limited feeding on the protein level required in the hog ration. Sci. Agr. 15:463.

Crampton, E. W. 1937. Self versus hand feeding for market hogs, with particular reference to effects on carcass measurements and quality. Sci. Agr. 17:529.

Crampton, E. W., G. C. Ashton and L. E. Lloyd. 1954. The effect of restricting feed intake of market hogs during the finishing period on the quality of the bacon carcass. J. Animal Sci. 13:327.

Crowther, C. 1937. Pig feeding Experiment. Pig Breeders Annual 17:125.

Cunningham, H. M., D. W. Friend and J. W. G. Nicholson. 1961. The effect of a purified source of cellulose on the growth and body composition of growing pigs. Can. J. Animal Sci. 41:120.

Cunningham, H. M., D. W. Friend and J. W. G. Nicholson. 1962. Efficiency of conversion of protein, energy, and carbon in pigs restricted late in the fattening period. Can. J. Animal Sci. 42:176.

Dinusson, W. E., D. W. Bolin and D. L. McIlroy. 1961. Fiber-energy-protein relationships in rations for swine. J. Animal Sci. 20:930. (Abstr.).

Dinusson, W. E., E. W. Klosterman and M. L. Buchanon. 1951. Stilbestrol, effect of subcutaneous implantation on growing-fattening swine. J. Animal Sci. 10:885.

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics 2:1.

Edwards, Joseph. 1936. Ad libitum feeding vs. controlled feeding. Pig Breeders Annual 16:119.

Ellis, N. R. and O. G. Hankins. 1935. The influence of the protein content of the ration on the growth and fattening of hogs fed at a moderately restricted level. Am. Soc. An. Prod. p. 107.

Ellis, N. R. and J. H. Zeller. 1931. Utilization of feed by swine as affected by the level of intake. Am. Soc. An. Prod. p. 270.

Ellis, N. R. and J. H. Zeller. 1938. The relative value of different levels of alfalfa meal in the ration of fall pigs. Am. Soc. An. Prod. p. 118.

Elson, C. E., E. A. Kline, W. A. Fuller and L. N. Hazel. 1961. Effect of age on the growth of porcine muscle. J. Animal Sci. 20:916. (Abstr.).

England, D. C., J. E. Oldfield, T. P. Davidson and R. W. Cooper. 1965. Pelleted versus meal barley rations for full or limited-fed pigs. J. Animal Sci. 24:597. (Abstr.).

Ferrin, E. F. and M. A. McCarty. 1928. Shall growing pigs be full-fed. Minn. Agr. Exp. Sta. Bul. 248.

Fishwick, V. C. 1936. Growing and fattening pigs. Pig Breeders Annual 16:115.

Fletcher, R. C., H. J. Tuma and R. W. Seerley. 1963. Effect of slaughter weight on body composition of barrows and gilts. J. Animal Sci. 22:1113. (Abstr.).

Forbes, R. M. and T. S. Hamilton. 1952. The utilization of certain cellulosic materials by swine. J. Animal Sci. 11:480.

Freeman, V. A. 1935. Limited rations for pigs. Mich. Agr. Exp. Sta. Quarterly Bul. 17:95.

Friend, D. W. and H. M. Cunningham. 1965. Growth and carcass studies with pigs fed once or five times daily. J. Animal Sci. 24:880.

Friend, D. W., H. M. Cunningham and J. W. G. Nicholson. 1962. Effect of an enzyme inhibitor on weight gain, feed consumption, and carcass characteristics of pigs. J. Animal Sci. 21:643.

Gillett, T. A., L. E. Orme, R. E. Christian, T. D. Bell, J. P. Baker and C. F. Peterson. 1962. Effect of dietary protein on carcass composition of swine. J. Animal Sci. 21:980. (Abstr.).

Greer, S. A. N., V. W. Hays, J. T. McCall and V. C. Speer. 1963. Effects of levels of feeding of corn and barley base diets on performance and carcass characteristics of finishing pigs. J. Animal Sci. 22:1120. (Abstr.).

Gregory, K. E. and G. E. Dickerson. 1952. Influence of heterosis and plane of nutrition on rate and economy of gains digestion, and carcass composition of pigs. Univ. of Mo. Res. Bul. 493. 48 pp.

