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To the Graduate Council:

I am submitting herewith a thesis written by Earl W. Law entitled "An analysis of the U.T. bull evaluation test 1971-1975." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

Haley M. Jamison, Major Professor

We have read this thesis and recommend its acceptance:

William R. Backus, Robert S. Dotson

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

May 1, 1975

To the Graduate Council:

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Haley M. Jamison, Major Professor

We have read this thesis and recommend its acceptance:

Wm R. Backus

Robert L. Dotson

Accepted for the Council:

Hilton A. Smith

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AN ANALYSIS OF THE UT BULL EVALUATION TEST 1971-1975

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee

Earl W. Law

June 1975

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ABSTRACT

Records on 383 bulls, tested at The University of Tennessee Bull Evaluation Station for five testing periods in 1971 through 1975, were studied to determine the degree to which one could predict 140-day weight. Objective measures from birth to weaning and observations prior to testing were used in studying the performance of animals on test.

These data indicated that the only significant prediction that can be made is predicting the first 28-day weight from the on test weight.

The overall mean for adjusted 205-day weight, on test weight, and backfat at the beginning of test was 551.26 pounds, 662.24 pounds, and 3.59 millimeters, respectively. The correlations between the adjusted 205-day weight and on test weight to the five feeding periods were highly significant ($P < .01$). The correlation between backfat at the beginning of test for the same periods were highly significant with the exception of the 112 and 140-day weights.

Many of the observations in these data were a part-whole relationship since the greatest contributions for predicting the 140-day weight were from on test weight, adjusted 205-day weight and backfat at the beginning of test. In order to remove the sources of environmental variation, the analyses were calculated on a within year-breed basis. In the data the order of inclusion of independent variable, on test weight, adjusted 205-day weight and backfat at beginning of test, were based on the readily available data. Weigh periods taken

each 28 days during the 140-day full feed periods were used as dependent variables.

In the 56-day weights, a decreased percent of the variation was explained, 87.86 percent. The percent of variation explained for 84, 112, and 140-day weights was 84.89, 80.78, and 74.80 percent, respectively.

In these data using prediction equations for weight at the five weight periods, y, which represents 28, 56, 84, 112, and 140-day weights, is the best estimator of the population.

Various combinations of independent variables could not be accurately used as predictors of 140-day weight. The percent variation explained in average daily gain by various combinations of independent variables revealed that a maximum daily gain of 8.146 percent could be accounted for.

The only significant prediction which can be drawn from these data is the ability to predict 28-day weight from on test weight. Accurate predictions cannot be made at any other full feed period.

TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION	1
II.	REVIEW OF LITERATURE	4
	The Effect of Initial Weight on Performance	4
	The Effect of Initial Age on Performance	4
	The Effect of Initial Condition on Performance	5
	Average Daily Gain (ADG) and Its Relationship to Performance	6
	The Effect of Length of Test on Performance	7
	The Effect of Year on Performance	9
	The Effect of the Energy Level of the Ration on Performance	10
	Composition of Growth as Affected by Performance	13
	The Effect of Breed on Performance	15
III.	EXPERIMENTAL PROCEDURE	16
	Source of Data	16
	Eligibility	16
	Feeding Procedure	17
	Observations Recorded During and After Test	17
	Method of Analysis	19
IV.	RESULTS AND DISCUSSION	21
	The Prediction Equations	24
V.	SUMMARY	49
LITERATURE CITED		51
VITA		55

LIST OF TABLES

TABLE PAGE

I. Rations 18

II. Means and Standard Deviations of Traits Studied . . . 22

III. Simple Correlation Among Certain Traits Studied . . . 23

IV. The Percent of Variation in the 28-Day Weight Explained by Various Combinations of Independent Variables 26

V. The Percent of Variation in the 56-Day Weight Explained by Various Combinations of Independent Variables 27

VI. The Percent of Variation in the 84-Day Weight Explained by Various Combinations of Independent Variables 28

VII. The Percent of Variation in the 112-Day Weight Explained by Various Combinations of Independent Variables 29

VIII. The Percent of Variation in the 140-Day Weight Explained by Various Combinations of Independent Variables 30

IX. Prediction Equations for Weights at the End of the 28-Day Period 32

X. Prediction Equations for Weights at the End of the 56-Day Period 33

TABLE PAGE

XI. Prediction Equations for Weights at the End of the 84-Day Period 34

XII. Prediction Equations for Weights at the End of the 112-Day Period 35

XIII. Prediction Equations for Weights at the End of the 140-Day Period 36

XIV. The Percent of Variation in Average Daily Gain During the First 28-Day Full Feed Period 37

XV. The Percent of Variation in Average Daily Gain During the Second 28-Day Full Feed Period 38

XVI. The Percent of Variation in Average Daily Gain During the Third 28-Day Full Feed Period 39

XVII. The Percent of Variation in Average Daily Gain During the Fourth 28-Day Full Feed Period 40

XVIII. The Percent of Variation in Average Daily Gain During the Fifth 28-Day Full Feed Period 41

XIX. Prediction Equations for Average Daily Gain During the First 28-Day Period 43

XX. Prediction Equations for Average Daily Gain During the Second 28-Day Period 44

XXI. Prediction Equations for Average Daily Gain During the Third 28-Day Period 45

XXII. Prediction Equations for Average Daily Gain During the Fourth 28-Day Period 46

XXIII. Prediction Equations for Average Daily Gain During the Fifth 28-Day Period 47

CHAPTER I

INTRODUCTION

The relationship of growth made by cattle during different periods of development is of a significant value to the beef cattle industry. Breeding animals must often be selected at a relatively young age. This success of selection depends largely on the cattle retaining the characteristics for which they were selected.

Prior to the early 1930's, research was started on the use of objective measurements for evaluating beef cattle. Within a few years it has been determined that there were a number of economically important traits that could be measured objectively. Most traits were shown to be sufficiently high in heritability to provide a sound basis for selection. Thus, the foundation for performance testing had been laid.

Performance testing has been proven to be important in economical beef production. The result has been a steady increase in the use of objective measurements as a basis for beef cattle improvement.

Economic traits of the beef animal include those that contribute to both productive efficiency and desirability of product. Rapid growth, efficient use of feed, regularity of reproduction and carcasses acceptable to both the packers and consumers are major economic traits of importance to the beef producer. Performance testing offers beef cattle breeders a way of measuring differences among animals in heritable characters. Thus, the use of these programs in the United

States has been widely accepted with more than 50 organizations fostering their use. The development of these organizations, and other groups with similar interest, led to the formation of the Beef Improvement Federation on February 1, 1968.

