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I am submitting herewith a thesis written by Richard Estill Groce entitled "Effects of Protein Levels on Feedlot Performance and Carcass Characteristics of Meat Type Swine." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Husbandry.

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EFFECTS OF PROTEIN LEVELS ON FEEDLOT PERFORMANCE AND
CARCASS CHARACTERISTICS OF MEAT TYPE SWINE

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Presented to
the Graduate Council of
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In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Richard Estill Groce

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ABSTRACT

Data collected on 68 hogs at the Knoxville Experiment Station, Knoxville, Tennessee, were used to determine the effect of varying protein levels on feedlot performance and carcass characteristics in swine. The protein level sequences were: (1) 12-12-12 percent, (2) 14-14-12 percent, (3) 16-14-13 percent, (4) 16-16-16 percent, (5) 18-16-14 percent and (6) 20-18-16 percent. The levels in each sequence were reduced at 75 pounds and again at 130 pounds.

In the period from weaning to 75 pounds, the 18 percent and 20 percent protein levels showed significantly ($P < .01$) greater gains when compared with the 12 percent and 14 percent protein levels. There were significant differences ($P < .01$ and $P < .05$) in feed conversion when 20 percent and 18 percent were compared to 12 percent and 14 percent protein and when 20 percent and 12 percent were compared to 12 percent, 16 percent and 18 percent protein, respectively.

In the period from 40 to 130 pounds, there were significant differences ($P < .01$) for ADG when comparisons of 12-12 percent and 14-14 percent versus 18-16 percent and 20-18 percent and 12-12 percent versus 14-14 percent were made. There was also a significant difference ($P < .05$) when 16-14 percent and 16-16 percent were compared to 12-12 percent, 14-14 percent, 18-16 percent and 20-18 percent protein in favor of the previous. In the feed conversion for this period, there were significant differences ($P < .05$ and $P < .01$) respectively when 20-18 percent and 18-16 percent protein were compared to 12-12 percent

and 14-14 percent protein and when 14-14 percent was compared to 12-12 percent protein in favor of the higher levels in both cases.

In the period from 40 pounds to market weight, there was a significant difference ($P < .01$) when 12-12-12 percent and 14-14-12 percent and 14-14-12 percent protein were compared with 18-16-14 percent and 20-18-16 percent protein in favor of the higher sequence levels. When compared with 12-12-12 percent protein, 14-14-12 percent protein was significantly ($P < .05$) greater. There was also a significant difference ($P < .05$) when 16-14-13 percent and 16-16-16 percent was compared to 12-12-12 percent, 14-14-12 percent, 18-16-14 percent and 20-18-16 percent protein. There were no significant differences in feed efficiency among any of the comparisons made.

When the pigs were somascope at 75 pounds, 20 percent and 18 percent protein was significantly greater ($P < .05$) than 14 percent and 12 percent protein for backfat thickness. Fourteen percent protein was also significantly greater than 12 percent protein for the same trait. When the pigs were somascope at 130 pounds, 20-18 percent and 18-16 percent protein was significantly lower ($P < .05$) than 14-14 percent and 12-12 percent protein. At the end of the test, there were no significant differences in backfat thickness (somascope or carcass backfat) for any of the comparisons made.

In the analysis for percent ham and loin, 20-18-16 percent and 18-16-14 percent protein was significantly greater ($P < .01$) than 14-14-12 percent and 12-12-12 percent protein. Percent lean cuts also showed significant differences ($P < .01$) in the above rations in favor

of the higher levels 16-16-16 percent was significantly greater ($P < .05$) than 16-14-13 percent protein for percent lean cuts. In the analysis for loin eye area, 20-18-16 percent and 18-16-14 percent was significantly greater ($P < .01$) than 14-14-12 percent and 12-12-12 percent protein. There were no significant differences for any of the comparisons for carcass length, ham quality scores, loin quality scores or loin marbling scores.

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CHAPTER I

INTRODUCTION

Considerable controversy surrounds the subject of dietary protein level effects on swine feedlot performance and carcass characteristics. Dietary protein levels are still widely used in formulating diets that supply the amino acid needs of the pig. Although a great amount of progress has been made in the past few decades in changing the swine in the United States from the "fat" to the "lean" type, this selection may have altered the ability of swine to utilize protein. If the ability of swine to utilize protein has been altered, a re-examination of ration protein levels would be necessary for pigs to be fed for maximum leanness and efficiency.

Much of the information available concerns protein utilization for the average pig. Information concerning protein utilization by the lean-type pig could be of great economic importance to present and future swine producers.

The objectives of this study were: (a) to compare differences in average daily gain and feed efficiency for pigs on six different levels of protein and (b) to compare differences in carcass characteristics of pigs fed the different protein levels.

CHAPTER II

REVIEW OF LITERATURE

Most studies support the hypothesis that average daily gain (ADG) was significantly increased by increasing dietary protein levels in swine rations (Jensen et al., 1955; Bowland and Berg, 1959; Boenker et al., 1960; Wagner et al., 1963, Seymour et al., 1964 and Crum et al., 1964). However, other workers have observed little or no effect on ADG in response to increased dietary protein levels (Wallace et al., 1954; Stevenson et al., 1960; Aunan et al., 1961; Greeley et al., 1964 and Holmes et al., 1965).

Many studies indicate that feed efficiency is improved by increasing dietary protein levels of the rations (Wallace et al., 1964; Bellis, 1965; Hale and Southwell, 1967 and Jurgens et al., 1967). Reports to the contrary (Wagner et al., 1963; Wong et al., 1968 and Lugos and Miles, 1970) state that dietary protein level had no significant effect on feed efficiency.

