EFFECT OF VARYING DIETARY PROTEIN AND ENERGY
LEVELS ON CARCASS QUALITY IN SWINE

by

WALTER HERBERT KENNICK

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APPROVED:

Redacted for Privacy

Associate Professor of Dairy and Animal Husbandry

In Charge of Major

Redacted for Privacy

Head of Department of Dairy and Animal Husbandry

Redacted for Privacy

Chairman of School Graduate Committee

Redacted for Privacy

Dean of Graduate School

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Typed by Verna Anglemier

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EFFECT OF VARYING DIETARY PROTEIN AND ENERGY LEVELS ON CARCASS QUALITY IN SWINE

INTRODUCTION

The trend in American diets in recent years has been away from consumption of large amounts of pork fat (15, pp.1-2). Concurrently there has been a large substitution of synthetics in the manufacturing fields, such as those of paints and soaps, that previously have been an active market for fats. Such decreased use of fats as food and raw materials in manufacturing has sharply lowered their market value.

Hogs as traditionally the largest producers of fat among the domestic animals have suffered proportionately at the market place. Historically lard was a valuable by-product of the packing industry and played a large part in domestic and foreign trade. At one time lard was more valuable than pork and hogs were selected for their ability to produce lard. Today the price of lard is generally much lower than that for pork meat and consequently its presence in excess has a depressing effect on value of butcher hogs (2, pp.12-13).

Today's pork industry is faced with the problem of producing market hogs that yield limited amounts of uneconomical fat and high percentages of desirable lean meat. This problem is accentuated by modern merchandising methods, since supermarkets, with their self service counters, cause pork to sell itself in competition with other meats on the basis of quality and eye appeal.

The deposition of excess fat on hogs is an expensive, uneconomical and unnecessary operation. Fats contain two and one quarter times as much energy (51, pp.39-44) as protein or carbohydrates and as stored in the hog contain very little water. Considerably more nutrients are required, therefore, to add a pound of gain in the form of fat than in the form of lean meat.

It has been demonstrated by several workers at various stations (38, pp.869-890) (52, pp.874-877) (50, p.903) that the proportion of lean to fat in hogs can be increased by restricting energy intake during the finishing period. This has generally resulted in a longer feeding period which requires more feed per pound of gain than necessary for full-fed control lots (68, p.1030) (9, pp.499-506) (7, pp.820-829). There are, however, conflicting reports on the phase of this work concerning feed conversion. Several workers (38, pp.869-890) (50, p.903) (71, pp.132-140) (10, pp.876-880) have demonstrated that a moderate feed restriction increases efficiency of feed conversion.

In approaching the problem of economical production of leaner market hogs, recourse has first been taken to the scientific literature. Discussions of growth characteristics of hogs, the effect of rate of feeding on carcass quality and feed economy, and of various means of evaluating carcass quality based on the fat:lean ratio of the carcass have been reviewed and reported herein.

In addition, an animal feed experiment is presented involving both level of feeding and the balance of protein to energy-supplying nutrients. Rations were formulated to supply low protein and low energy, high protein and low energy, low protein and high energy, and high protein and high energy. These were fed in comparison with a control lot fed a standard Oregon State College finishing ration. The results of this experiment were evaluated in terms of the economical production of hogs having a high lean to fat ratio, and were used as a basis for recommendations concerning future work on this same problem.

REVIEW OF LITERATURE

McMeekan (46, pp.276-349) (47, pp.350-510) (48, pp. 511-569), in extensive studies of the growth characteristics of the pig, found that growth tends to progress from the extremities, feet, tail, and head, towards the center of the body, the longissimus dorsi muscle being the last muscle to develop completely. These studies also point out that there is an order of predominance in tissue development, skeletal development coming first, muscle second and fat last. Hankins (32, pp.450-468), in a study of carcass composition at progressively increasing weights from fifty to three hundred and fifty pounds, points out that the percentage of the empty body composed of protein, ash and water decreases while the percentage of fat shows a sharp increase. Another worker (11, p.1271) studying the ratio of tissue growth in hams from pigs from weaning to market weight found that the ratio of lean growth was one to three and one quarter while that for fat growth was one to seven and one quarter. Crampton (21, pp.321-326) found that muscle growth increases from birth to sixteen weeks while fat deposits increase up to market weight.

Alteration of Carcass Quality

Carcass quality in any animal depends basically upon its relative composition in terms of bone, muscle, connective tissues, fat and offals (46, pp.276-349). These characteristics are the result of growth and development changes occurring within the body. Differences in the rate, order and extent of development of particular parts and particular tissues is responsible for the difference in the form and composition, and in consequence, in the carcass quality of individual animals. Many influences are capable of actively controlling and modifying these growth and development changes.

Crampton has stated (19, p.413), "There is evidence that leanness of bacon rasher is correlated with rate of live weight gain to two hundred pounds which suggests that restricting feed intake (total digestible nutrients) during the fattening period might result in leaner carcasses regardless of the kind of ration." In a later experiment (21, pp.321-326) he found that restriction of feed intake to two pounds less than full feed reduced daily gains by 0.45 pounds per day and significantly decreased deposits of backfat. Actual muscle area of the loin and bacon rasher were increased by this restricted intake.

Restricted Feed Intake

Jordan (38, pp.869-890) in an experiment with controlled corn intake found that there is a significant correlation between rate of gain and degree of fatness. Feeding 72 per cent of a full feed reduced the fat in the carcass by 4.4 per cent and increased the protein by 1 per cent. Robinson et al. (60, p.752) found that restricting the dry feed intake of hogs being fed on pasture increased the percentage of lean cuts, shoulder, loin and ham, from 49.6 per cent to 55.4 per cent. In another experiment (71, pp.132-140) it was found that restricting feed intake to three per cent of the live body weight increased the proportion of lean cuts from 52.0 per cent of the chilled carcass weight to 56.2 per cent of the chilled carcass weight. Lucas and Calder (44, pp.287-323) found that restricting the feed intake during the latter part of the finishing period increased the loin eye muscle area from 27.2 square centimeters to 29.1 square centimeters.