Hafez, E. S. E., R. E. Mauer and M. E. Ensminger. 1958. Limited vs. full feeding as related to carcass components with particular reference to meat production. J. Animal Sci. 17:1158. (Abstr.).

Hale, O. M., D. W. Beardsley and B. L. Southwell. 1962. Effect of energy level on performance and carcass traits of growing-fattening swine. J. Animal Sci. 21:377. (Abstr.).

Hale, O. M. and B. L. Southwell. 1966. Protein requirements as related to breed and sex of swine. J. Animal Sci. 25:259. (Abstr.).

Hammond, J. and G. N. Murray. 1937. Body proportion of different breeds of bacon pigs. J. Agr. Sci. 27:394.

Handlin, D. L., J. R. Ables, D. H. Kropf and R. F. Wheeler. 1961. Effect of finishing rations on gains, feed efficiency, and carcass characteristics of swine. J. Animal Sci. 20:585.

Heeney, M. W., J. C. Hillier and L. E. Walters. 1964. Carcass composition of full and limited fed swine. J. Animal Sci. 23:877. (Abstr.).

Hilditch, T. P., C. H. Lea and W. H. Pedelty. 1939. The influence of low and high planes of nutrition on the composition and synthesis of fat in the pig. Biochem. J. 33:493.

Hillier, J. C., J. A. Whatley, J. V. Whiteman and D. I. Card. 1951. The effect of energy content of the ration and rate of gain on certain characteristics of pork. Okla. Agr. Exp. Sta. M. P. 22.

Hochstetler, L. N., J. A. Hoefer, A. M. Pearson and R. W. Luecke. 1959. Effect of varying levels of fiber of different sources upon growth and carcass characteristics of swine. J. Animal Sci. 18:1397.

Hoefer, J. A., A. M. Pearson, J. W. Stevenson and R. W. Luecke. 1959. Effect of varying levels of fiber of different sources upon growth and carcass characteristics of swine. J. Animal Sci. 18:1397.

Hoefer, J. A., A. M. Pearson, J. W. Stevenson and R. W. Luecke. 1963. Effect of fibrous feedstuffs fed during the finishing period on gain, feed efficiency and carcass characteristics of swine. Mich. Agr. Exp. Sta. Quarterly Bul. 45:480.

Horvath, D. J. and K. C. Elliot. 1962. Comparison of wastage by several swine self feeders. J. Animal Sci. 21:1039. (Abstr.).

Jensen, A. H., D. E. Becker and S. W. Terrill. 1959. Oats as replacement for corn in complete mixed rations for growing-finishing swine. J. Animal Sci. 18:701.

Jensen, A. H., D. E. Becker and S. W. Terrill. 1959b. Growth inhibitory effect of oat hulls in rations for growing-finishing swine. J. Animal Sci. 18:1356.

Jordan, C. E., W. M. Beeson and J. R. Wiley. 1956. Producing leaner market hogs by different feed combinations and controlled corn intake. J. Animal Sci. 15:869.

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

Keese, W. C., D. L. Handlin, G. C. Skelley, Jr. and R. F. Wheeler. 1964. Effect of feed restriction on finishing swine. J. Animal Sci. 23:880.

Kidwell, J. F. and J. E. Hunter. 1956. The utilization of a high level of alfalfa by growing-fattening swine. J. Animal Sci. 15:1067.

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

Larsen, L. M., P. Bertun, D. C. England and J. E. Oldfield. 1960. Effect of barley hulls and purified cellulose in swine rations on carcass composition. J. Animal Sci. 19:969. (Abstr.).

Lucas, I. A. M. and A. P. C. Calder. 1956. The response of different types of pigs to varying levels of feeding from weaning to bacon weight with particular reference to carcass quality. J. Agr. Sci. 47:287.

Lucas, I. A. M., I. McDonald and A. F. C. Calder. 1960. Some further observations upon the effects of varying the plane of feeding for pigs between weaning and bacon weight. J. Agr. Sci. 54:81.

Magee, W. T. 1963. The relationship between the effect of inbreeding and sex on 154-day weights in swine. J. Animal Sci. 22:820. (Abstr.).

Mansfield, W. S. and W. R. Trehane. 1936. Final report on pig feeding experiment conducted on Cambridge University Farm. J. Roy. Agr. Soc. 97:172.