Results of studies concerning the effects of dietary protein on carcass characteristics were varied as much as those concerning performance traits. In some studies it was concluded that increased dietary protein levels results in decreased carcass backfat and increased percentage of the four lean cuts (Boenker et al., 1960; Stevenson et al., 1960; Wagner et al., 1963; Seymour et al., 1964; Hale and Southwell, 1967 and Sagahara et al., 1969). However, Bowland and Berg (1959); Aunan et al. (1961); Clawson et al. (1962); Dukelow et al. (1963) and

Greeley et al. (1964) reported that dietary protein level had little or no effect on carcass backfat or percentage of the four lean cuts.

National Research Council (1968) protein recommendations for pigs fed corn-based rations are 16 percent from 20 to 30 kg, 14 percent from 35 to 60 kg and 13 percent from 60 to 100 kg of body weight. Although these levels appear to provide adequate growth and overall feed efficiency, many people have wondered if increased protein levels might maximize growth and efficiency and at the same time yield more desirable carcasses.

Catron et al. (1952) conducted a study involving 128 Duroc pigs which were fed a corn-soybean oil meal ration supplemented with minerals and vitamins from weaning to 200 pounds. The initial protein levels were 20, 18, 16 and 14 percent. When the pigs reached an average weight of 75 pounds the protein contents of the rations were reduced to 17, 15, 13 and 11 percent and at 150 pounds the levels were further reduced to 14, 12, 10 and 8 percent protein. In order to evaluate the effect of an antibiotic on the protein requirement of the pig, two of the four lots of pigs on each set of protein levels received 10 mg of aureomycin hydrochloride per pound of ration. In the initial to 75 pound weight period, no significant differences in daily gain resulted by varying the protein levels. There was significant difference in feed efficiency in the no-antibiotic groups with the pigs on the 18 percent ration having the lowest feed required (258 pounds) per 100 pounds of gain. In the 75 to 150 pound weight period, no significant differences were found in daily gain while feed efficiencies showed a steady increase as the percent protein was

lowered. Significant differences in ADG for the pigs on no-antibiotic rations were reported for the 150 to 200 pound weight period with the pigs on the 10 percent protein level having the greatest gains. None of the differences in feed per 100 pound gain were found to be significant in this period. In the initial to 200 pound weight period, daily gains varied in the no-antibiotic groups with the peak of the curve at or near the 16 to 13 to 10 percent protein levels. No significant differences were found in feed efficiencies or backfat measurements due to different levels of protein. Dressing percentages, body length, body depth and percent of lean were not significantly influenced by the protein content of the ration or by the absence or presence of antibiotic.

In three experiments concerning protein levels, Wahlstrom (1954) found that a 12 percent protein ration produced slower gains than higher levels (18 to 14 percent vs. 16 to 22 percent) of protein from weaning to 100 pounds and a 9 percent protein ration did not support normal growth from 100 pounds to market weight. Very little difference in rate of gain or feed efficiency was obtained between the 18-14, 16-12 or 14-10 percent protein levels until the pigs reached 100 pounds. From 100 to 200 pounds the pigs on 14 or 12 percent protein had greater gains than pigs on 10 percent. There was no significant differences in backfat thickness on carcass length. However, the low protein group had significantly smaller loin eye areas.

Ashton et al. (1955) reported that feeding pigs protein levels over the range from 10 to 20 percent of the ration resulted in carcasses with a significantly greater proportion of lean as the level of protein increased.

Some reports support the idea that the quality and source of the protein in the ration influence performance and carcass characteristics of pigs as much as protein levels. Kropf et al. (1959) reported that rations containing 16 and 12 percent total protein were found to support good growth of swine from weaning to 200 pounds when these rations contained small amounts of a high quality protein source such as brewers' yeast and dried skim-milk. Smith et al. (1967) found that satisfactory growth could be obtained from weanling pigs fed a 11.3 percent protein corn-soybean meal diet when at least 50 percent of the amino acids were supplied by soybean meal. Carcass leanness was improved up to 14.3 percent dietary protein but further increased in protein level did not increase percent lean cuts. However, Bayley and Summers (1968) reported that there was no significant improvements in gain or feed efficiency when either lysine or methionine was added separately, but there was a substantial response when they were added together.

In a study by Aunan et al. (1961) 226 pigs were fed in four experiments to determine the influence of protein content of rations on various measures of carcass merit and performance. Protein levels compared in three experiments were 18 and 14 percent initially with each level being reduced three percentage units when the pigs reached 125 pounds. In the fourth experiment initial levels of 16 and 14 percent protein were reduced to 11 percent at 125 pounds were compared with a 12 percent level fed throughout the experimental period. Differences of carcass characteristics were not statistically significant. However, there were fairly consistent small differences in several measurements

in favor of the higher protein levels. Initial protein levels of 14, 16 or 18 percent did not have a significant effect on daily gain.

Baker et al. (1967) reported that protein level had no effect on backfat thickness or carcass length, but other criteria of carcass leanness were reported by increased dietary protein.

In an experiment by Wong et al. (1958), one group of pigs was given a growing ration (17 percent protein) until slaughter. A similar group received the growing ration to a body weight of 50 kg, and then a finishing ration (13 percent protein) until slaughter. No significant treatment differences were found for any performance traits studied. Pigs fed the higher level of protein had less carcass backfat and smaller live backfat probe measurements than those fed at the lower level.

Hale and Southwell (1967) conducted a study in which they found that pigs fed diets containing either 18-15 percent or 16-13 percent protein sequences were more efficient in utilizing feed and had a higher yield of lean cuts than pigs fed the 14-11 percent protein diets. Pigs fed diets 18-15 percent protein had less backfat than pigs fed diets containing either 16-13 percent or 14-11 percent protein and had a larger loin eye area.

In a similar experiment, Davis et al. (1965) stated that no improvement in growth rate and feed conversion were obtained at levels greater than 18 percent crude protein, but the carcass quality was improved up to 22 percent crude protein. Lee et al. (1967) reported that the higher protein levels in the diets resulted in an increase in rate of gain, feed efficiency and carcass leanness.

Both Stevenson et al. (1960) and McConnell (1970) stated that protein level affects carcass characteristics such as backfat and lean cuts, but does not affect daily gains.