Dilution of Digestible Nutrients

Axelson and Eriksson (5, pp.881-891) using wheat straw as a source of crude fiber, found that the optimum crude fiber content of a ration for growing and finishing pigs is from 6.2 to 6.8 per cent. Maximum daily gain was used as a criterion for establishing this optimum. It was also noted by these workers that the hogs fed above the optimum amount of crude fiber tended to yield leaner carcasses. Crampton (20, pp.327-331) in an experiment in which he diluted the basal ration from 0 to 50 per cent with various roughages found that alfalfa hay was especially effective in reducing the fat to lean ratio. He concluded that as the level of alfalfa increased from 0 to 50 per cent of the diet, the rate of gain, dressing percentage, depth of backfat, per cent of bacon belly and per cent of fat back decreased significantly while the per cent of lean cuts, shoulder, loin and ham, increased significantly. Several other workers (5, pp.881-886) (18, p.41) (50, p.903) (68, p.1030) (72, p.211) (39, pp. 1067-1071) (9, pp.499-506) have confirmed the fact that the percentage of lean meat in the pork carcass can be increased by diluting the ration fed to hogs with various types of roughage feeds. Jordan (38, pp.869-890) found that he could increase the percentage of lean cuts in the pork carcass by diluting the ration with a mineral mix, one part ground limestone, one part steamed bone meal and one part iodized salt, but the increased feed required to produce a pound of gain made this practice economically infeasible.

Peterson et al. (57, pp.241-258) and Hill and Dansky

(37, p.763) working with broilers found that increasing the fiber content of the ration decreased the body fat content. They also noted that raising the protein level above the optimum level did not change the fat to lean ratio.

Economics of Limiting Feed Intake

There are conflicting reports in the literature concerning the economic feasibility of restricting the diet of hogs to produce leaner carcasses. Whatley *et al*. (68, p.1030), Bohman *et al*. (9, pp.499-506) and Becker *et al*. (7, pp.820-829) in their experiments with rations diluted with fibrous materials found that the feed required per pound of gain was increased in the diluted rations. Merkel *et al*. (50, p.903) on the other hand found that hogs hand fed at a level of 70 per cent of full feed and hogs fed a ration diluted to 69 per cent of the total digestible nutrients of a full ration made more economic gains than full fed hogs.

Merkel's findings are confirmed by other workers (38, pp.869-890) (71, pp.132-140) (10, pp.876-880) (26, pp.706-722) (23, pp.723-745), while still others (39, pp.1067-1071) (44, pp.287-323) concluded that a moderate restriction of from 10 to 20 per cent in feed intake had no significant effect on efficiency of feed conversion.

Hanson *et al.* (33, pp.830-838) in an experiment designed to determine the inhibitory effect of dehydrated alfalfa meal in the hog ration, found that although small percentages of alfalfa in the ration decreased rate of daily gain they did not depress efficiency of gain until the alfalfa exceeded 15 per cent of the ration. At 30 per cent there was a significant decrease in efficiency of feed conversion.

Means of Raising Energy and Protein Levels

The optimum protein levels to be fed to various weights of growing and fattening hogs, using rate of gain as a criterion, have been well established by the National Research Council (53, pp.2-21) and others (16, p.255) (45, pp.77-106) (52, p.1093). However, the effect of protein-to-energy relationships and the effect of feeding above-optimum amounts of protein as related to carcass quality are not so well established.

Robinson *et al.* (60, p.752) found that as the protein level in a ration for finishing hogs was raised from 10 per cent to 12, 15 and 20 per cent the percentage of lean cuts in the carcass increased from 46.5 per cent to 48.8, 51.4 and 56.1 per cent respectively and that the percentage of fat trimmings dropped from 28.1 per cent to 26.7, 24.1 and 19.7 per cent respectively as the protein content increased. Mitchell concluded (51, pp.39-44) that the best way to produce over-fat carcasses in swine is to feed rations deficient in protein; however, he did not find that a surplus of protein increased lean meat in the carcass. Sewell (63, p.1233) in an experiment comparing 14 and 18 per cent protein levels found no significant difference in the backfat measurements.

Peterson et al. (57, pp.241-258) and Hill and Dansky (37, p.763) working with chickens found that a sub-optimum level of protein in the ration produced increased body fat which diminished as the protein level approached the optimum level for growth but did not diminish beyond that point. Hill concluded that protein requirements for maximum growth appear to be relatively constant, absolute quantities, related to productive energy value through their influence on feed intake.

Since fats contain 2.25 times as much net energy (51, pp.39-44) as protein or carbohydrate they are logical substances to use in increasing the net energy of a ration. Fats have dropped sufficiently in price in recent years to compete with other feeds as a source of energy in the rations of livestock and poultry.

Thomas and Munro (67, pp.139-150) in an experiment with rats demonstrated that the isocaloric exchange of fat for carbohydrate in the feed did not affect protein metabolism. Deuel (24, pp.639-649) (22, pp.569-582) in an extensive study of experimental data and from personally conducted experiments concluded that the optimum level of fat in the diet of a rat is 30 per cent. This is considerably higher than the 1.5 per cent normally found in hog rations made up of grain and protein supplements (53, p.4).

Forbes *et al.* (27, pp.203-212) and Sheer *et al.* (64, pp.583-592) in work with young albino rats confirmed Deuel's findings concerning the optimum fat level in rat diets.

Biely and March (8, pp.1220-1227) found that the addition of fat to the rations of poultry increased rate of gain and efficiency of feed conversion. This was explained on the basis of the fact that the energy requirement of the growing chicken may be higher than the calorie level provided by present day (1954) rations. They also pointed out that replacing part of the carbohydrate feeds with fat lowered the per cent of crude fiber in the diet and allowed more rapid and efficient digestion and absorption in the small intestine. Scott *et al.* (62, p. 554) and Sunde (66, pp.49-52) also found that the addition of fat to poultry rations increased daily gains and improved feed efficiency.

Barrick *et al.* (6, p.899) in an experiment in which hogs were fed rations containing 10 per cent of various plant and animal fats found that the lots receiving the fat supplement gained faster and converted feed more efficiently than the control lot. Anglemier and Oldfield (1, pp.1-5) found that replacing 10 per cent of the barley with sardine oil in a growing and finishing ration reduced the feed required per pound of gain from 3.5 pounds for the control group to 3.3 pounds for the group receiving sardine oil. Similar results have been found in experiments conducted by other workers (17, p.1255) (42, pp.630-647) (35, pp.1046-1051).