Through the efforts of a group of innovative educators at The University of Tennessee, "Sire Evaluation," a new state project, was adopted in the fall of 1970. These educators realized the need for a central beef bull evaluation station in Tennessee. Many progressive purebred breeders had expressed a desire for a facility of this caliber.

Breeders had been aware of the fact that efficient selection for traits of economic importance -- growth rate and quality -- was the most productive tool for improvement. Beef cattle numbers in Tennessee during the past 25 years have more than tripled. In 1953 there were 302,000 head of beef cows on farms in Tennessee, whereas in 1974 there were 1,200,000 cows reported. The demand for bulls with records of known performance from birth to weaning and during the post-weaning period has increased many fold during the past quarter century.

Research indicates that selection of traits of economic importance of an animal from birth to weaning is predictive of the future performance of the individual. Estimates of these effects at this age may not accurately measure the true breeding value of the individual. However, research has shown that selections based on weaning performance and performance of the individual animal on full feed, 140 days post weaning, would be more precise.

The Tennessee Bull Evaluation Station was developed to offer to the public beef bulls that have already exhibited outstanding gaining ability up to weaning age and which possess indications of having superior beef quality. These beef bulls would then supply beef breeders with the opportunity to accelerate and improve their herd performance -- purebred or commercial.

No statistical analysis has been made to compare or study the effect of various lengths of test in an attempt to understand the growth curve of these animals. The objective of this study was to examine the possibility of predicting feed test performance by the use of objective measurements taken prior to the test period.

CHAPTER II

REVIEW OF LITERATURE

Research on the performance of bulls at 28-day weight intervals has not been attempted extensively. Most researchers have not studied a combination of factors simultaneously and identified differences in performance. Among these factors, length of test, initial weight, initial condition, initial age, energy level of ration and composition of growth, should be worthy of consideration.

I. THE EFFECT OF INITIAL WEIGHT ON PERFORMANCE

Brown and Keaton (1974) realized a highly significant effect of initial weight on all traits measured in that study. Larger animals usually required more feed per pound of gain; consequently, they consume larger quantities of feed and gain faster.

Beginning weight had a significant effect on average daily gain during the first 28-days only (Brown and Keaton, 1974) and a highly significant effect on feed conversion during all 28-day periods.

II. THE EFFECT OF INITIAL AGE ON PERFORMANCE

Schalles and Marlowe (1967) revealed that age at the beginning of the test had a significant negative influence on 365-day weight in one project and a similar trend at another test location with no significance. It was found that end-of-test type score was significantly influenced by age and approached significance ($P < .10$). As the age of bulls increased typed score had a tendency to increase.

Brown and Keaton (1974) reported age at the beginning of the test as having a highly significant effect on final grade and weight. No effect was noticed on average daily gain in relation to initial age. The mean for age at the beginning of all test was 287 days. This study also indicated that age at the beginning of a test had a highly significant effect on weight during the first three 28-day testing periods. Brinks et al. (1962) found that age-of-calf effects were significant only for final weight.

Considering that growth does slow down as the animal ages, the age an animal enters a testing program should be controlled. Gramlich and Thalmann (1930), in a comparison of ages, found the results were clearly in favor of the calves of both sexes insofar as economy of production.

Brown et al. (1956) revealed that the rate at which mature weight was approached was relatively uniform at earlier ages but changed rather rapidly between 12 and 60 months of age.

III. THE EFFECT OF INITIAL CONDITION ON PERFORMANCE

Brown and Keaton (1974) found that groups scoring thin at the beginning of the test had the highest final grade, the largest final weight, and the third best average daily gain. The thin bulls also consumed more feed. Those bulls being scored fat had the smallest final weight, the lowest average daily gain and had the poorest feed conversion, thus indicating that bulls in a below average condition prior to the testing program perform best.

Schalles and Marlowe (1967) found that as preweaning type score increased end-of-test type score increased, and rate of gain and 365-day weight decreased.

Stonaker _et al._ (1952) studied feedlot and carcass characteristics of 87 steer calves with the unselected progeny of comprest, intermediate and large type of purebred Hereford cows and 13 bulls of these three different types. Comprest type steers gained approximately 20 percent less per day; however they ate about 20 percent less feed per day and thus required almost exactly the same total digestible nutrients to produce a pound of gain. Rate of gain, total gain and total feed consumption were greatly different and appeared to be a function of size.

Koch _et al._ (1973) presented genetic and phenotypic correlations among traits. Birth weight was more closely correlated with post-weaning daily gain (r_G = 0.42, r_P = 0.31 for bulls) than it was with preweaning daily gain (r_G = 0.10, r_P = 0.18). Preweaning daily gain was not closely related with postweaning gain in bulls (r_G = 0.14, r_P = 0.15).

IV. AVERAGE DAILY GAIN (ADG) AND ITS RELATIONSHIP TO PERFORMANCE

Brown and Keaton (1974) found that average daily gain showed a consistent decline from the beginning of test to the final 140-day period of test. However, average daily gain did increase from year to year, indicating the changes being made by the breeder. Feed conversion showed a general increase in all years from the beginning to the end of the test.

Zinn (1964) indicated that growth rate, expressed as ADG for a particular period, weaning weight, off-test-weight, or weight per day of age, was one of the most important production traits considered in present day selection programs.

Beef animals can be expected to have a lower ADG as they increase in age and reach their mature size.

Levy et al. (1971) indicated no evidence of compensatory growth, and the daily gain of the treated animals was significantly lower than that of the control animals.

V. THE EFFECT OF LENGTH OF TEST ON PERFORMANCE

Zinn et al. (1970) evaluated feedlot growth characteristics and carcass grade factors of 100 Hereford steers and 100 Hereford heifers. A feeding period of 270-days with evaluation at 30-day intervals was used. Average daily gain increased with increasing time on feed up to 180 days. Marbling score and carcass grade increased significantly up to 240 days on test.

Zinn et al. (1970) found that average daily gain increased with increasing time on feed to a high of 0.93 kg. at 180 days. There was no significant increase in average daily gain after 120 days on feed.

Zinn et al. (1970a) revealed that heifers had a higher relative growth constant from weaning through 56 days on feed, after which the relative growth constant of the steers was greater. During the 280-day feedlot period steers had a 3.52 percent greater relative growth rate than heifers, resulting in a greater live weight at slaughter, 361.9 and 343.1 kg. for steers and heifers, respectively.