While many workers have reached conflicting conclusions about the effect of protein levels on ADG, some other workers have stated that early differences in daily gains disappeared before the end of the trial. Noland and Scott (1960), using protein levels of 12, 16 and 20 percent, found that during the period from weaning to 75 pounds the linear component of the protein effect was highly significant for ADG. Likewise, Davey and Morgan (1969) reported that pigs fed 20 percent protein gained significantly faster than those fed the 12 percent level in the 140-day analysis. The 196-day analysis of gains on a smaller number of pigs indicated that the average gain of those fed the 20 percent protein remained above that of those given the 12 percent protein diet, but the difference was no longer significant.

Kornegay et al. (1972) found that during Phases I (15 to 34 kg) and II (34 to 68 kg) ADG for the pigs tested was lower ($P < .01$) and feed per gain was higher ($P < .01$) when the lower protein levels were fed. During Phase III (68 kg to market) there was little difference in feedlot performance of pigs fed the various combinations of protein levels. Protein combinations were (percent protein): (1) 16-16-16, (2) 16-16-14, (3) 16-14-14, (4) 16-14-12, (5) 14-14-14, (6) 14-14-12, (7) 14-12-12, (8) 12-12-12. Overall ADG was higher and the feed per gain was lowered for pigs fed combinations 1 through 3 as compared to pigs fed combinations 4 through 6. Pigs fed combinations 1 through 6 had higher ADG and lower feed per gain than pigs fed combinations 7 and 8.

Loin-eye area and marbling were greater for pigs fed combinations 1 through 6 than for pigs fed 7 and 8. Pigs fed combinations 1 through 3 had larger loin-eye areas and shorter carcass than pigs fed combinations 4 through 6. The loin-eye areas from pigs fed combinations 1 and 2 were larger than from pigs fed combination 3. Dressing percent, average backfat thickness and quality score were not different between pigs fed the various protein combinations.

CHAPTER III

EXPERIMENTAL PROCEDURE

I. FACILITIES

The experimental animals were fed in pole-type barns open to the south side with the north side closed during the winter and open for ventilation during the summer. The pens were five feet wide and 20 feet long with an automatic waterer and one two-hole self feeder per pen, with the feeder being located under the roof and the waterer at the opposite end of the pen. The floor was solid concrete with a slight slope to the outside gutter to provide drainage. Pens were cleaned daily or as needed.

II. RATIONS

The composition of the rations fed in this experiment is shown in Table 1. There were six rations with the initial protein levels being reduced at 75 pounds and again at 130 pounds. The protein sequence levels were: (1) 12-12-12 percent, (2) 14-14-12 percent, (3) 16-14-13 percent, (4) 16-16-16 percent, (5) 18-16-14 percent and (6) 20-18-16 percent. These protein sequences were fed until slaughter at approximately 220 pounds.

III. MANAGEMENT AND DATA COLLECTION

Following weaning, Duroc, Hampshire and Duroc X Hampshire cross-bred pigs from the U.T. Swine Herd at the Knoxville Station were

TABLE 1. PERCENTAGE COMPOSITION OF RATIONS

Ingredient	Percent Protein					
	12	13	14	16	18	20
#2 Yellow Corn (8.5%)	861	831	801	751	681	621
SBOM (44%)	70	100	110	150	200	250
Meat Scraps (50%)	25	25	40	50	50	60
Dehy. Alf. Meal (17%)	25	25	30	30	50	50
Dical. Phos.	10	10	10	10	10	10
Salt	5	5	5	5	5	5
Trace Min. Premix ^a	1	1	1	1	1	1
Antibiotics ^b	1	1	1	1	1	1
Vit. Premix ^c	2	2	2	2	2	2
Total	1,000	1,000	1,000	1,000	1,000	1,000

^aProvides an addition to the ration of 1,000 ppm of Mu, 1 ppm Ca, 100 ppm Fe, 10 ppm Cu, and 100 ppm Zn.

^bContains 10 gm chlorotetracycline per pound.

^cProvides an addition to the ration of 2 gm of riboflavin, 4 gm pantothenic acid, 9 gm. niacin, 10 gm choline, 10 mg B₁₂, 500,000 I.U. Vitamin A and 250,000 I.U. Vitamin D.

allotted for the test. The pigs, weighing from 30 to 50 pounds, were divided on the basis of breed, sex, weight and litter. Six pigs per pen and two pens per ration were used. Initial weight and ultrasonic estimates of backfat were recorded. The pigs were weighed at 14-day intervals throughout the experiment and ultrasonic estimates of backfat were taken when the pigs weighed 75 and 130 pounds and again at 220 pounds when the pigs were taken off the test. Feed efficiency was calculated on a bi-weekly basis and at the end of the test.

IV. SLAUGHTER PROCEDURES

As the pigs reached slaughter weight, they were slaughtered and processed packer style using the procedures outlined by the National Livestock and Meat Board (1952). Final backfat thickness was measured on each carcass, with the value reported being the mean value of individual fat depth measurements over the first rib, last rib and last lumbar vertebra. Loin-eye area at the 10th rib was traced and the area determined with a compensating planimeter. Hams, loins and loin marbling were scored by U.T. meats researchers according to Pork Quality Standard, Special Bulletin 9, University of Wisconsin (1963).

V. STATISTICAL ANALYSES

Weaning to 75 Pounds Feedlot Performance Data

Weaning to 75 pounds feedlot performance data was evaluated using a set of orthogonal contrasts. Table 2 illustrates these orthogonal comparisons.

TABLE 2. ORTHOGONAL COMPARISONS FOR WEANING TO 75 POUNDS
FEEDLOT PERFORMANCE DATA

Rations (Percent Protein)	12	14	16	18	20
X1	-2	-1	0	1	2
X2	2	-1	-2	-1	2
X3	-1	2	0	-2	1
X4	1	-4	6	-4	1

Seventy-Five Pounds to Market Weight Feedlot Performance and Carcass Data

Seventy-five pounds to market weight and carcass data was evaluated using the set of orthogonal contrasts illustrated in Table 3.