There is a lack of agreement as to whether the addition of fats to the diet has a significant effect on the per cent of fat in the carcass. Barrick _et al_. (6, p.899) found that there was a significant increase in backfat but not in weight of lean cuts. Clawson _et al_. (17, p.1255) confirmed these findings while Kropf (42, pp.630-647) found no significant difference in backfat measurements taken from hogs fed a basal ration and hogs fed 10 or 15 per cent added fat.

The type of fat fed to hogs must be carefully chosen as according to Burr and Barnes (13, pp.256-278) and to Shortland (65, pp.924-926) the pig is very responsive to dietary fats, its body lipids being modified quite readily by the diet without apparent effect upon metabolism or health. Deuel (25, p.525) has stated that when large amounts of fat are fed not all will be metabolized, and that the remainder is laid down in the tissue largely in the original form.

The addition of "bland" or milk-flavored fats to hog diets does not cause any off flavors in the meat. Kropf (42, pp.630-647) found that a panel of judges was unable to identify the meat from hogs fed a supplement of fat when compared to the meat from hogs fed a conventional ration.

As reported by Kraybill (41, p.11), Rice (59, pp.56-59) and Schweigert (61, pp.55-58) the addition of fat to livestock rations has many desirable non-nutritive effects. They report that the inclusion of 1 to 3 per cent fat in a ration helps considerably to reduce the dust problem in feed mixing, which in turn prevents the loss of dry feed. Fats tend to coat and protect mixing and conveying equipment as well as to facilitate the pelleting of feed. Moreover, fat additions tend to improve the color and texture of many feeds which improves the palatability of these feeds (61, pp.55-58).

Methods of Evaluating Carcasses

The physical separation of the lean and fat in the whole carcass and the chemical analysis of a whole carcass are too expensive in time and money for most experimental budgets; however, there has been considerable work done to demonstrate the correlation between certain body and carcass measurements and the "lean cut-out", weight of shoulder, loin and ham, and fat-to-lean ratio of the carcass. Brown et al. (12, p.97) have demonstrated that the specific gravity of the carcass has a high positive correlation to the loin eye area, per cent primal cuts, per cent lean cuts and a negative correlation to backfat thickness and per cent of fat cuts. Whiteman et al. (70, p.859) further demonstrated that the specific gravity of the untrimmed ham has a correlation coefficient of 0.948 to the specific gravity of the carcass and confirmed previous work indicating that the specific gravity of the carcass is a good criterion of the fat-to-lean ratio of the carcass.

Aunan and Winters (4, pp.319-325) using a hollow coring device found that samples taken from various locations on the hog carcass gave highly significant indications of lean-to-fat ratio in the carcass. Several workers (40, pp.659-663) (49, pp.1-49) (56, pp.86-92) (58, pp.85-92) (14, p.899) have demonstrated that the cross sectional area of the longissimus dorsi muscle taken at the tenth rib is an excellent indicator of the yield of lean cuts. Whiteman and Whatley (69, p.591) have further stated that the size of the loin eye muscle determines the real value of the pork loin. These workers and others (56, pp.896-901) found very little if any value to carcass length or dressing percentage as indicators of cut-out value of the carcass. Backfat, on the other hand, is highly correlated to carcass traits whether taken as a live probe or carcass measure (49, pp.1-49) (56, pp.481-484) (34, pp.313-318). Backfat has a positive correlation to yield of fat cuts and a negative correlation to yield of lean cuts and lean area of the loin.

The yield of fat cuts, which are the trimmed belly, leaf lard, backfat and fat trimming, is much more variable than the yield of lean cuts and shows a positive correlation of 0.91 ± 0.02 to the fat percentage of the whole carcass as indicated by ether extraction of a representative sample from the carcass (31, p.257).

Lessley and Kline (43, pp.485-489) in a study of 222 barrow carcasses found that the left side yielded significantly ($P < .01$) heavier ham, picnic, lean cuts and primal cuts but lighter bellies and Boston butts than the right side. These variations were due to splitting differences and the authors suggest that where it is impractical to use the average of both sides, which reduces variance, then one side should be used consistently, either right or left. Aunan and Winters (4, pp.319-325) also noted that cutting errors introduce large variances in the yield of primal cuts.

Another source of variance, pointed out by Fredeen *et al*. (30, pp.99-103) in a study of 1384 gilt and 1384 barrow carcasses, is the difference of fat to lean characteristics due to sex variances. Gilts, in this study, had an average back fat measure of 1.33 inches and a loin eye area of 3.96 square inches while the same measures on barrows showed 1.44 inches of backfat and 3.42 square inches loin eye. In other studies (29, pp.91-94) (28, pp.95-99) the same workers found the same thing true of a variety of breeds under various feeding programs. Herbert and Crown (36, p.1269) in a study of carcass characteristics of barrows and gilts found that gilts have a significantly higher percentage of ham and loin, a larger area of loin eye, more separable lean in the ham and thicker lean in the ham while barrows have a thicker backfat and more separable fat in the ham.

Pelleting Experimental Rations

It has been demonstrated (10, pp.876-880) that pelleting of experimental rations reduces waste and insures each experimental animal in a group receiving the unaltered ration as formulated for that group.

EXPERIMENTAL

Considerable emphasis has been placed on the importance of producing hogs that yield high-quality carcasses. In general, high quality has meant carcasses that show a low percentage of fat with a high percentage of lean cuts. So far, selection of breeding stock has been the major procedure recommended for improving the carcass quality of market hogs. However, there is ample evidence that feeding methods can also affect carcass quality.

The experiment reported herein was designed to determine the effect on carcass quality, of feeding various levels of protein and energy. The levels to be fed were chosen within the range considered practicable for economical production.

Methods and Materials

Fifty purebred weaned Berkshire pigs of approximately the same age and similar breeding were selected from 67 pigs from the Oregon State College swine herd. They were fall-farrowed pigs from 12 litters. There were 15 gilts and 35 barrows in the experiment. Average body weight at start of the pre-trial period was 65.1 pounds. The animals were randomly segregated into five groups of ten pigs each. The average weight of each group at the beginning of the experiment was: group 1, 66.1 pounds; group 2, 64.1 pounds; group 3, 65.2 pounds; group 4, 64.9 pounds; group 5, 65.2 pounds. The pigs were in good health and had been treated against internal parasites.