McCampbell, H. C. and D. M. Baird. 1965. Response of boars, barrows, and gilts on normal and high energy rations. J. Animal Sci. 24:290. (Abstr.).

McMeekan, C. P. 1940. Growth and development in the pig with special reference to carcass quality characters. Parts I-IV. J. Agr. Sci. 30-31.

McMeekan, C. P. and J. Hammond. 1939. Improvement of carcass quality in pigs. J. Ministry Agr. 46:238.

Meade, R. J., H. E. Hanke, M. E. Tumblesome, D. Wass and L. E. Hanson. 1964. Effects of feed restriction and protein intake on performance of market hogs. J. Animal Sci. 23:1201. (Abstr.).

Merkel, R. A., R. W. Bray, R. H. Grummer, P. H. Phillips and G. Bohstedt. 1958. The influence of limited feeding, using high fiber rations, upon growth and carcass characteristics of swine. I. Effect upon feed lot performance. J. Animal Sci. 17:3.

Merkel, R. A., R. W. Bray, R. H. Grummer, P. H. Phillips and G. Bohstedt. 1958b. The influence of limited feeding, using high fiber rations, upon growth and carcass characteristics of swine. II. Effects upon carcass characteristics. J. Animal Sci. 17:13.

Mulholland, R., E. S. Erwin and R. S. Gordon. 1960. Protein-energy ratios for barrows and gilts marketed at 145 and 195 pounds. J. Animal Sci. 19:1278. (Abstr.).

Nickelson, W. F., D. E. Becker, A. H. Jensen, B. C. Breidenstein and H. W. Norton. 1961. Varying dietary protein and energy levels on the gain and carcass characteristics of swine. J. Animal Sci. 20:945. (Abstr.).

Noland, P. R. and M. J. Burris. 1956. The effect of oral administration of methyl testosterone on swine growth and development. J. Animal Sci. 15:1014.

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

Orme, L. E., T. B. Keith, R. H. Hall, J. P. Baker and D. O. Everson. 1965. Comparison of limited vs. full feeding on feed efficiency and carcass composition. J. Animal Sci. 24:866. (Abstr.).

Pearson, A. M., G. E. Combs, Jr., H. D. Wallace, R. B. Sleeth, J. W. Stroud, J. M. Shepard and M. Koger. 1952. The effects of stilbestrol implants on swine of different sexes. J. Animal Sci. 11:251.

Perry. T. W., W. M. Beeson, M. Mohler, F. N. Andrews and M. Stob. 1956. The effect of various levels of orally administered methyl testosterone on growth and carcass composition of swine. J. Animal Sci. 15:1008.

Plank, R. N. and R. T. Berg. 1963. Inheritance and plane of nutrition in swine. I. Effects of season, plane of nutrition, sex, and sire on feedlot performance and carcass characteristics. Can. J. Animal Sci. 43:72.

Proctor, Frank and N. C. Wright. 1927. Bulk in animal feeding. J. Agr. Sci. 17:392.

Rahnefeld, G. W. 1965. Breed and sex effects on the relationship between weight and fatness in Lacombe and Yorkshire swine and their reciprocal crosses. Can. J. Animal Sci. 45:33.

Robinson, D. W. 1964. Plane of nutrition and compensatory growth. An. Prod. 6:227.

Robison, W. L. 1920. Full and limited feeding of fall pigs. Ohio Agr. Exp. Sta. Bul. Vol. 5, No. 11-12. p. 275.

Robison, W. L. 1928. The effect of grains, fiber, type, and weight on the yield of pork cuts. Am. Soc. An. Prod. p. 91.

Robison, W. L. 1940. Effect of high protein rations on pigs. Ohio Exp. Sta. Mimeo 801.

Robison, W. L., L. E. Kunkle and V. R. Cahill. 1952. The influence of various factors on the yields of pork cuts. J. Animal Sci. 11:752.

Salmela, A. B., W. E. Rempel and R. E. Comstock. 1960. The reaction of three kinds of single-cross pigs to three levels of feed intake. I. Feedlot performance. J. Animal Sci. 19:84.

Salmela, A. B., W. E. Rempel and C. E. Gates. 1963. The reaction of three kinds of single-cross pigs to three levels of feed intake. II. Carcass characteristics. J. Animal Sci. 22:886.