TABLE 3. ORTHOGONAL COMPARISONS FOR 75 POUNDS TO MARKET
WEIGHT AND FEEDLOT PERFORMANCE AND CARCASS DATA

Rations	12	14	16	16	18	20
(Percent	12	14	14	16	16	18
Protein)	12	12	13	16	14	16
X1	1	1	0	0	-1	-1
X2	1	-1	0	0	0	0
X3	0	0	0	0	1	-1
X4	0	0	1	-1	0	0
X5	-1	-1	2	2	-1	-1

A set of dummy independent variables (X_1 , X_2 ---- X_4 and X_1 , X_2 ---- X_5) to create valid orthogonal contrasts was generated using 'IF' and 'GO TO' label transfer statements in the SAS fortran option. These

dummy independent variables were then all regressed on each dependent variable in the data set.

The models used in the analysis were: weaning to 75 pounds

$$Y = M + b_1 (X_1 - \bar{X}_1)^2 + b_2 (X_2 - \bar{X}_2)^2 \dots + b_4 (X_4 - \bar{X}_4)^2$$

$$75 \text{ pounds to market and carcass } Y = M + b_1 (X_1 - \bar{X}_1)^2 + b_5 (X_5 - \bar{X}_5)^2 \text{ when}$$

$X_1, X_2 \dots X_5$ were the dummy independent variables.

These models can also be expressed as follows:

$$Y = M + \text{tmt} + \text{pens/tmt}$$

The contrast found in Table 3 can be explained as follows:

X_1 = 12-12-12 percent and 14-14-12 percent protein vs. 18-16-14 percent and 20-18-16 percent protein (low vs. high protein)

X_2 = 12-12-12 percent protein vs. 14-14-12 percent protein (low protein vs. second lowest protein)

X_3 = 18-16-14 percent protein vs. 20-18-16 percent protein (second highest protein vs. highest protein)

X_4 = 16-14-13 percent protein vs. 16-16-16 percent protein (N.R.C. recommendation vs. straight 16 percent)

X_5 = 16-14-13 percent and 16-16-16 percent protein vs. 12-12-12 percent, 14-14-12 percent, 18-16-14 percent and 20-18-16 percent protein (two intermediate levels vs. two high and two low levels).

CHAPTER IV

RESULTS AND DISCUSSION

I. EFFECT OF PROTEIN LEVELS ON GAINS

Effect from Weaning to 75 Pounds

The effect of crude protein levels on average daily gains (ADG) are shown in Table 4 and also in Figure 1. For each increase in protein levels there was an increase in average daily gain. ADG of pigs fed rations containing the 18 and 20 percent crude protein were significantly ($P < .01$) higher than for those fed rations containing 12 and 14 percent crude protein rations. In contrast, Catron et al. (1952) and Wahlstrom (1954) did not find any significant differences in ADG of pigs in this general weight group which were fed varying levels of protein.

Effect from 40 to 130 Pounds

In the period from 40 to 130 pounds (see Table 4) some significant differences were found between the ADG of pigs on different protein levels. There was a significant difference ($P < .01$) when 12-12 percent and 14-14 percent protein were compared with 18-16 percent and 20-18 percent protein in favor of the higher protein levels. A significant difference ($P < .01$) was also found when 14-14 percent was compared against 12-12 percent protein. The gains of the pigs fed 14-14 percent protein was greater than the gains of the pigs on 12-12 percent protein from 40 to 130 pounds. This is in agreement with Auman et al. (1961) who found a highly significant ($P < .01$) decrease in ADG when weanling pigs were fed a 12 percent protein diet up to a

TABLE 4. FEEDLOT PERFORMANCE OF PIGS FED VARYING PROTEIN LEVEL SEQUENCES TO MARKET WEIGHT

Phase and Criteria	Protein Level Sequences					
	1	2	3	4	5	6
I, 40 to 75 lb.	12	14	16	16	18	20
II, 75 to 130 lb.	12	14	14	16	16	18
III, 130 lb. to market	12	14	13	16	14	16
No. of pigs	12	12	10	12	11	11
Avg. initial wt., lb.	37.50	40.85	38.50	39.35	41.40	38.20
Avg. final wt., lb.	202.00	221.00	214.60	211.50	223.50	215.00
Avg. daily gain, lb.	0.78	1.31	1.43	1.49	1.61	1.70
40 to 75 lb.	1.08	1.44	1.62	1.55	1.65	1.52
40 to 130 lb.	1.26	1.52	1.73	1.59	1.68	1.65
40 lb. to market						
Feed per lb. gain, lb.						
40 to 75 lb.	3.92	2.71	2.58	2.33	2.63	2.23
40 to 130 lb.	3.66	2.97	3.11	2.77	3.07	2.82
40 lb. to market	3.87	3.51	3.51	3.53	3.49	3.50