The five groups of pigs were allotted ration treatments as follows:

Group 1. Control--Basal ration

Group 2. Experimental--Low protein, low net energy

Group 3. Experimental--High protein, low net energy

Group 4. Experimental--Low protein, high net energy

Group 5. Experimental--High protein, high net energy

The compositions of the rations fed are presented in detail in Table 1. The basal ration (O.S.C. No. 20) was one used in previous experiments and had proved adequate to support satisfactory growth.

Each group was housed in an 8 by 16 foot pen. These pens were divided into two sections, one holding the feeder and waterer and the other bedded down with straw. In addition, all groups had access to a paved outside pen. The animals had free access to water at all times and were fed ad libitum. A record of the feed given to each group was maintained as it was put into the self feeders. The feed not eaten at the end of the experiment was deducted from the total fed. Efficiency of feed use in this study is calculated as pounds of feed per pound of gain in body weight on a group basis. The animals

Table 1
Composition of Rations Used in Experiment

Feedstuffs	Ration 1 Control	Ration 2 Low Protein Low Net Energy	Ration 3 High Protein Low Net Energy	Ration 4 Low Protein High Net Energy	Ration 5 High Protein High Net Energy
	(pounds)	(pounds)	(pounds)	(pounds)	(pounds)
Ground barley	540	465	380	440	340
Ground oats	270	270	270	270	270
Soybean oil meal	50	50	50		50
Tankage	50	50	135		50
High fat mix*				200	200
Alfalfa meal	75	150	150	75	75
Calcium carbonate	10	10	10	10	10
Iodized salt	5	5	5	5	5
Total	1000	1000	1000	1000	1000

* Commercial feed (Swift and Co.) containing 25 per cent fat and 30 per cent protein

were weighed individually each week and were identified by ear notches. Gain per day is the average gain per day during the test period.

The growing ration, fed during the pre-trial period, was prepared at the Oregon State College swine barn and fed in meal form. Each constituent of the ration was carefully weighed and thoroughly mixed before being put into the self feeders.

The finishing ration, fed to the pigs from an approximate weight of 100 pounds to market weight of 185 pounds, was prepared by a commercial feed mill from ingredients supplied by Oregon State College and in accordance with the formulas listed in Table 1. A representative of the Department of Animal Husbandry was present during the ration preparation. All finishing rations were similarly prepared in quantities calculated to be sufficient for the entire feeding period. The feed was stored in multiwall paper sacks at normal barn temperature until used.

Proximate analyses on the samples of the various rations were determined in the Animal Nutrition Laboratory, Oregon State College, according to the official methods of the Association of Official Agricultural Chemists (3, pp.367-374). Results are tabulated in Table 2. Except for the figures for dry matter content, the

Table 2
Proximate Analysis of Experimental Rations

	Ration	Dry Matter	Crude Protein*	Ether Extract	Crude Fiber	Ash	Nitrogen-Free Extract**	Net Energy***
		%	%	%	%	%	%	Therms per 100 lbs.
1.	Control	87.28	16.16	2.30	8.12	5.21	55.49	70.85
2.	Low protein, low net energy	87.23	16.75	1.70	11.22	5.63	51.93	68.80
3.	High protein, low net energy	86.84	20.51	1.92	11.14	6.75	46.52	68.54
4.	Low protein, high net energy	88.19	15.43	6.26	7.60	7.78	51.12	87.04
5.	High protein, high net energy	88.87	19.68	7.18	8.27	8.61	45.13	87.26

* N x 6.25
** Calculated by difference
*** Calculated from Morrison's estimated net-energy values

data are calculated on a dry weight basis.

Prior to the beginning of the experiment all groups were fed, ad libitum, the basal ration (O.S.C. No. 20) in meal form, until the pigs reached a weight of approximately 100 pounds. There were no significant differences in rate of gain or efficiency of feed conversion between groups during this pre-trial period. The average weight of each group when put on experimental ration was: group 1, 102.4 pounds; group 2, 101.6 pounds; group 3, 100.3 pounds; group 4, 102.1 pounds; group 5, 95.5 pounds. The mean weight of all animals put on experimental ration was 100.98 pounds.

The week that each animal's weight exceeded 185 pounds, at weekly weighing time, the animals were individually removed and slaughtered at a commercial abattoir. Thickness of backfat was measured prior to slaughter at the first rib, tenth rib and last lumbar vertebra by both live probe (34, pp.313-318) and Lean Meter (54, pp.481-484). Each carcass was tagged with its ear notch number for identification before the heads were removed.

After slaughter the warm carcass was weighed and dressing percentage ($\frac{\text{warm carcass weight}}{\text{live weight}} \times 100$) calculated. Thickness of backfat was calculated by averaging measurements taken opposite the first rib, tenth rib and last lumbar vertebra of each animal. The individual carcass length was measured from the anterior edge of the first rib to the anterior edge of the "H-bone". The carcasses were cut by a skilled wholesale butcher. Weights were taken and recorded for the following cuts: trimmed ham, loin, shoulder, belly, fat trimmings, lean trimmings, and miscellaneous cuts (feet, spareribs, and jowl). A tracing was made of the cross section of the rough loin at the tenth rib.

Cut-out percentages were figured for all cuts separately as well as for lean cuts and fat cuts as groups. The cross-sectional area of the longissimus dorsi, miscellaneous lean and total area were determined with a planimeter from the tracings of the cross sectional cut of the rough loin at the tenth rib.

All data were analyzed statistically by analysis of variance.

RESULTS AND DISCUSSION

The animals in group four (low protein, high energy) suffered from diarrhea to some extent when first put on their experimental ration. This condition cleared up rapidly but their feces remained softer than that of the other groups throughout the experimental feeding period. There was a very slight diarrhea in group five (high protein, high energy) which cleared up within two days. Both these groups were fed rations containing considerable added fat. The week ending January 29th was very cold and the automatic waterers were frozen for five days. The animals were watered by hand in troughs during this period.