Schmoll, R. J. 1966. The effect of selected citrus bioflavonoics and celery oil on the performance of growing-finishing swine. M. S. Thesis. Southern Illinois Univ.

Seerley, R. W., G. E. Poley and R. C. Wahistrom. 1964. Energy and protein relationship studies with growing-finishing swine. J. Animal Sci. 23:1016.

Self, H. L., R. W. Bray and B. J. Reierson. 1957. Lean cut yield and an evaluation of hams and loins of the U. S. D. A. pork carcass grades. J. Animal Sci. 16:642.

Self, H. L., R. H. Grummer, O. E. Hays and H. G. Spies. 1960. Influence of three different feeding levels during growth and gestation on reproduction, weight gains, and carcass quality in swine. J. Animal Sci. 19:274.

Shorrock, R. W. 1940. The restricted feeding of bacon pigs. J. Agr. Sci. 30:598.

Shroder, J. D. 1963. Limited feeding studies with swine. J. Animal Sci. 22:1130. (Abstr.).

Skjervold, H., N. Standal and R. Bruflot. 1963. Effect of one form of exercise on body development in pigs. J. Animal Sci. 22:458.

Sleeth, R. B., A. M. Pearson, H. D. Wallace, D. H. Kropf and M. Koger. 1953. Effects of injection of testosterone, estradiol, and a combination of the two upon growing-fattening swine. J. Animal Sci. 12:322.

Smith, H. J., J. W. Cole, C. S. Hobbs, J. A. Erwing, E. J. Chapman and J. B. McLaren. 1950. The effect of pasture on rate and efficiency of gain and on carcasses of swine full fed and fed 80 and 60 percent of full feed. J. Animal Sci. 9:676.

Smolinsky, E., M. E. Turmbieson, R. J. Meade, L. E. Hanson and J. Auman. 1963. Influence of restricted feeding on performance of growing pigs and on carcass characteristics. J. Animal Sci. 22:1131. (Abstr.).

Snedecor, G. W. 1956. Statistical methods. (5th ed.) Iowa State College Press, Ames, Iowa.

Stothers, S. C. 1963. Restricted intake of pellets of mash and the performance and carcass quality of finishing pigs. J. Animal Sci. 22:1131. (Abstr.).

St. Pierre, J. M., F. B. Morrison and J. P. Willman. 1934. Relative efficiency of limited and full-feeding for fattening pigs in dry lot. Am. Soc. An. Prod. p. 101.

Swell, R. F. and J. L. Carmon. 1959. Effect of variations in dietary energy density on carcass value in swine. J. Animal Sci. 18:1483. (Abstr.).

Teague, H. S. and L. E. Hanson. 1954. The effect of feeding different levels of cellulosic material to swine. J. Animal Sci. 13:206.

Thrasher, D. M., A. M. Mullins, R. F. Boulware and C. W. Newman. 1962. Effects of self-feeding rations of varying energy content on performance and carcass characteristics of pigs. La. State Univ., A. S. Mimeo Cir. 62-9.

Thrasher, D. M., H. P. Roberts and A. M. Mullins. 1964. Effects of restricted feeding, wet feed, and frequency on pig performance. J. Animal Sci. 23:895. (Abstr.).

Thrasher, G. W., T. W. Perry, F. N. Andrews, W. M. Beeson and M. Stob. 1959. The effect of estrogenic and androgenic compounds upon growth and carcass composition of swine. J. Animal Sci. 18:399.

Tribble, L. F., G. L. Amick, J. F. Lasley and S. E. Zobrisky. 1958. The effect of sex and stilbestrol on growth, feed efficiency and carcass characteristics of swine. J. Animal Sci. 17:1179. (Abstr.).

Tribble, L. F. and W. H. Pfander. 1955. Growth, feed efficiency, and carcass desirability of swine as affected by level of protein, chlortetracycline (aureomycin) and feed intake. J. Animal Sci. 14:1224. (Abstr.).

Troelsen, J. E. and J. M. Bell. 1962. Ingredients and processing interrelationships in swine feeds. IV. Effects of various levels and kinds of fibrous diluents in finisher rations, fed as meal or pellets, on performance and carcass quality of swine. Can. J. Animal Sci. 42:63.