Gramlich and Thalmann (1930) used 88 steers and heifers and divided them according to age into eight groups consisting of two-year-olds, yearlings, and calves. Spayed heifers were used in this study with the addition of open heifers in the yearling and calf groups. Two-year-olds made the greatest gain during the first 100 days of the feeding period and the calves made the greatest gain during the last 100 days. The gain made by the yearlings were quite uniform throughout the 175-day period.

Eller (1972) studied records from 1540 yearling bulls from three central test stations and strongly suggested that post-weaning performance tests for estimation of breeding value should be terminated at a constant physiological age rather than a constant chronological age.

Swiger and Hazel (1961) found high genetic covariances indicating that to a large degree the same genes affect gain in weight of beef cattle during different parts of the growing period up to a year of age. This suggests that selection for weight at a year of age may be made earlier in the animal's lifetime with little loss of efficiency of selection. Thus, this could reduce the cost of evaluating animals through testing programs and perhaps eliminate the excessive fattening of breeding stock. Also, it was found that a short postweaning evaluation of about three months is adequate for selection for weight at one year of age.

Swiger *et al.* (1965) using a selection index found that selection for adjusted final weight should be a recommended procedure for the beef industry. Swiger *et al.* (1963) found that estimates suggested that 200-day weights would be about 0.52 as efficient as 550-day weight in selecting for that weight. If it were advantageous to terminate the evaluation period at about one year of age, the loss in accuracy would not be expected to be serious.

VI. THE EFFECT OF YEAR ON PERFORMANCE

Brown and Keaton (1974) using 1277 bulls during ten test years found that year had a highly significant variation on all traits. Year had a significant effect on feed consumption. Using least square analysis, Brown and Keaton (1974) also computed the means showing effects of year, location, breed, age and weight at the beginning of the test on measured traits in the performance of each of the 28-day periods. Year had a highly significant effect on weight for all 28-day periods. However, variation in final grade was not significant (low choice to choice). Schalles and Marlowe (1967) found a significant year effect on the 365-day weights. Consistent improvement was witnessed from the beginning to the ending of a five-year test program.

These results reflect a difference in environmental conditions as well as differences in individual animals. As performance programs have become more popular, producers have selected animals of greater performance from their herds.

Brown and Absher (1971) indicated that the effects of year, type score, and the interactions of year with type score and breed had a highly significant ($P < .01$) influence on selling price. In 1968 and 1969 bulls with higher type scores tended to sell for higher prices. Each performance trait, growth rate, 205-day adjusted weight, and postweaning ADG accounted for highly significant ($P < .01$) amounts of variation.

VII. THE EFFECT OF THE ENERGY LEVEL OF THE RATION ON PERFORMANCE

McCroskey et al. (1958), using 96 lots of 12 choice Hereford calves, studied the effect of self fed mixtures of feed, varying from 35 to 80 percent concentrate, on gain, feed efficiency, and carcass merit. Only small differences were observed among the lots due to rations used. Although the mixtures containing the higher levels of concentrates supplied more TDN per pound of ration, feed intake among the lots was such that actual TDN intake was similar. Thus there were relatively small differences in rate of gain, TDN per pound of gain, or days on feed required to reach a designated slaughter grade.

Zinn et al. (1969) evaluated the results of 40 beef calves randomly assigned to two treatments (early weaned and normal weaned). Early weaned were immediately started on an all concentrate ration. The normal weaned calves remained with their dam on pasture. When weaned (208 ± 32 days) they were immediately started on the identical concentrate ration. During Phase 1 (at 124 days) average daily gain (ADG) for the early weaned calves was slightly greater than that of the normal weaned calves, 0.83 and 0.74 kg., respectively. During Phase 2 (125 to 319 days) ADG was significantly greater ($P < .05$) for the normal weaned calves, 0.87 and 0.72 kg., respectively. Also, Zinn et al. (1970a) used similar crossbred steers and heifers, genetically and by age, and randomly assigned them to two treatments. Both groups were started on an all-concentrate ration containing 14 percent crude protein and continued on this ration (ad libitum) for the first 56 days on feed. Treatment two was switched to a ration (ad libitum) containing 14.3 percent roughage at this point. After 112 days on feed, Treatment one was also switched to the part-roughage ration. After 280 days on test the animals were slaughtered, and the carcass data were collected. Mean weight gains were greater ($P < .01$) for the cattle on the part-roughage ration between 56 and 112 days on feed. All other treatment mean weight gains were not significantly different.

Gramlich and Thalmann (1930) using a shelled corn and alfalfa hay ration found that two-year-olds made greater gains than yearlings, and the yearlings exceeded the calves. The same ranking existed in the amount of feed required to produce 100 pounds of gain. The difference between two-year-olds and yearlings was considerably less than between yearlings and calves.

Winchester and Howe (1955) found that under conditions of feed scarcity beef cattle between the ages of six and twelve months can be carried at an energy level as low as maintenance, if the nutritional needs other than those for energy are supplied. This occurred without later loss in efficiency of feed utilization, meat quality or in the proportion of lean meat as compared with fat and bone in the carcass.

Guilbert *et al.* (1944) from the standpoint of total feed required to produce a unit of product obtained greater efficiency from a high plane of nutrition with continuous growth and development. The degree of approach to the ideal that may be made under specific conditions depends upon the relative costs of different phases of production.

In two experiments, (Folman *et al.*, 1974), 80 bull calves were restricted to a maintenance ration for 90 days, from either 180 or 270 days of age. During the refeeding period previously restricted bull calves showed compensatory growth. They gained significantly faster than continuously fed controls.

During the entire experiment bull calves fed a maintenance ration for 90 days gained slower but converted feed to gain more efficiently than controls fed *ad libitum*. Folman *et al.* (1974) concluded that in intensively raised bull calves fed a maintenance ration for 90 days may prolong the fattening period but may produce feed-to-gain conversion ratios which are equal to or better than those of continuously fed controls.

Periods of restricted feeding are a normal feature of many systems of beef husbandry because of dependence on a variable supply of feed, including forage and concentrates. The world wide increase in feed prices will tend to shift some of the emphasis in beef cattle husbandry from growth rate to feed conversion. Different types of restricted refeeding may be practical means of converting feed more efficiently into live weight gain, according to Folman *et al.* (1974). Drori *et al.* (1974) found similar results.

