THE GROWTH PATTERN OF VARIOUS BODY AND CARCASS PARTS AND PROPORTIONS OF BEEF STEERS AS INFLUENCED BY DIFFERENT PLANES OF NUTRITION

By

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Thesis submitted to the Graduate Faculty of the

Virginia Polytechnic Institute

in partial fulfillment for the degree of

Doctor of Philosophy

in

Animal Science
(Animal Breeding)

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December 1968

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ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to all those who contributed to the completion of this thesis. He is particularly indebted to Dr. R. C. Carter, who gave the topic of this thesis and also who gave generously his time in carefully reading and pointing out ways in which the manuscript might be improved. His valuable comments and suggestions were of great help in the preparation of this thesis. The author is also indebted to Drs. J. A. Gaines, who carefully read and edited the manuscript; J. P. Fontenot, who furnished the records of the data used in this thesis; R. F. Kelly, who suggested a part of the work; and K. Hinkelmann, who made a very important suggestion in modifying the model and procedure of the test of significance and for his many other helpful comments. To the remainder of his committee, Professor G. W. Litton, Drs. B. Harshbarger and P. B. Siegel, the author wishes to express his thanks for their guidance and encouragement and for serving on the committee. The author wishes also to thank Mrs. Donna Brubaker for her excellent job in typing the manuscript, and Mrs. Carrie Lindsay for her invaluable help in the final preparation of this thesis.

The author is deeply indebted to his wife, Ligaya, for her continued encouragement and understanding for more than three years of graduate studies.

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INTRODUCTION

In studying the development and differentiation of an organism, particularly farm animals, one usually has to resort to an objective way of describing the relative changes in the different parts and tissues of the body that occurred during a pre-determined growth range. A common procedure is to run a slaughter experiment in which groups of animals are slaughtered at some pre-determined age and measurements are taken on parts and organs at the different slaughter times. The observations obtained and the corresponding group means of a particular body part or proportion are plotted against a supposedly independent variable, the most common of which is live-weight or age and, depending on the pattern of the plotted points in the coordinate system, the next step is to fit to those points the appropriate polynomial or exponential model. In the case of using the whole, part, or any convenient standard measurement such as live-weight, a decision has to be made whether to use a simple linear regression or the so called allometry equation which has been widely used by Huxley (1932) and others. According to this author, the equation provides a first approximation to a general law of differential growth and it states that the size of a part, y, is related to some standard, x (whether the whole body, the rest of the body without y, or some other part of the body selected as standard for reasons of convenience), according to the formula $y = bx^a$, where b and a are constants. The constant b, representing the value of y when x = 1, has no biological significance.

The constant a, however, is of significance since it can be considered as the ratio of the specific growth rates of y and x.

Reeve and Huxley (1945) as cited by Zuckerman (1950) pointed out some of the shortcomings of the allometry equation. They showed that a single straight line on the double log grid will not, in many cases, describe a change in proportion during the entire period of growth. They emphasized that the allometry equation ignores the factor of time and this makes it difficult to link differential growth in time by means of particular formula.

At the present time, little information is available on the statistical description of the growth pattern in time of the various parts and tissues or their proportions in beef steers. In the light of the increasing importance of the knowledge about the growth behavior of body proportions, or the more desirable and therefore expensive cuts in beef production, two big questions concerning these problems need to be answered. These questions are (i) in beef steers, how does a part or organ, or its proportion of the total body, change with age after weaning up to what may be considered maturity when fed a particular plane of nutrition?; and (ii) will the growth pattern of the part or proportion of the body be the same for different planes of nutrition? These questions may be answered in a general way but perhaps vaguely and the need for more concrete evidence in the form of a statistical approach is extremely important, both academic and otherwise. And because slaughter experiments in cattle are costly, every reasonable statistical analysis should be done on the gathered data to verify relevant hypotheses within the context of the general objectives for which the slaughter experiment was carried out. For the reason just mentioned, this investigation was made to apply appropriate statistical technique to slaughter data which were readily available and which were obtained from a well-designed experiment for the main purpose of answering those questions mentioned above.

REVIEW OF LITERATURE

1. Measurement of Growth and Form

Zuckerman (1950) gave the definition of growth described by Richards and Kabanagh (1945) as a fundamental attribute of living organisms, manifested by a change in size of the individual, or in the number of organisms in a unit of environment, the change normally being an increase, with possibilities of negative growth or decrease in size under adverse conditions. The 'form of an object' which was described by Thompson (1942) could be defined when we know its magnitude and direction, related to the further concept or 'dimension' of 'Time'. For this reason, the author added that the first step in the measurement of growth and form is to obtain satisfactory data in which the measurements of change in form are related to time.