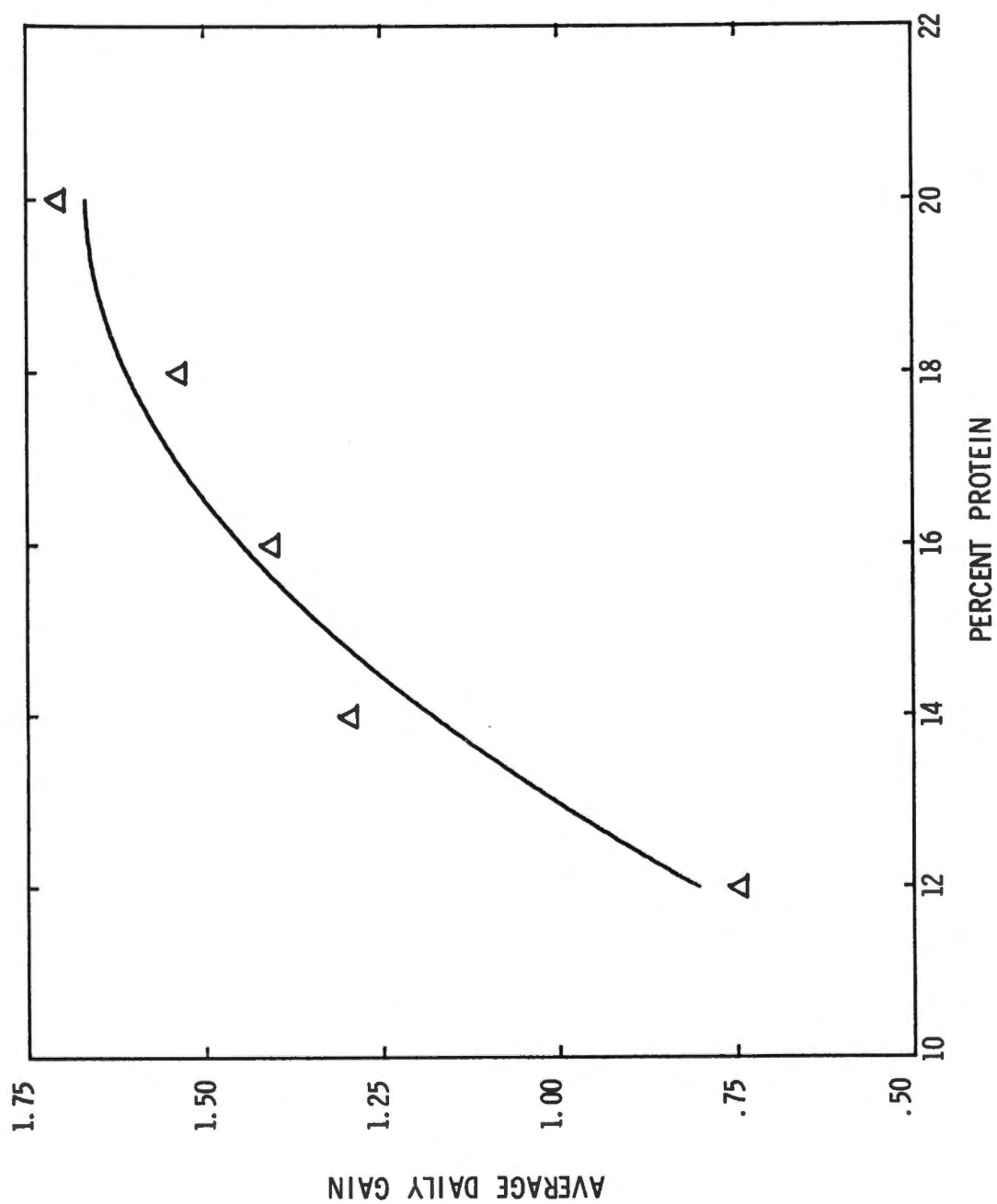


Figure 1. Mean average daily gain for pigs fed 12, 14, 16, 18 or 20 percent crude protein from weaning to 75 pounds.

weight of 125 pounds as compared with pigs fed 14 or 16 percent protein diet. Lugas and Miles (1970) reported similar results. There were no significant differences when either 16-14 percent was compared with 16-16 percent protein or when 18-16 percent was compared with 20-18 percent protein. However, there was a significant difference ($P < .05$) in favor of 16-14 percent and 16-16 percent protein when compared against 12-12 percent, 14-14 percent, 18-16 percent and 20-18 percent protein.

Effect from 40 Pounds to Market Weight

In the overall period from 40 pounds to market weight, there was a significant difference ($P < .01$) when 12-12-12 percent and 14-14-12 percent protein were compared in favor of the latter. This is in agreement with Seymore et al. (1964) who stated that pigs fed a high level of protein (20, 17 and 14 percent) grew significantly faster than pigs fed lower protein (16, 13 and 10 percent). Jensen et al. (1955) and Bowland and Berg (1959) reported similar results. When 16-14-13 percent protein was compared with 16-16-16 percent protein, no significant differences were found. Also there were no significant differences between 18-16-14 percent and 20-18-16 percent protein. However, there was a significant difference in favor of 16-14-13 percent protein and 16-16-16 percent protein were compared against 12-12-12 percent, 14-14-12 percent, 18-16-14 percent and 20-18-16 percent protein.

When ADG and feed conversion were analyzed for periods of 75 to 130 pounds and 130 pounds to market weight, there were no significant differences for any of the comparisons made.

II. EFFECT OF PROTEIN LEVELS ON FEED CONVERSION

There were no significant differences in overall feed conversion from 40 pounds to market weight for any of the comparisons made. Wong et al. (1968) reported similar results when they stated that feeding a 17 percent protein ration was not significantly different from feeding a 17 percent protein ration to 50 kg weights and dropping to a 13 percent ration. This is in disagreement with Wagner et al. (1963) and Clawson et al. (1962).

However, in the period from 40 to 75 pounds, there were some significant differences found for two of the comparisons made. There was a significant difference ($P < .01$) when 20 percent and 18 percent protein were compared against 12 percent and 14 percent protein in favor of the higher protein levels. There was also a significant difference ($P < .05$) in favor of 20 percent and 12 percent protein versus 14 percent, 16 percent and 18 percent protein. In the period from 40 to 130 pounds the results were similar to those reported above for feed conversion. There was a significant difference ($P < .05$) in favor of the 20-18 percent and 18-16 percent protein when it was compared to 12-12 percent and 14-14 percent protein. There was also a significant difference ($P < .01$) in favor of 14-14 percent when compared to 12-12 percent protein. These results are supported by Baker et al. (1967) who reported that feed efficiency was improved as the levels of dietary protein were increased. In contrast, Boenker (1960) reported that protein levels had little influence on feed efficiency from weaning to 125 pounds.

In general increasing crude protein levels improved feed conversion for pigs until they reached approximately 130 pounds. However, at the end of the trial these differences had disappeared.