VIII. COMPOSITION OF GROWTH AS AFFECTED BY PERFORMANCE

In defining or explaining weight and size differences, Eller (1972) indicated that weight alone is not a sufficient measure of size, and that selection for adjusted yearling weight alone would tend to favor fatter animals and would produce animals of several different skeletal sizes and body shapes. In the same study, condition score tended to measure fatness on a relative basis.

Brown and Keaton (1974) concluded, for a weight range of 970 to 1051, that heavier weights in the final years reflect that more animals of a larger breed were being tested and breeders were possibly selecting more on size than at the initiation of the testing programs. This study also found daily feed consumption increased slightly from the beginning to 84 days and remained constant for the two remaining weigh periods, indicating larger size and increased maintenance cost.

Zinn (1964) found that an inverse relationship between rate of gain and the percent of muscle in the carcass is the result of a positive interrelationship of rate of gain and fat. Those cattle gaining faster would be heavier and presumably fatter than slow gainers for a given period of time fed. It was also concluded that faster gaining cattle reached a desired weight at a younger age when they still had considerable potential for growth relative to becoming fatter.

Missouri studies (Hedrick et al., 1963) showed that rate of gain is negatively correlated ($r = -0.26$) with fat thickness. Zinn et al. (1967) studied growth of fat, bone and edible portion on 200 steers and heifers at 30-day intervals over a 270-day feeding period. Treatment means for percent fat trim increased significantly ($P < .01$) from zero to 150 days on feed, after which no significant change occurred. From zero to 270 days on feed the growth constant for fat trim was $K = 0.00766$, and bone $K = 0.00209$. Zinn (1967) found similar results indicating that external fat deposition did not increase significantly after 150 days on feed.

Stonaker et al. (1952) confirmed that comprest type steers were consistently given higher feeder grades than were the conventional type calves. Differences in daily gains were large and highly significant ($P < .01$). The comprest type steers reached the low choice grade at an average weight of 689 pounds, whereas conventional type steers averaged 852 pounds when ready for slaughter.

Zinn et al. (1970) provided information on carcass conformation as it related to time on feed. Carcass conformation score increased ($P < .01$) through each treatment period up to 150 days on feed. After this time the conformation score changed very little.

Dinkel and Busch (1973) using 679 grade steers found results indicating that adjusted yearling weight in breeding stock should be the single most important trait in a selection program aimed at improving production.

Cundiff et al. (1971) found a low positive genetic correlation between growth rate and marbling, suggesting that if muscle and bone growth are positively associated with mature size and if marbling and fatness are negatively associated with mature size, then it may be possible to alter the shape of the growth curve through simultaneous selection for marbling and growth rate. Gregory (1965) revealed that measuring growth rate in bulls on a relatively high energy ration after weaning to 12 to 15 months of age should be a close approximation of the period of life cycle in which the industry is most interested.

Morrow *et al.* (1974) studied estimates of mature weights and rate of maturing to determine the effects of using weights taken in different seasons for estimating growth curve parameters. This study indicated that a single annual weight from one to five years of age is adequate for estimating growth curve parameters.

Kidwell and McCormick (1956) concluded that at a given weight or age, animals of larger mature size will gain more rapidly on less feed than animals of smaller mature size.

IX. THE EFFECT OF BREED ON PERFORMANCE

Brown and Keaton (1974) measured traits including grade, weight, ADG, feed consumption per day, and feed consumption per pound of gain, and found that overall analysis and analysis by 28-day periods were significantly affected by breed in all these traits. However, breeders selected the animals to be tested, thus feeding the upper end and would not be a representative sample of the breed.

CHAPTER III

EXPERIMENTAL PROCEDURE

I. SOURCE OF DATA

The materials and data in this study were collected over a five year period (1971-1975) from The University of Tennessee Bull Evaluation Station. This study consisted of six evaluation periods. Five of these periods were terminated in the spring of each year with an additional group in 1973 terminated in the fall. Each group of bulls were sold at auction in the performance tested sale immediately following the testing period. Those animals being tested were a clear representation of a major portion of all counties in Tennessee.

A total of 383 bulls of different breeds were used in obtaining data for this study. This number represents those beef bulls which completed the 140-day feeding trial. However, some of these animals did not meet the requirements for the performance sale. This program began in 1971 at Brentwood, Tennessee and was relocated and has been at Spring Hill, Tennessee since that time.

II. ELIGIBILITY

Tennessee breeders who were enrolled in the Tennessee Beef Cattle Improvement Program (TBCIP) and whose bulls meet the minimum requirements were eligible. Only purebred registered bulls were accepted to the program. The animals must have been born between

September 1 and February 28.

A screening committee consisting of breed representatives, State Department of Agriculture personnel, Extension livestock specialists and Animal Science research personnel made the approval as to "fit for testing" upon arrival at the station. Any bull deemed unsuitable for test was returned home by the owner.

A minimum adjusted 205-day weight of 500 pounds was required for testing in the 1974-75 test. This is an adjusted weight/day of age of 2.44 pounds or an average daily gain from birth to weaning of 2.1 pounds using 70 pounds as a constant for birth weight. All bulls had to remain on test for the entire 140-day test period unless removal for health or other reasons was authorized.

III. FEEDING PROCEDURE

All animals were fed daily in amounts that would keep feed available almost continuously. The ration fed assured maximum growth and development and is shown in Table I.

IV. OBSERVATIONS RECORDED DURING AND AFTER TEST

Each animal used in the testing program was estimated for backfat ultrasonically at the beginning and ending of the testing period. A Branson Sonoray Model 12 was utilized to estimate the subcutaneous fat thickness at the beginning and end of the test period. The location of measurement was between the twelfth and thirteenth ribs and approximately three-fourths the length of the

TABLE I

RATIONS

	Starter Rations[a]	Main Rations[b]
#2 Yellow Corn (Steam Rolled)	623	828
Soybean Meal (44% C.P.)	300	275
Alfalfa Meal Pellets (17% C.P.)	100	100
Cottonseed Hulls	840	660
Molasses	100	100
Animal Fat	20	20
Trace Mineralized Salt	10	10
Limestone	7	7
Vitamin A (I.U./ton)	2 $\overline{M}$	2 $\overline{M}$
Aureomycin (mg./ton)	8000	

[a]Adjusted period, first four weeks of test and per-sale period.