Huxley (1932) pointed out that all but the simplest animals reach their adult shape and size by differential growth in different directions. His work has given prominence to the expression of change $y = bx^a$, usually known as the allometry equation, which had previously been used to express a specific-organ/body-weight relation in animals. The allometry equation in linear form, $\log y = \log b + a \log x$, implies that the interrelation between the size of a part and the whole is best expressed by a power function, and that the ratio of the specific or logarithmic growth rates of any two dimensions remains constant through the growth period. However, according to Thompson, the size of a part is in many cases directly proportional to the total size of an animal, and a simple linear function gives a better fit between the variable than the parabolic relationship implied by the allometry function.

From the studies about farm animals, Hammond (1950) summarized the following observations on growth. He said that there are various ways of measuring growth, as actual weight, percentage increment, or weight gained per day. According to him, the live-weight growth curve of the animal as a whole is made up of the sum of the different parts and tissues of the body, each of these growing at different rates, which gives rise to changes in the form and composition of the body as the animal matures. He has shown that the maximum growth rate for bone is attained before that of muscle, while fat is latest in development. Similarly, he added, for the different parts of the body, the head matures early, the neck later and the loin last. According to him also, in late maturing breeds and under low-plane feeding, the curves for growth of the different tissues and parts of the body are extended in time, whereas, in early maturing breeds and under high-plane of nutrition they are compressed.

Yates (1950) gave three different steps that are involved in fitting some mathematical relation to the observed data. These steps are: (a) choice of the type of relation, (b) estimation of the values of the parameters which enter into the equation representing the chosen relation, and (c) testing of the agreement of the fitted curve with original data.

2. Body Composition

Changes in proportion of carcass on different planes of nutrition were studied by Moulton *et al.* (1922). They found that in Hereford-Shorthorn beef steers, the proportions of skeleton and of total organs are greatest at birth and that of total fleshy parts is greatest at four years. They concluded that the composition of the whole cuts of meat is affected by increasing age and fatness. They further concluded that percent of fatty tissue increases and percent bone decreases.

In 1923, Ritchie *et al.* investigated the effect of age and nutrition on the distribution of nitrogen, ash, and phosphorus in beef flesh. They found that age or plane of nutrition seems negligible with regards to the proportion of ash, phosphorus, and nitrogen.

In a study about age and chemical development of mammals, Moulton (1923) reported that mammals show a rapid decrease in relative water content and decrease in protein and ash content from earliest life until the time of chemical maturity is reached. After this time, he said, there is little further change and nearly constant composition is shown. The author further reported that cattle developed in the concentration of protein and ash very rapidly from early intrauterine life until the age of five months is reached -- at about that time the change suddenly becomes very slow and there is no further change in nitrogen. On the other hand, he added, the curve for water shows just the reverse, *i.e.*, a rapid decrease in water on the fat-free basis and then practically constant percentage after five months.

In 1940, McMeekan made a study on the composition of pigs and reported that the composition of the carcass changes markedly with increasing age. In terms of actual weights of the respective tissues, he found that the rate of increase of muscle exceeds all other tissues from birth to 24 weeks, when it is overtaken by fat, and the rate of increase of bones is below both muscle and fat from four weeks onward. He also reported that the percentages of dry matter and fat increases and the percentage of water, protein, and ash decrease with age.

Pearson (1963) reviewed in his paper some direct and indirect methods of estimating body composition that were previously published by other workers. For example, in dilution techniques, he mentioned, a straight line relationship between percent fat and percent water for pigs weighing 181-220 lbs. has been found by Gnaidinger which was not in agreement with a curvilinear relationship found by Clawson.

Orme (1963) made a review of the pertinent literature on live animal and carcass measurements, and indices, to predict carcass composition in cattle, sheep, and swine. He concluded that the validity and usefulness of animal appraisal techniques depends largely upon the following: (a) objectives for which they are intended, (b) the care with which they are taken, and (c) the ability to repeat particular measurement.

Kelly *et al.* (1968), in the same experiment from which the data of this dissertation was obtained, computed the correlation between specific gravity of beef carcass cuts and their composition. The estimating equation (simple linear regression) for the chemical composition and percent yield were obtained for various ranges of percentage fat using specific gravity as the independent variable.

Studies on body composition have been comprehensively reviewed by Seebeck (1968). In his summary he stated the following conclusions: (a) to assess changes that occur during development, sets of measurements have to be made on animals at successive intervals (longitudinal study), or on other animals of different sizes, either at the same time or at a pre-arranged sequence of times (cross-sectional study), (b) to express development, the power function $y = bx^a$ seems most appropriate, and (c) if the development of the parts of the whole is being studied, the weight of the whole should be used as a criterion for measuring growth and therefore as an independent variate in the statistical analysis.