The feed consumption, rate of growth and feed conversion figures are given in Table 3. The groups were all fed *ad libitum* from a self feeder making a statistical analysis of feed consumption and feed conversion impractical. The group averages indicate that the low energy rations were more economically converted into meat than were the high energy rations. The control group had a significantly lower rate of gain than did the groups fed the experimental ration.

Group five, that receiving the high energy, high protein ration had the lowest daily gains of the groups

Table 3
Average Weight Gain and Feed Efficiency of Pigs on Various Protein and Energy Level Diets

Lot Number	1 Control	2 Low Protein Low Net Energy	3 High Protein Low Net Energy	4 Low Protein High Net Energy	5 High Protein High Net Energy
Number of pigs per lot	10	10	10	10	10
Average initial weight (pounds)	102.40	101.60	100.30	102.10	98.50
Average final weight (pounds)	187.85	192.80	192.65	191.90	192.75
Average daily gain (pounds)	1.31	1.50	1.57	1.53	1.39
Days to reach slaughter weight	65.10	60.90	58.80	58.80	69.90
Average daily feed intake	5.35	6.11	6.65	6.67	6.37
Feed per pound of gain (pounds)	4.07	4.09	4.23	4.37	4.59

being fed experimental rations, however this difference was not of sufficient magnitude to be statistically significant. This experiment indicates that the feeding of protein at levels above the optimum recommended for hogs from 100 pounds to market weight does not stimulate additional growth during the finishing period.

Prior to slaughter, backfat thickness measurements at the first rib, tenth rib and last lumbar vertebra were taken on each animal with live probe and Lean Meter (see Plate 1). It was found that the measures as taken by both of these methods were very similar. The Lean Meter is much faster and inflicts a smaller wound than the live probe method. Care must be taken in making the backfat measure at the first rib. A thin superficial muscle, the trapezius, lies within the fat and will give a false reading by either the live probe or Lean Meter, unless it is completely penetrated.

The Lean Meter is a patented device for measuring backfat (54, pp.481-484). Its operation depends upon the difference in conductivity of lean and fat tissues. The needle which penetrates the tissue has two electrodes at its tip which are connected to a dial. When the dial registers it is in lean tissue, when not registering it is in fat tissue.

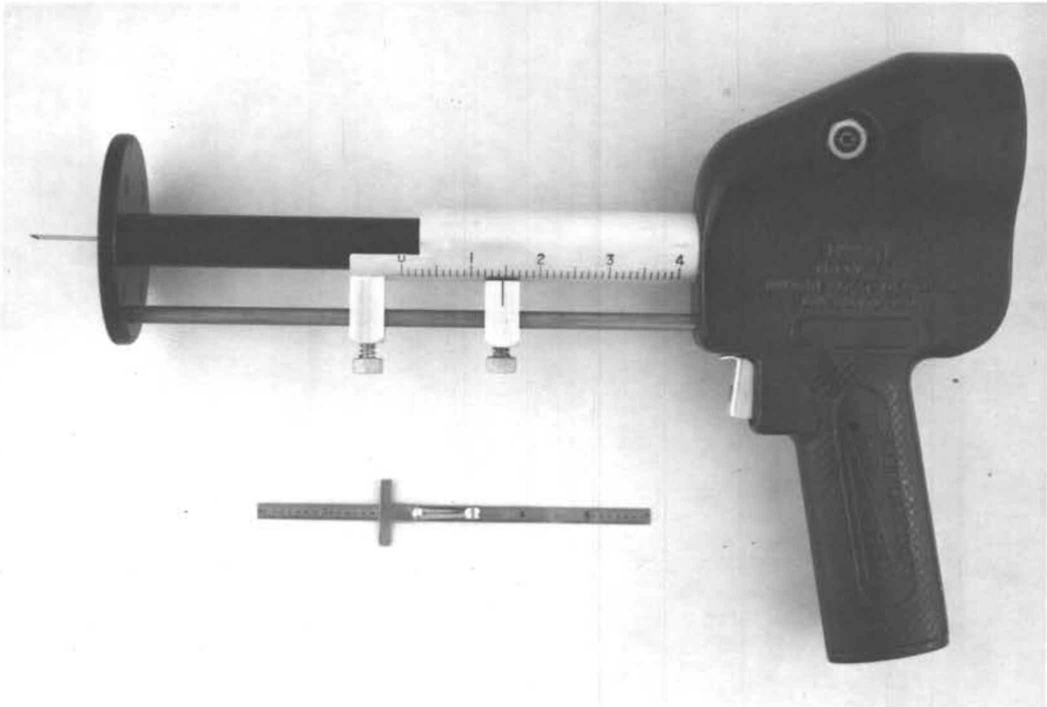

Plate 1. Instruments for measuring backfat.
Top, Lean Meter with probing needle exposed
Bottom, Small steel rule with adjustable marker

An attempt was made to measure through the *longissimus dorsi* with the Lean Meter to determine its thickness. This attempt was not successful as there was no end point reading. It was concluded that the fat layers beneath the *longissimus dorsi* were not thick enough to be indicated by the Lean Meter. There was no significant difference among the groups in backfat measured before or after slaughter.

Backfat measurements were taken on the live animals in this experiment to determine their fat deposition. In an experiment of this type, where the animals are sacrificed at the finish, the live backfat measures are of no particular value since the actual carcass measures and yield of cuts can be determined. These measures are, however, of considerable value in making *in vivo* evaluations of body composition in animals which cannot be slaughtered for some reason.

Cross sectional tracings of the rough loin, taken at the tenth rib, showed a considerable variation in area of *longissimus dorsi*, area of miscellaneous lean and area of fat. These variations are shown by Plates 2, 3, and 4. There were no significant differences between groups in these characteristics.