[b]Last 100 days of test.

l. dorsi from the chine end. The point of measurement was determined by palpation of the posterior edge of the twelfth rib and the lateral edge of the *l. dorsi* muscle. Reading was made directly from the oscilloscope of the Model 12 instrument. The lead standard furnished with the Branson Model 12 Sonoray was used to calibrate the instrument. This standard was set equal to 3.3 cm. on the oscilloscope. Weight gains were measured and evaluated at 28-day intervals and sent to the breeders.

Also at the beginning and end of the test bulls were scored for frame, muscling and soundness (FMS). Scores were based on a five point scale where three was average for the breed and five was in the upper 20 percent of the breed. Any bull scoring less than three (average for the breed) for frame, muscling or soundness was not allowed to sell.

Subjective and objective evaluation, along with eye appeal, was used as a tool for establishing the order of selling. Breeds were rotated in the selling order each year.

V. METHOD OF ANALYSIS

Selection of an appropriate mathematical model that adequately describes biological relationships is extremely important. The incorporation of certain factors into a model is determined by the judgment of the investigator. The model considered appropriate for estimates of the multiple regression was:

$$Y = b_0 + b_1X_1 + b_2X_2 + \ldots b_nX_n$$

where:

$b_1, b_2 \ldots b_n$ are regression coefficient estimates of the population parameter beta;

$X_1, X_2 \ldots X_n$ are the independent variables (prediction variables);

Y is the dependent variable (response predicted variable).

The prediction equations were based on the formula:

$$\hat{Y} = \bar{y} + b_1(X_1 - \bar{X}_1) + b_2(X_2 - \bar{X}_2)x \ldots b_n(X_n - \bar{X}_n)$$

where:

$\hat{Y}$ is the estimation of the dependent variables;

$\bar{y}$ is the overall mean of the dependent variables;

b is the regression of the independent variables;

x is the independent variable of the individual bull;

$\bar{x}$ is the overall mean of the independent variable.

CHAPTER IV

RESULTS AND DISCUSSION

Objective measures recorded on prospective herd sires from birth to weaning and observations recorded prior to the beginning of the testing period should be of value in predicting performance during the full feeding period.

Overall means and standard deviations of the traits studied are presented in Table II. Simple coefficients (r) of correlations between all traits were calculated and are presented in Table III.

The overall mean for 205-day adjusted weaning weight and on test weight was 551.26 and 662.24 pounds, respectively. At the end of the first 28-day period the mean weight was 759.03 pounds. The overall mean of backfat at the beginning of the test was 3.59 millimeters.

The relationships between the 205-day weight and the 28, 56, 84, 112 and 140 day weights were 0.43, 0.43, 0.43, 0.43 and 0.41, respectively. These relationships were significant ($P < .01$). The correlation of on test weight with the five weight periods are highly significant ($P < .01$). These relationships were 0.96, 0.94, 0.92, 0.90 and 0.86, respectively. The correlation between backfat at the beginning of the test and the five weight periods was 0.20, 0.16, 0.14, 0.11 and 0.06, respectively. These relationships were highly significant with the exception of the 112 and 140 day weight.

TABLE II

MEANS AND STANDARD DEVIATIONS OF TRAITS STUDIED

Trait	Mean	Standard Deviations
Actual Weaning Weight	533.29	81.29
205-day Adjusted Weight	551.26	56.74
Average Daily Gain	2.28	.28
Adjusted Average Daily Gain	2.36	.28
On Test Weight	662.24	114.69
28-day Weight	759.03	120.78
56-day Weight	856.23	127.99
84-day Weight	934.96	131.95
112-day Weight	1009.49	135.32
140-day Weight	1075.83	134.54
Frame	3.51	.82
Muscle	3.53	.68
Soundness	3.51	.78
Backfat at the Beginning of Test	3.59	2.04
Backfat at the End of Test	10.38	3.65
Sale Price	914.13	494.76

TABLE III

SIMPLE CORRELATION AMONG CERTAIN TRAITS STUDIED

1. Actual Weaning Weight	1.00	.65	.68	.64	.69	.65	.65	.62	.61	.57	.16	.16	.04	.33	-.62	.28
2. 205-day Adjusted Weight		1.00	.93	.99	.43	.43	.43	.43	.43	.41	.09	.08	-.04	.29	-.04	.29
3. Average Daily Gain			1.00	.94	.45	.44	.43	.43	.42	.41	.11	.08	.01	.31	.03	.34
4. Adjusted Average Daily Gain				1.00	.42	.42	.42	.41	.41	.39	.09	.07	-.04	.29	-.02	.30
5. On Test Weight					1.00	.96	.94	.92	.90	.86	.17	.17	.00	.25	-.05	.16
6. 28-day Weight						1.00	.97	.96	.94	.91	.18	.19	-.01	.20	-.06	.19
7. 56-day Weight							1.00	.98	.96	.94	.18	.18	-.04	.16	-.07	.21
8. 84-day Weight								1.00	.98	.96	.20	.19	-.04	.14	-.07	.22
9. 112-day Weight									1.00	.98	.25	.22	.01	.11	-.11	.27
10. 140-day Weight										1.00	.27	.24	.03	.06	-.08	.29
11. Frame											1.00	.37	.49	-.20	-.21	.45
12. Muscling												1.00	.42	-.20	-.28	.44
13. Soundness													1.00	-.17	-.19	.36
14. Backfat at the Beginning of Test														1.00	.40	-.03
15. Backfat at the End of Test															1.00	.06
16. Sale Price																1.00

$P < .05$ = A Relationship of $\pm$ .098 or greater.

$P < .01$ = A Relationship of $\pm$ .128 or greater.

Several preliminary analyses with all possible combinations were used to predict the 140-day weight. From these analyses, the greatest contributions were from on test weight, 205-day adjusted weight and backfact at the beginning of the test. Therefore, these were included in all models.

Many of the observations recorded were a part-whole relationship. For example, average daily gain and adjusted average daily gain are a part-whole relationship of weaning weight. Thus, the relationships are correlated but they were not independent of each other.

I. THE PREDICTION EQUATIONS

In order to remove the sources of environmental variation, the analyses were calculated on a within year-breed basis.

The selection of the independent variables to be used in the models are extremely important. Those independent variables that are not correlated, yet independent of each other, are the best predictors of the dependent variable. The order of inclusion of the independent variables in the models are also important. In these data, the inclusion of the independent variables chosen were based on the readily available data.