III. EFFECT OF PROTEIN LEVELS ON CARCASS CHARACTERISTICS

At the start of the study, the pigs were somascoped to measure backfat thickness. At this time there were no significant differences among any of the treatments. Figure 2 shows the four somascope measurements that were taken during the study. When the pigs reached approximately 75 pounds, there was a significant difference ($P < .05$) for the comparison of 12 percent and 14 percent against the 18 percent and 20 percent protein. There was also a significant difference ($P < .05$) between the 12 percent and the 14 percent rations. Both of these differences were in favor of the higher protein levels. At 130 pounds there was a significant difference ($P < .05$) in favor of the higher protein level when 20-18 percent and 18-16 percent protein were compared against 14-14 percent and 12-12 percent protein. Here again the difference was in favor of the higher levels. As the pigs reached market weight (approximately 220 pounds) they were somascoped for the fourth time. At this time there were no significant differences for any of the comparisons made. When the pigs were slaughtered, the backfat thickness was measured and here again there were no significant differences. The correlation between the carcass backfat thickness and the final somascope measurement was 0.70. This finding is supported by Clawson et al. (1962) and Dukelow et al. (1963) who also reported no significant differences in backfat thickness due to varying the

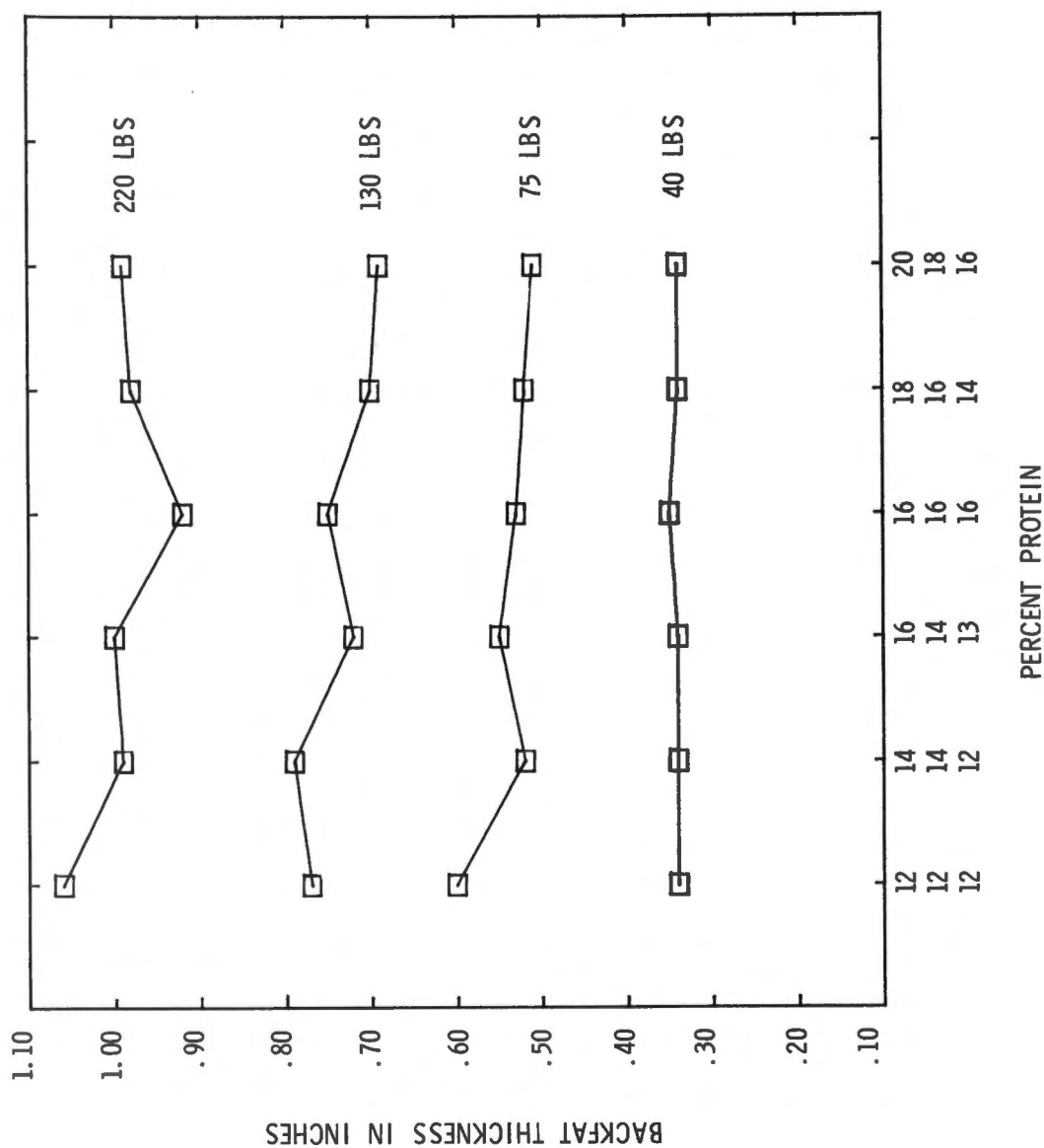


Figure 2. Mean somascope estimates from weaning to market when crude protein levels are changed at 75 and 130 pounds for six different rations.

protein levels. Table 5 shows the response of carcass traits to varying protein levels. There was a significant difference ($P < .01$) in percent ham and loin in favor of 20-18-16 percent and 18-16-14 percent when compared with 12-12-12 percent and 14-14-14 percent protein. This was the only significant difference for any of the comparisons made. However, the differences between 16-16-16 percent and 16-14-13 percent approached significance as did the comparison of 16-16-16 percent and 16-14-13 percent against 12-12-12 percent, 14-14-12 percent, 18-16-14 percent and 20-18-16 percent protein.