Average weights of the various cuts are presented in Table 4. Lot five, which received the high protein,

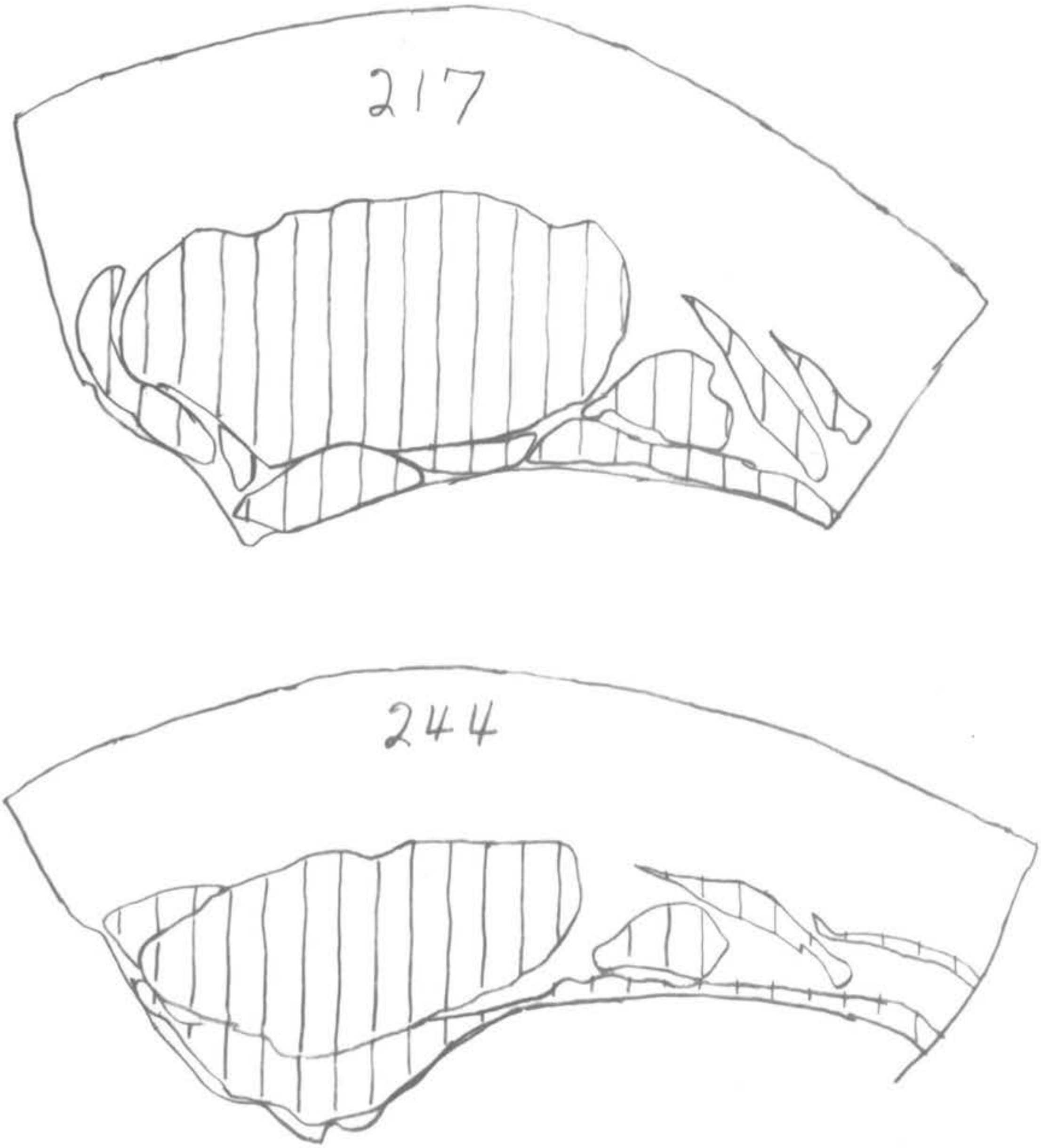

Plate 2. Cross sectional tracings of the rough loin taken at the tenth rib. Note the difference in area of the <u>longissimus dorsi</u>.