Weight periods, normally taken each 28 days during the 140 day full feeding periods, seem logical to use as dependent variables. On test weight, taken after the 15 day adjustment period and at an age of between 210 and 300 days, seemed to be a logical choice for an independent variable. This observation, in conjunction with the 205-day adjusted weight and the beginning backfat measurements were the choices for the independent variables.

Tables IV through VIII show the percent of variation in the five weight periods explained by various combinations of independent variables. From these data one would conclude that the 140-day weights could not be accurately predicted. However, as can be seen from Table IV, when using the on test weight as the independent variable, 93 percent of the variation in 28-day weight was explained. The inclusion of 205-day adjusted weight increased the percentage by only 0.22 percent. When on test backfat was incorporated the increased variation explained was only 0.23 percent.

In Table V, the independent variable, on test weight, accounts for 87.86 percent of the variation in 56-day weight. The inclusion of 205-day adjusted weight increased prediction accuracy by only 0.73 percent. When incorporating on test backfat, the amount of variation explained was increased by only 0.71 percent.

In analyzing the 84-day weight period, it was found that the R^2 value becomes more ineffective in predicting the 140-day weight. The on test weight explained 84.89 percent of the 140-day weight variation. The addition of the two independent variables increased the variation explained by 0.99 percent. When only the adjusted 205-day weight was included, the increase in variation accounted for was only 0.57 percent.

On test weight in Table VII reveals 80.78 percent variation in 112-day weight explained. Only 0.51 percent more variation was

TABLE IV

THE PERCENT OF VARIATION IN THE 28-DAY WEIGHT EXPLAINED BY VARIOUS COMBINATIONS OF INDEPENDENT VARIABLES

Model Number	On Test Weight	Adjusted 205-Day Weight	Back Fat at the Beginning of Test	Percent Variation Explained	Increased Variation Explained[a]
1	X			92.94	
2	X	X		93.16	0.22
3	X	X	X	93.39	0.23

[a]The increases due to adding the last variable after variation due to the previous variable had been accounted for.

TABLE V

THE PERCENT OF VARIATION IN THE 56-DAY WEIGHT EXPLAINED BY VARIOUS COMBINATIONS OF INDEPENDENT VARIABLES

Model Number	On Test Weight	Adjusted 205-Day Weight	Back Fat at the Beginning of Test	Percent Variation Explained	Increased Variation Explained[a]
1	X			87.86	
2	X	X		88.59	0.73
3	X	X	X	89.30	0.71

[a]The increase due to adding the last variable after variation due to the previous variable had been accounted for.

TABLE VI

THE PERCENT OF VARIATION IN THE 84-DAY WEIGHT EXPLAINED BY VARIOUS COMBINATIONS OF INDEPENDENT VARIABLES

Model Number	On Test Weight	Adjusted 205-Day Weight	Back Fat at the Beginning of Test	Percent Variation Explained	Increased Variation Explained[a]
1	X			84.89	
2	X	X		85.46	0.57
3	X	X	X	86.45	0.99

[a]The increase due to adding the variable after variation due to the previous variable had been accounted for.

TABLE VII

THE PERCENT OF VARIATION IN THE 112-DAY WEIGHT EXPLAINED BY VARIOUS COMBINATIONS OF INDEPENDENT VARIABLES

Model Number	On Test Weight	Adjusted 205-Day Weight	Back Fat at the Beginning of Test	Percent Variation Explained	Increased Variation Explained[a]
1	X			80.78	
2	X	X		81.29	0.51
3	X	X	X	83.18	1.89

[a]The increase due to adding the last variable after variation due to the previous variable had been accounted for.

TABLE VIII

THE PERCENT OF VARIATION IN THE 140-DAY WEIGHT EXPLAINED BY VARIOUS COMBINATIONS OF INDEPENDENT VARIABLES

Model Number	On Test Weight	Adjusted 205-Day Weight	Back Fat at the Beginning of Test	Percent Variation Explained	Increased Variation Explained[a]
1	X			74.80	
2	X	X		75.19	0.39
3	X	X	X	78.21	3.02

[a]The increase due to adding the last variable after variation due to the previous variable had been accounted for.

explained when adjusted 205-day weight was considered. Adding the second independent variable found 1.89 percent increase in variation explained. The variation explained in the 140-day weight by on test weight was 74.80 percent (Table 8, page 29). The inclusion of adjusted 205-day weight explained 0.39 percent. Adding the second independent variable increased the variation explained by 3.02 percent.

The prediction equations for weights at the five weight periods are included in Tables IX through XIII. In these data, Y is the best estimator of the population. Y is the symbol for 28, 56, 84, 112 and 140-day weights, respectively.

Tables XIV through XVIII reveal the percent variation in average daily gain (ADG) during the 28, 56, 84, 112 and 140-day full feed periods, respectively. From these data it can be concluded that various combinations of the independent variables chosen cannot be used as accurate predictors of 140-day weight. Table XIV indicated that by using the on test weight as the independent variable, 0.299 percent variation was explained in the first 28-day period. Including the adjusted 205-day weight gave an increase of 0.146 percent. Incorporating the third variable, beginning backfat, increased the variation explained by 3.426 percent.

In evaluating the second 28-day full feed period, one finds the amount of variation in ADG explained by on test weight to be 1.421 percent. The addition of adjusted 205-day weight and backfat at the beginning of test increased the accuracy by 2.773 percent. When only adjusted 205-day weight was used as the independent variable,

TABLE IX

PREDICTION EQUATIONS FOR WEIGHTS AT THE END OF THE 28-DAY PERIOD

Variable	Equations
X_1	$Y = 86.648 + (1.015)(X_1)$
X_1X_2	$Y = 76.957 + (1.007)(X_1) + (0.029)(X_2)$
$X_1X_2X_3$	$Y = 69.100 + (1.015)(X_1) + (0.053)(X_2) - (3.044)(X_3)$

X_1 = On Test Weight.

X_2 = Adjusted 205-Day Weight.

X_3 = Back Fat at Beginning of Test.

TABLE X

PREDICTION EQUATIONS FOR WEIGHTS AT THE END OF THE 56-DAY PERIOD

Variable	Equations
X_1	$Y = 163.458 + (1.046)(X_1)$
X_1X_2	$Y = 141.970 + (1.026)(X_1) + (0.065)(X_2)$
$X_1X_2X_3$	$Y = 127.668 + (1.042)(X_1) + (0.109)(X_2) - (5.541)(X_3)$

X_1 = On Test Weight.