In the analysis of the effects of varying protein level on the percent lean cuts (trimmed ham, shoulder and loin) there was a significant difference ($P < .01$) in favor of 20-18-16 percent and 18-16-14 percent protein when compared to 14-14-12 percent and 12-12-12 percent protein. There was also a significant difference between 16-16-16 percent and 16-14-13 percent protein in favor of the higher sequence levels. This is in agreement with Hale and Southwell (1967) and Stevenson *et al.* (1960) who stated that the pigs fed diets containing either 18-15 percent or 16-13 percent protein sequences had a higher yield of lean cuts than pigs fed the 14-11 percent protein diets.

Of the comparisons made for the analysis of loin eye areas, only the first was significantly different ($P < .01$). This was in favor of 20-18-16 percent and 18-16-14 percent protein when compared against 14-14-12 percent and 12-12-12 percent protein. The comparison of 14-14-12 percent versus 12-12-12 percent approached significance. These comparisons agree with Crum *et al.* (1964).

TABLE 5. AVERAGE FINAL WEIGHTS AND CARCASS MEASUREMENTS FROM PIGS FED
VARYING PROTEIN LEVEL SEQUENCES TO MARKET WEIGHTS

Phase and Criteria	Protein Level Sequences					
	1	2	3	4	5	6
I, 40 to 75 lb.	12	14	16	16	18	20
II, 75 to 130 lb.	12	14	14	16	16	18
III, 130 lb. to market	12	12	13	16	14	16
No. of pigs	12	12	10	12	11	11
Avg. final wt., lb.	202.00	221.00	214.60	211.50	223.50	215.00
Avg. percent ham and loin	37.84	38.43	38.76	40.05	39.23	39.67
Avg. percent lean cuts	56.45	57.16	57.17	58.98	58.28	58.85
Avg. length, in.	30.28	30.84	30.74	30.81	31.27	30.68
Avg. backfat thickness, in.	1.30	1.24	1.27	1.22	1.24	1.21
Avg. loin eye area, sq. in.	3.98	4.42	4.52	4.56	5.06	4.75
Avg. ham quality score ^a	2.93	2.93	2.88	2.77	2.89	2.59
Avg. loin quality score ^a	2.85	2.61	2.79	2.45	2.89	2.52
Avg. loin eye marbling ^b	5.73	5.00	5.21	4.73	4.27	4.28

^aScored from 1 through 5 with 1 = extremely pale, soft and watery and 5 = dark, very firm and very dry.

^bScored from 1 through 11 with 1 = devoid and 11 = very abundant.

Analysis of the remaining carcass traits (carcass length, backfat thickness, ham quality scores, loin quality scores and loin marbling quality scores) did not reveal any significant differences for any of the comparisons made nor did any of them approach significance.

CHAPTER V

SUMMARY

Data collected on 68 hogs at the Knoxville Experiment Station, Knoxville, Tennessee, were used to determine the effect of varying protein levels on feedlot performance and carcass characteristics in swine. The protein level sequences were: (1) 12-12-12 percent, (2) 14-14-12 percent, (3) 16-14-13 percent, (4) 16-16-16 percent, (5) 18-16-14 percent and (6) 20-18-16 percent. The levels in each sequence were reduced at 75 pounds and again at 130 pounds.

In the period from weaning to 75 pounds, the 18 and 20 percent protein levels showed significantly ($P < .01$) greater gains when compared with the 12 and 14 percent protein levels. There were significant differences ($P < .01$ and $P < .05$) in feed conversion when 20 and 18 percent were compared to 12 and 14 percent protein and when 20 and 12 percent were compared to 14, 16 and 18 percent protein, respectively.

In the period from 40 to 130 pounds, there were significant differences ($P < .01$) for ADG when comparisons of 12-12 percent and 14-14 percent versus 18-16 percent and 20-18 percent and 12-12 percent versus 14-14 percent were made. There was also a significant difference ($P < .05$) when 16-14 percent and 16-16 percent were compared to 12-12 percent, 14-14 percent, 18-16 percent and 20-18 percent protein in favor of the previous. In the feed conversion for this period, there were significant differences ($P < .05$ and $P < .01$) respectively

when 20-18 percent and 18-16 percent protein were compared to 12-12 percent and 14-14 percent protein and when 14-14 percent was compared to 12-12 percent protein in favor of the higher levels in both cases.

In the period from 40 pounds to market weight, there was a significant difference ($P < .01$) when 12-12-12 percent and 14-14-12 percent protein were compared with 18-16-14 percent and 20-18-16 percent protein in favor of the higher sequence levels. When compared to 12-12-12 percent protein, 14-14-12 percent was significantly ($P < .05$) greater. There was also a significant difference ($P < .05$) when 16-14-13 percent and 16-16-16 percent was compared to 12-12-12 percent, 14-14-12 percent, 18-16-14 percent and 20-18-16 percent protein. There were no significant differences in feed efficiency among any of the comparisons made.

When the pigs were somascoped at 75 pounds, 20 percent and 18 percent protein was significantly greater ($P < .05$) than 14 percent and 12 percent protein for backfat thickness. Fourteen percent protein was also significantly greater than 12 percent protein for the same trait. When the pigs were somascoped at 130 pounds, 20-18 percent and 18-16 percent protein was significantly lower ($P < .05$) than 14-14 percent and 12-12 percent protein. At the end of the test, there were no significant differences in backfat thickness (somascopes or carcass backfat) for any of the comparisons made.

In the analysis for percent ham and loin, 20-18-16 percent and 18-16-14 percent protein was significantly greater ($P < .01$) than 14-14-12 percent and 12-12-12 percent protein. Percent lean cuts also showed significant differences ($P < .01$) in the above rations in favor

of the higher levels 16-16-16 percent was significantly greater ($P < .05$) than 16-14-13 percent protein for percent lean cuts. In the analysis for loin eye area, 20-18-16 percent and 18-16-14 percent was significantly greater ($P < .01$) than 14-14-12 percent and 12-12-12 percent protein. There were no significant differences for any of the comparisons for carcass length, ham quality scores, loin quality scores or loin marbling scores.