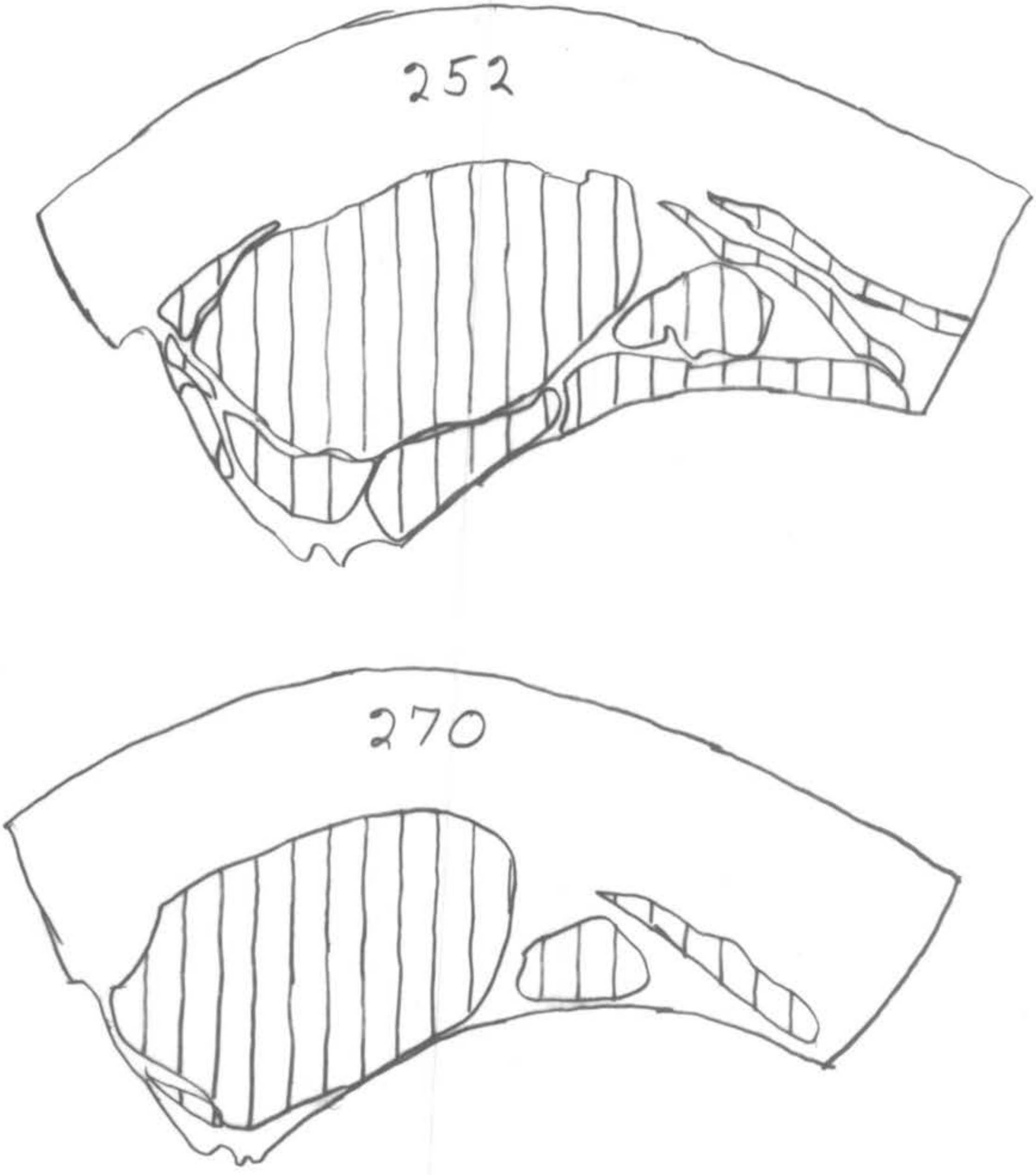

Plate 3. Cross sectional tracings of the rough loin taken at the tenth rib. Note the difference in miscellaneous lean (other than longissimus dorsi).

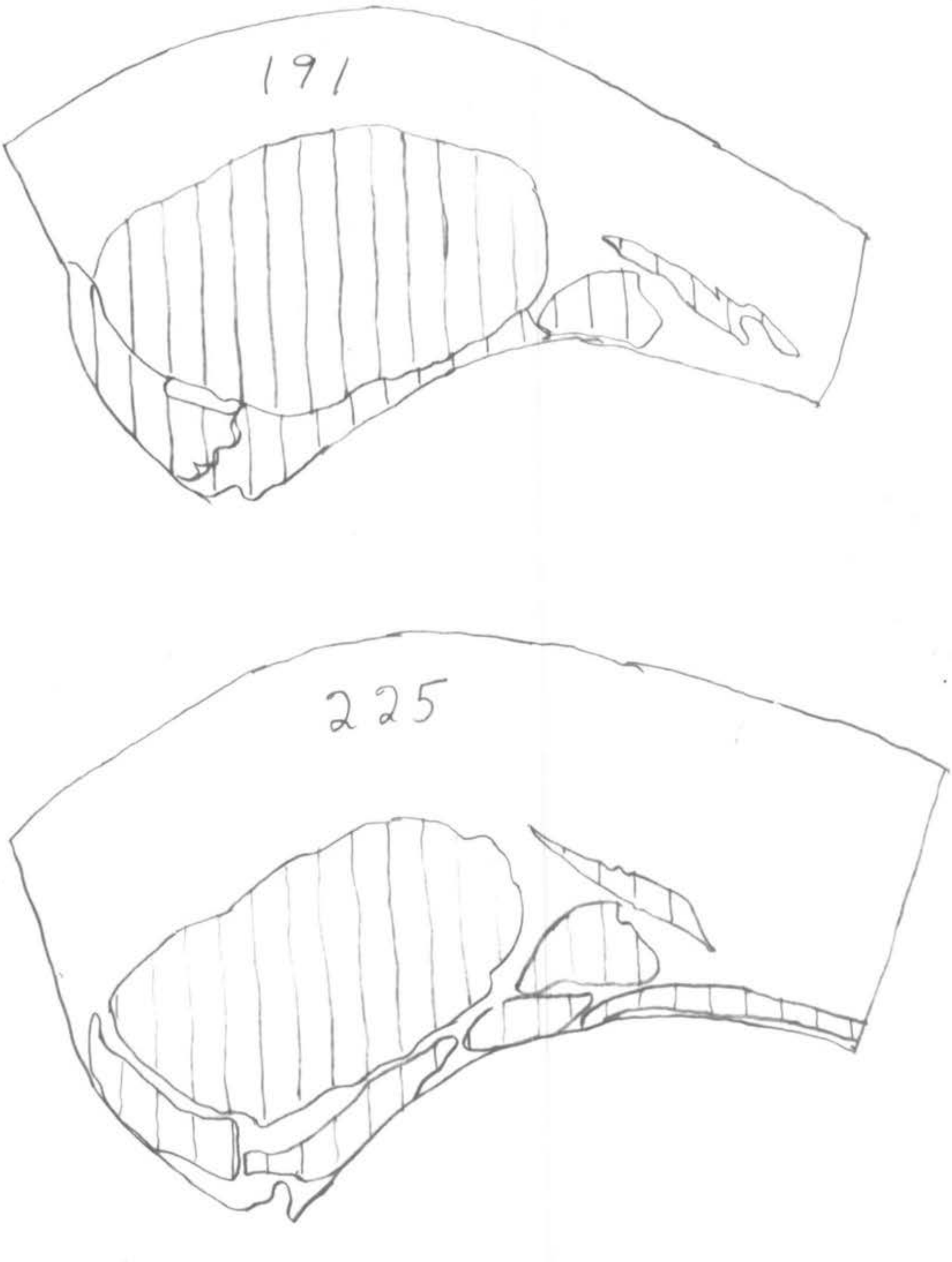

Plate 4. Cross sectional tracings of the rough loin taken at the tenth rib. Note the difference in area of fat.