X_2 = Adjusted 205-Day Weight.

X_3 = Back Fat at Beginning of Test.

TABLE XI

PREDICTION EQUATIONS FOR WEIGHTS AT THE END OF THE 84-DAY PERIOD

Variable	Equations
X_1	$Y = 233.015 + (1.060)(X_1)$
X_1X_2	$Y = 207.060 + (1.038)(X_1) + (0.076)(X_2)$
$X_1X_2X_3$	$Y = 189.558 + (1.057)(X_1) + (0.129)(X_2) - (6.780)(X_3)$

X_1 = On Test Weight.

X_2 = Adjusted 205-Day Weight.

X_3 = Back Fat at Beginning of Test.

TABLE XII

PREDICTION EQUATIONS FOR WEIGHTS AT THE END OF THE 112-DAY PERIOD

Variable	Equations
X_1	$Y = 307.235 + (1.060)(X_1)$
X_1X_2	$Y = 269.793 + (1.032)(X_1) + (0.104)(X_2)$
$X_1X_2X_3$	$Y = 244.967 + (1.059)(X_1) + (0.179)(X_2) - (9.618)(X_3)$

X_1 = On Test Weight.

X_2 = Adjusted 205-Day Weight.

X_3 = Back Fat at Beginning of Test.

TABLE XIII

PREDICTION EQUATIONS FOR WEIGHTS AT THE END OF THE 140-DAY PERIOD

Variable	Equations
X_1	$Y = 403.961 + (1.015)(X_1)$
X_1X_2	$Y = 376.404 + (0.991)(X_1) + (0.081)(X_2)$
$X_1X_2X_3$	$Y = 345.209 + (1.025)(X_1) + (0.175)(X_2) - (12.085)(X_3)$

X_1 = On Test Weight.

X_2 = Adjusted 205-Day Weight.

X_3 = Back Fat at Beginning of Test.

TABLE XIV

THE PERCENT OF VARIATION IN AVERAGE DAILY GAIN DURING THE FIRST 28-DAY FULL FEED PERIOD

Model Number	On Test Weight	Adjusted 205-Day Weight	Back Fat at the Beginning of Test	Percent Variation Explained	Increased Variation Explained[a]
1	X			0.299	
2	X	X		0.445	0.146
3	X	X	X	3.871	3.426

[a]The increase due to adding the last variable after variation due to the previous variable had been accounted for.

TABLE XV

THE PERCENT OF VARIATION IN AVERAGE DAILY GAIN DURING THE SECOND 28-DAY FULL FEED PERIOD

Model Number	On Test Weight	Adjusted 205-Day Weight	Back Fat at the Beginning of Test	Percent Variation Explained	Increased Variation Explained[a]
1	X			1.421	
2	X	X		1.556	0.135
3	X	X	X	4.329	2.773

[a]The increase due to adding the last variable after variation due to the previous variable had been accounted for.

TABLE XVI

THE PERCENT OF VARIATION IN AVERAGE DAILY GAIN DURING THE THIRD 28-DAY FULL FEED PERIOD

Model Number	On Test Weight	Adjusted 205-Day Weight	Back Fat at the Beginning of Test	Percent Variation Explained	Increased Variation Explained[a]
1	X			0.337	
2	X	X		0.381	0.044
3	X	X	X	1.139	0.758

[a]The increase due to adding the last variable after variation due to the previous variable had been accounted for.

TABLE XVII

THE PERCENT OF VARIATION IN AVERAGE DAILY GAIN DURING THE FOURTH 28-DAY FULL FEED PERIOD

Model Number	On Test Weight	Adjusted 205-Day Weight	Back Fat at the Beginning of Test	Percent Variation Explained	Increased Variation Explained[a]
1	X			0.0004	
2	X	X		0.293	0.293
3	X	X	X	4.475	4.182

[a]The increase due to adding the last variable after variation due to the previous variable had been accounted for.

TABLE XVIII

THE PERCENT OF VARIATION IN AVERAGE DAILY GAIN
DURING THE FIFTH 28-DAY FULL FEED PERIOD

Model Number	On Test Weight	Adjusted 205-Day Weight	Back Fat at the Beginning of Test	Percent Variation Explained	Increased Variation Explained[a]
1	X			4.266	
2	X	X		4.624	0.358
3	X	X	X	8.146	3.522

[a]The increase due to adding the last variable after variation due to the previous variable had been accounted for.

the increased variation accounted for was only 0.135 percent. On test weight in Table XVI, page 38, showed the percent variation explained in gain during the third 28-day period as 0.337 percent. The inclusion of adjusted 205-day weight increased the variation explained by 0.044 percent. Adding the second independent variable increased the variation explained to 0.758 percent.

The percent of variation in average daily gain during the fourth 28-day full feed period for on test weight was 0.0004 percent. When the two independent variables were included, the increased variation was 4.182 percent. However, when only adjusted 205-day weight is used as the independent variable, the increased variation explained was 0.293 percent. Thus, one could conclude that beginning backfat had greatest influence on the variation explained.

During the fifth 28-day period, the percent variation explained for on test weight was 4.266. The inclusion of the two independent variables increased the variation explained by 0.35 and 3.522, respectively.

From these data, one would conclude that the only significant predictions that can be made is predicting 28-day weight from on test weight. Predicting weights at any of the other full feed periods could not be accurately accomplished.

The prediction equations for average daily gain during the five weight periods are included in Tables XIX through XXIII. In these data, Y is the best estimator of the population.

The results stated above were in agreement with those of previous authors. Brown and Keaton (1974) reported that average daily gain

TABLE XIX

PREDICTION EQUATIONS FOR AVERAGE DAILY GAIN
DURING THE FIRST 28-DAY PERIOD

Variable	Equations
X_1	$Y = 86.648 + (0.015)(X_1)$
X_1X_2	$Y = 76.957 + (0.007)(X_1) + (0.029)(X_2)$
$X_1X_2X_3$	$Y = 69.100 + (0.015)(X_1) + (0.053)(X_2) - (3.044)(X_3)$

X_1 = On Test Weight.

X_2 = Adjusted 205-Day Weight.

X_3 = Back Fat at Beginning of Test.

TABLE XX

PREDICTION EQUATIONS FOR AVERAGE DAILY GAIN
DURING THE SECOND 28-DAY PERIOD

Variable	Equations
X_1	$Y = 76.810 + (0.031)(X_1)$
X_1X_2	$Y = 65.014 + (0.019)(X_1) + (0.036)(X_2)$
$X_1X_2X_3$	$Y = 58.567 + (0.026)(X_1) + (0.056)(X_2) - (2.498)(X_3)$

X_1 = On Test Weight.