Vestal, C. M. 1921. Fiber in the rations for fattening hogs. Am. Soc. An. Prod. p. 43.

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

Wagner, G. R., A. J. Clark, W. Hays, V. C. Speer and J. T. McCall. 1961. Effect of energy and protein intake and sex on growth and feed efficiency of pigs. J. Animal Sci. 20:955. (Abstr.).

Waldren, D. E. 1964. Influence of energy and protein level in rations for finishing market pigs on performance and carcass characteristics. Can. J. Animal Sci. 44:168.

Wallace, H. D., G. E. McCabe, A. Z. Palmer, J. W. Carpenter, M. Koger and G. E. Combs. 1960. Feedlot performance and carcass traits of growing-finishing swine as influenced by sex and breed. Fla. Agr. Exp. Sta. Mimeo 60-13

Wallace, H. D., J. I. McKigney, A. M. Pearson and T. J. Cunha. 1955. The influence of chlortetracycline on the growth and carcass characteristics of swine fed restricted rations. J. Animal Sci. 14:1095.

Wallace, H. D., A. Z. Palmer, J. W. Carpenter, N. H. Anh and G. E. Combs. 1963a. The influence of feed restriction, high level copper supplement and sex on the feedlot performance and carcass characteristics of swine. Fla. Agr. Exp. Sta. Mimeo 63-16.

Wallace, H. D., A. Z. Palmer, J. W. Carpenter and G. E. Combs. 1963b. The influence of feeding a constant level of feed from 100 pounds liveweight to market weight on feedlot performance and carcass characteristics of swine. Fla. Agr. Exp. Sta. Mimeo 64-5.

Whatley, J. A. Jr., D. I. Card, J. V. Whiteman and J. C. Hillier. 1951. Influence of breeding and energy content of the ration on pork carcasses. J. Animal Sci. 10:1030.

Winters, L. M., R. E. Comstock, D. F. Jordan and O. M. Kisor. 1942. The effect of sex on the development of the pig. I. Differences in growth between boars and barrows by lines of breeding. J. Animal Sci. 1:41.

Winters, L. M., C. F. Sierk, and J. N. Cummings. 1949. The effect of plane of nutrition on the economy of production and carcass quality in swine. J. Animal Sci. 8:132.

Woehling, H. L., G. D. Wilson, R. H. Grummer, R. W. Bray and L. E. Casida. 1951. Effect of stilbestrol and testosterone pellets implanted into growing and fattening pigs. J. Animal Sci. 10:889.

Woodman, H. E. and R. E. Evans. 1941. Nutrition of the bacon pig. VI. Minimum level of protein intake consistent with quick growth and satisfactory quality. Part III. J. Agr. Sci. 31:223.

Woodman, H. E. and R. E. Evans. 1954. Nutrition of the bacon pig. XI. Minimum level of protein intake consistent with quick growth and satisfactory carcass quality. Part IV. J. Agr. Sci. 35:133.

Woodman, H. E. and R. E. Evans. 1948. Nutrition of the bacon pig. XIII. Minimum level of protein intake consistent with maximum rate of growth. Part V. J. Agr. Sci. 38:354.

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

Woodman, H. E., R. E. Evans, W. G. Turpitt and E. H. Callow. 1939. Nutrition of the bacon pig. III. Minimum level of protein intake consistent with quick and satisfactory carcass quality. Part I. J. Agr. Sci. 29:115.

Young, E. P., E. C. Leffel and J. E. Foster. 1962. Influence of energy and protein consumption on growth and carcass characteristics of finishing swine. J. Animal Sci. 21:1018. (Abstr.).

Zobrisky, S. E., W. G. Moody, L. F. Tribble and H. D. Nauman. 1961. Meatiness of swine as influenced by breed, season, and sex. J. Animal Sci. 20:923. (Abstr.).

Zobrisky, S. E., L. F. Tribble, J. F. Lasley and H. D. Nauman. 1959. The relationship between growth, carcass, and meat characteristics of littermate boars, barrows, gilts, and spayed gilts. J. Animal Sci. 18:1484. (Abstr.).

Zobrisky, S. E., L. F. Tribble, W. G. Moody and H. D. Nauman. 1960. Live hog and carcass relationships between boar, barrow, and gilt littermates. J. Animal Sci. 19:1245. (Abstr.).