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APPENDIX

TABLE 6. ANALYSIS OF VARIANCE FOR FIVE ORTHOGONAL CONTRASTS OF FEEDLOT PERFORMANCE FOR PIGS ON VARYING LEVELS OF PROTEIN

Source	d.f.	Sum of Squares				Feed/Gain	
		ADG		ADG		40 to 130 lbs.	40 lbs. to Market
		40 to 130 lbs.	40 lbs. to Market				
Tmt	5	2.4889	1.6637	5.8137			1.3263
Contrast 1	1	1.2301**	0.8939**	1.5857*			0.4686
Contrast 2	1	0.7776**	0.4108*	2.8566**			0.7561
Contrast 3	1	0.0896	0.0038	0.2761			0.0049
Contrast 4	1	0.0216	0.1064	0.5633			0.0065
Contrast 5	1	0.3700	0.2488*	0.5320			0.0902
Pen/Tmt	6	0.2568	0.2484	0.9802			1.9699
Residual M.S.	56	0.1016	0.0928	0.0000			0.0000

*Significant at 0.05 level.

**Significant at 0.01 level.

TABLE 7. ANALYSIS OF VARIANCE FOR FIVE ORTHOGONAL CONTRASTS OF CARCASS CHARACTERISTICS FOR PIGS ON VARYING LEVELS OF PROTEIN

Source	d.f.	Sum of Squares							
		Percent Ham and Loin	Percent Lean Cuts	Length	Backfat Thickness	LEA	Ham Quality	Loin Quality	Marbling
Tmt	5	36.8279	58.2714	5.9186	0.0657	7.3595	0.8430	1.6669	16.1949
Contrast 1	1	19.6125**	35.3676**	2.0732	0.0258	5.7071**	0.3500	0.00003	11.9876
Contrast 2	1	2.0416	3.0104	1.8592	0.0210	1.1616	0.0000	0.3504	3.2266
Contrast 3	1	1.0242	1.7309	1.8635	0.0078	0.4576	0.4378	0.6774	0.0145
Contrast 4	1	7.4156	15.1125*	0.1051	0.0106	0.0240	0.0300	0.3333	0.8712
Contrast 5	1	6.7340	3.0500	0.0176	0.0005	0.0092	0.0252	0.3058	0.0950
Pen/Tmt	6	8.2716	9.8771	5.8429	0.2304	1.2006	4.1975	3.3474	23.1900
Residual M.S.	56	3.3160	5.1033	1.3128	0.0401	0.3671	0.8717	0.6635	3.5945

*Significant at 0.05 level.

**Significant at 0.01 level.

TABLE 8. CORRELATIONS AMONG VARIOUS TRAITS

	ADG Over- all	FE all	Percent Ham and Lean	Percent Cuts	Carcass Length	Carcass Backfat	LEA	Ham Quality Score	Loin Quality Score	Loin Marbling Score	1st Reading Scope	2nd Reading Scope	3rd Reading Scope	4th Reading Scope	ADG 1st Period	FE 1st Period	ADG 2nd Period	FE 2nd Period
ADG Overall	1.00	-0.39**	-0.16	-0.14	0.35**	0.46**	0.66**	-0.06	0.13	0.16	0.12	0.16	0.16	0.31**	0.27*	0.69**	-0.40**	0.91**
FE Overall		1.00	-0.16	-0.15	-0.25*	0.09	-0.31*	0.04	0.02	0.17	0.11	0.20	0.15	0.09	-0.35**	0.62**	-0.34**	0.75**
Percent Ham and Loin			1.00	0.93**	-0.09	-0.57**	0.18	-0.11	-0.20	-0.21	-0.03	-0.28*	-0.31**	-0.61**	0.17	-0.32**	-0.09	-0.35**
Percent Lean Cuts				1.00	-0.09	-0.56**	0.19	-0.13	-0.19	-0.19	-0.09	-0.30*	-0.37**	-0.65**	0.14	-0.31**	-0.09	-0.33**
Carcass Length					1.00	-0.11	0.48**	-0.16	-0.10	-0.02	-0.22	-0.16	-0.21	-0.06	0.17	-0.14	0.27	-0.15
Carcass Backfat						1.00	0.15	0.01	0.21	0.22	0.28*	0.36**	0.57**	0.70**	0.19	0.09	0.38	0.15
Loineye Area							1.00	-0.16	-0.01	0.07	0.10	0.06	0.07	0.01	0.58**	-0.33**	0.61**	-0.29*
Ham Quality Score								1.00	0.67**	0.33**	0.06	-0.08	0.07	0.09	-0.07	0.06	-0.05	0.09
Loin Quality Score									1.00	0.46**	-0.01	0.05	0.14	0.19	0.01	0.13	0.07	0.15
Loin Marbling Score										1.00	-0.22	-0.05	0.09	0.04	-0.10	0.17	0.07	0.20
1st Somascope Reading											1.00	0.49**	0.32**	0.25*	0.15	-0.05	0.14	-0.02
2nd Somascope Reading												1.00	0.55**	0.34**	0.11	0.34**	0.17	0.32
3rd Somascope Reading													1.00	0.48**	0.32**	0.07	0.46**	0.09
4th Somascope Reading														1.00	0.06	0.20	0.21	0.22
ADG 1st Period															1.00	-0.67**	0.81**	-0.57**
FE 1st Period																1.00	-0.47**	0.91**
ADG 2nd Period																	1.00	-0.40**
FE 2nd Period																		1.00

*Significant at 0.05 level.

**Significant at 0.01 level.

VITA

Richard Estill Groce was born in Fayetteville, Tennessee on March 12, 1949. He was reared in Lincoln County, Tennessee, and graduated from Central High School in May, 1967. He enrolled at Middle Tennessee State University in September, 1967 and transferred to the University of Tennessee in September, 1969. He received the B.S. degree from that institution in June, 1971. He entered the Graduate School of the University of Tennessee in September, 1971. He received the M.S. degree in Animal Husbandry in March, 1973.