X_2 = Adjusted 205-Day Weight.

X_3 = BAck Fat at Beginning of Test.

TABLE XXI

PREDICTION EQUATIONS FOR AVERAGE DAILY GAIN DURING THE THIRD 28-DAY PERIOD

Variable	Equations
X_1	$Y = 69.558 + (0.014)(X_1)$
X_1X_2	$Y = 65.089 + (0.012)(X_1) + (0.010)(X_2)$
$X_1X_2X_3$	$Y = 61.890 + (0.015)(X_1) + (0.020)(X_2) - (1.239)(X_3)$

X_1 = On Test Weight.

X_2 = Adjusted 205-Day Weight.

X_3 = Back Fat at Beginning of Test.

TABLE XXII

PREDICTION EQUATIONS FOR AVERAGE DAILY GAIN DURING THE FOURTH 28-DAY PERIOD

Variable	Equations
X_1	$Y = 74.220 + (0.0005)(X_1)$
X_1X_2	$Y = 62.733 - (0.006)(X_1) + (0.028)(X_2)$
$X_1X_2X_3$	$Y = 55.409 + (0.002)(X_1) + (0.051)(X_2) - (2.837)(X_3)$

X_1 = On Test Weight.

X_2 = Adjusted 205-Day Weight.

X_3 = Back Fat at Beginning of Test.

TABLE XXIII

PREDICTION EQUATIONS FOR AVERAGE DAILY GAIN DURING THE FIFTH 28-DAY PERIOD

Variable	Equations
X_1	$Y = 96.726 - (0.046)(X_1)$
X_1X_2	$Y = 106.611 - (0.041)(X_1) - (0.023)(X_2)$
$X_1X_2X_3$	$Y = 100.242 - (0.034)(X_1) - (0.004)(X_2) - (2.468)(X_3)$

X_1 = On Test Weight.

X_2 = Adjusted 205-Day Weight.

X_3 = Back Fat at Beginning of Test.

showed a consistent decline from the beginning of test to the final 140-day period of test. Swiger et al. (1963) stated that 200-day weights would be 0.52 percent as efficient as 550-day weight in selecting for adjusted final weight. Hedrick et al. (1963) showed that rate of gain is negatively correlated (r = 0.26) with fat thickness. Zinn (1967) found similar results. Brown and Keaton (1974) and Schalles and Marlowe (1967) found that year had a highly significant variation on all traits. Overall analysis and analysis by 28-day periods were significantly affected by breed for all traits as observed by Brown and Keaton (1974).

Brown et al. (1956) found that the rate at which mature weight was approached was relatively uniform at earlier ages but changed rapidly between 12 and 60 months of age.

CHAPTER V

SUMMARY

Records on 383 bulls, tested at The University of Tennessee Bull Evaluation Station for five testing periods in 1971 through 1975, were studied to determine the degree to which one could predict 140-day weight.

Objective measures from birth to weaning and observations prior to testing were used in studying the performance of animals on test.

These data indicated that the only significant prediction that can be made is predicting the first 28-day weight from the on test weight.

The overall mean for adjusted 205-day weight, on test weight, and backfat at the beginning of test was 551.26 pounds, 662.24 pounds, and 3.59 millimeters, respectively. The correlations between the adjusted 205-day weight and on test weight to the five feeding periods were highly significant ($P < .01$). The correlation between backfat at the beginning of test for the same periods were highly significant with the exception of the 112 and 140-day weights.

Many of the observations in these data were a part-whole relationship since the greatest contributions for predicting the 140-day weight were from on test weight, adjusted 205-day weight and backfat at the beginning of test. In order to remove the sources of environmental variation, the analyses were calculated on a within year-breed basis. In the data the order of inclusion of independent variable, on test weight, adjusted 205-day weight and backfat at the beginning

of test, were based on the readily available data. Weigh periods taken each 28 days during the 140-day full feed periods were used as dependent variables.

From the percent variation in the five weight periods, one would conclude that 140-day weights could not be accurately predicted. In the initial 28-day weight period, the inclusion of beginning backfat and adjusted 205-day weight increased the variation explained by only 0.23 percent with 93 percent of the variation explained by using on test weight.

In the 56-day weights, a decreased percent of the variation was explained, 87.86 percent. The percent of variation explained for 84, 112, and 140 day weights was 84.89, 80.78, and 74.80 percent, respectively.

In these data using prediction equations for weight at the five weight periods, y , which represents 28, 56, 84, 112 and 140-day weights, is the best estimator of the population.

Various combinations of independent variables could not be accurately used as predictors of 140-day weight. The percent variation explained in average daily gain by various combinations of independent variables revealed that a maximum daily gain of 8.146 percent could be accounted for.

The only significant prediction which can be drawn from these data is the ability to predict 28-day weight from on test weight. Accurate predictions cannot be made at any other full feed period.

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VITA

Earl W. Law was born April 7, 1947, in Macon County, Lafayette, Tennessee. He received his elementary and secondary education in the public school system of Macon County and was a 1965 graduate of Macon County High School, Lafayette, Tennessee.

In September 1965, he entered The University of Tennessee, Knoxville, to study agriculture and was awarded his Bachelor of Science degree in Animal Husbandry in December 1969. While attending The University of Tennessee, Mr. Law, in 1965, did part-time work at The U.T. Blount Farm-Swine Department, and in 1968-69 at the Food Technology and Science Meat Processing Laboratory. He was an active member of the Block and Bridle Club and served as a club officer, co-chairman of B & B Round-Up and chairman of numerous other committees. Also he was a member of The University of Tennessee Intercollegiate Meats, Livestock and Horse Judging Teams, respectively. He was a recipient of an alumni scholarship in 1968 and 1969.

In February 1970, he joined The University of Tennessee Agricultural Extension Service staff. His first assignment was in Clay County, Celina, Tennessee, where he served as Assistant County Agent. He is now serving as Extension Leader in Monroe County, Madisonville, Tennessee.

Mr. Law enrolled in The University of Tennessee Graduate School in 1971, and in June 1975, received the Master of Science degree with a major in Animal Science.

In 1974 he received national recognition as Outstanding Youth Agent and is a member of the Honor Society of Gamma Sigma Delta at The University of Tennessee.