Table 4
Average Carcass Measures and Yield of Wholesale Cuts from Pigs Fed Various Levels of Protein and Net Energy

	1 Control	2 Low Protein Low Net Energy	3 High Protein Low Net Energy	4 Low Protein High Net Energy	5 High Protein High Net Energy
Average slaughter weight	185.22	189.43	182.63	184.88	182.80
Average dressing percentage (warm carcass)	69.72	69.23	70.33	71.40	72.02
Average carcass length (inches	29.35	29.29	29.08	29.02	29.17
Average backfat (average of three measures in inches	1.20	1.21	1.18	1.20	1.20
Average loin eye area (square inches)	3.95	4.08	3.98	4.07	4.26
Average weight of ham (pounds)	12.95	13.18	12.69	12.91	12.91
Average weight of trimmed loin (pounds)	11.21	11.48	11.22	11.63	11.72
Average weight of trimmed shoulder (pounds)	12.31	12.48	12.29	12.63	12.95
Average weight of trimmed belly (pounds)	9.12	8.96	8.97	9.50	8.77
Average weight of fat trimming (pounds)	10.91	10.95	10.56	10.53	10.74

Table 4, continued

	1 Control	2 Low Protein Low Net Energy	3 High Protein Low Net Energy	4 Low Protein High Net Energy	5 High Protein High Net Energy
Average weight of lean trimming (pounds)	3.33	3.20	3.33	3.41	3.60
Average weight miscellaneous cuts: Spareribs, jowl, feet and tail (pounds)	6.85	6.70	6.61	6.57	6.68
Average lean cuts percentage of chilled carcass	56.68	56.80	56.36	56.30	57.26

high energy ration, had the highest average weight and per cent of lean cuts. Lot five also had the lowest weight of fat cuts. The variation in fat to lean cut proportions within the groups was much higher than the variation between the groups. The variation between the groups did not approach statistical significance.

On the basis of this experiment as conducted it is evident that the addition of protein or energy either alone or in combination above the levels provided in the control ration does not significantly affect the lean-fat ratio.

There is considerable variation added to the cut-out values as taken in this experiment due to human error in cutting. Since other work has indicated that specific gravity of the carcass and untrimmed ham is highly correlated to lean-fat ratio (12, p.97), carcass evaluations made on the basis of specific gravity might eliminate a large part of the experimental error arising from cutting variation. Such a technique might well be used to evaluate fat-lean ratios in future experiments.

Another source of within-group variance in this experiment came from using both gilts and barrows for the experiment. Gilts yield significantly leaner carcasses than do barrows (30, pp.99-103). The between-sex variation was evidenced in this experiment by the fact the gilts had an average loin-eye area of 4.32 ± .105 square inches while the barrows had an average loin-eye area of 3.95 ± 1.490 square inches. This difference was highly significant at the 1.25 per cent level of probability as calculated by Student's t-distribution. The barrows had a significantly ($P < .01$) higher variation in area of the longissimus dorsi, as calculated by Snedecor's F-distribution, than did the gilts. It would be advisable in further studies of this kind to use only animals of one sex.

Variation between litters also contributed to the within group variation. The average loin-eye area for the litters varied from 3.62 square inches to 4.55 square inches; this variation was significant ($P < .025$). The average loin-eye area of all experimental animals was 4.06 square inches.

Enough animals should be selected from each litter of pigs so that they can be randomly distributed, one to each group. Due to the limited number of animals of one sex in a litter of pigs this procedure would limit the experiment to a maximum of four groups. This procedure would provide one replication for each litter represented in the experiment. These replications would reduce the error term in the statistical analysis and in so doing help prevent the rejection of a true hypothesis.

SUMMARY AND CONCLUSIONS

1. Fifty pigs averaging 100.98 pounds were randomly alloted to five groups on ration treatments as follows.

   Group 1. Control--Basal ration

   Group 2. Experimental--low protein, low net energy

   Group 3. Experimental--high protein, low net energy

   Group 4. Experimental--low protein, high net energy

   Group 5. Experimental--high protein, high net energy

2. All groups fed experimental rations showed a significantly ($P < .01$) higher daily gain than did the control group, indicating practical possibilities for manipulation of energy ratios in finishing rations for swine.

3. The increased gains derived from experimental rations had no detrimental effect on carcass quality as determined by backfat measures, fat:lean ratio, area of <u>longissimus</u> <u>dorsi</u> or cut-out per cent. The protein level of the low protein groups was apparently sufficient to maintain adequate growth. Increasing protein level did not produce a statistically significant increase in lean meat, however there was a trend towards leaner carcasses at higher protein

levels.

4. There was no improvement in efficiency of feed conversion. The animals were group fed making a statistical analysis of feed efficiency impractical, however there was a trend which indicated that the low energy rations were converted more efficiently than were the high energy rations, regardless of protein level. Further experimentation is recommended to design rations that will produce both higher gains and improved efficiency of feed conversion.

5. Carcasses were evaluated by both live backfat and carcass measurements. Backfat measures were taken on the live hog as they reached market weight of 185 pounds using both the live probe and Lean Meter. Both methods gave essentially the same values and since the Lean Meter is faster and inflicts a smaller wound it is to be recommended for measuring backfat on live hogs. There was no significant difference in backfat between the groups. In an experiment in which carcass data can be taken by direct measure after slaughter there is no advantage in making live backfat measures.

   Carcass length and carcass backfat measures taken before the animals were cut into wholesale cuts showed no significant differences among the groups in either carcass length or carcass backfat. Individual weights were taken and recorded on all wholesale cuts. These weights were analyzed by analysis of variance both separately and in combination of lean cuts, shoulder, loin and ham and fat cuts, belly and fat trimmings. There were no significant differences among groups in any of these analyses.

Cross sectional tracings of the rough loin taken at the tenth rib were evaluated for area of lean, area of fat and fat to lean ratio. These evaluations were analyzed statistically and showed no significant differences among groups. Evaluation of tracings of the rough loin is to be highly recommended as a method of evaluating hog carcasses as it is influenced very little by cutting error. Yield of lean cuts, though a measure of the market value of a carcass, is not a good method for evaluating experimental results. There is a large amount of variation introduced into the yield of lean cuts by the variation in point of separation and degree of fat trimming.

6. Comparison of barrows and gilts showed significant sex influences to occur in relation to lean yield, and further indicated that barrows were more variable

in their individual lean yield than were gilts. This would indicate that within group variation could be greatly reduced by using only gilts in future experiments.

7. The increased gains made during finishing period by the pigs on the experimental ration suggests the desirability of further study in manipulation of energy:protein ratios to arrive at a combination offering maximum monetary returns. It is noteworthy that in this study, none of these increased gains were made at the expense of carcass quality. Future studies should be made under conditions wherein individual feed conversion efficiency can be calculated, and where within group variation is reduced by using only one sex, preferably gilts.

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