MATERIAL AND METHODS

A. Description of the Data

The data used in this study were obtained from an experiment conducted at Blacksburg, Virginia, by members of the Animal Science Department of the Virginia Polytechnic Institute, from December, 1955, to November, 1958, described by Kelly *et al.* (1968). The objective of the experiment was to obtain estimates of the effects of age (time), and of the energy level of the ration fed, on the body proportions and carcass composition of beef steers from approximately 7 to 30 months of age.

The experiment involved a total of 108 steers, 54 Aberdeen-Angus and 54 Hereford, and consisted of two trials, one trial being started in each of the years 1955 and 1956. In each trial there were three blocks or replicates of 18 steers each. In the first trial there were two blocks of 18 Herefords and one of 18 Angus; in the second, one of Herefords and two of Angus. The steers were quite uniform in weight and grade within a block. They averaged about 443 lbs. live-weight at time of purchase, and were estimated to be about seven months of age.

Two steers from each block of 18 were slaughtered immediately at the beginning of the experiment and the remaining 16 assigned equally to the four nutritional regimens as follows:

1. Maintenance (Ration I). This ration was designed to supply the necessary protein, vitamins, minerals, and energy to maintain but not to permit increase of the initial body weight.

2. Full Roughage (Ration II). Mixed legume-grass hay was fed ad libitum, supplemented by necessary minerals.

3. Limited Concentrates (Ration III). A concentrate mixture was fed at the rate at which the animal gained approximately 1.3 lbs. per day, along with a full feed of mixed legume-grass hay.

4. Full Feed (Ration IV). A fattening ration consisting of 40% ground legume-grass hay and 60% concentrates, was fed ad libitum.

Two steers from each subset, six in all, were slaughtered at the beginning of each trial to obtain an estimate of the initial carcass composition and proportions of the various body and carcass components. Thereafter, it was planned to slaughter three animals from each treatment, one per subset, in each trial, at six-month intervals. As it turned out, the actual slaughter times were 5, 10, 16, and 23 months after the beginning of the experiment.

Slaughter was done according to accepted standard procedures as described in the Proceedings of the 4th Reciprocal Meats Conference (National Livestock and Meat Board, 1950). After a chill of 48 to 72 hours at an average of about 35° Centigrade, the carcasses were removed from the cooler and divided just behind the 12th rib into front and hind quarters. The front and hind quarters of the right side of the carcass were cut into wholesale cuts as recommended by Wellington (1953). The wholesale cuts were divided into meat (lean and fat) and bone. The meat was passed through a meat grinder with a 9.5 mm. plate and then finely ground in a silent cutter. Samples of the finely ground meat were removed, packaged, frozen, and stored at -20°C until analyzed. Moisture content of the samples was determined by lypolization of a large sample of the meat. Crude protein, ash, and ether extract determination were made on dry samples by official methods of the Association of Official Agricultural Chemists (1950). A large number of body and carcass measurements were taken on each animal slaughtered, as well as determination of chemical composition of the carcass.

In this study the following attributes were chosen for consideration:

1. Percentage Hot Carcass. The weight of the dressed carcass immediately after slaughter expressed as a percentage of the live-weight of the animal just before slaughtering.

2. Empty-Body Weight. The live-weight of the animal before slaughter minus the weight of the contents of the gastrointestinal tract and the blood.

3. Percentage Meat. The total weight of the meat (lean and fat) in the right half of the carcass expressed as a percentage of the total weight of the meat plus bone.

4. Percentage Front Quarter. The weight of the front portion of the right half of the chilled dressed carcass expressed as a percentage of the total weight of the chilled carcass.

5. Percentage Hind Quarter. The weight of the hind portion of the right half of the dressed chilled carcass expressed as a percentage of the total weight of the whole chilled carcass.

6. Percentage Head. The weight of the head expressed as a percentage of the total live-weight of the animal.

7. Percentage Moisture. The moisture content of the meat (muscle and fat) from the right side of the carcass expressed in percent.

8. Percentage Crude Protein. The total amount of crude protein in the meat expressed in percent.

9. Percentage Ether Extract. The total amount of ether extract in the meat expressed in percent.

10. Percentage Ash. The mineral content of the meat expressed in percent.

B. Methods of Statistical Analysis

1. Preliminary Analysis of Variance

Before proceeding to the analysis of variance to determine the effect of age on various measured body and carcass components, a preliminary analysis of variance of the percentage hot carcass was done for each plane of nutrition. The objective in doing this preliminary analysis was to determine whether the effect of breed and the effect of trial were significant.

According to the design of the experiment, the observed value of the percentage hot carcass would be represented by the linear model

$$Y_{ijkl} = m + s_i + b_j + (sb)_{ij} + t_k + (st)_{ik} + e_{ijkl} \qquad (1)$$

$i = 1,2, \ldots,5;\ j = 1,2;\ k = 1,2;\ l = 1,2,\ldots n_{ijk}$

where Y_{ijkl} was the percentage hot carcass of the lth steer in the ith slaughter time, jth breed and kth trial; m was the true mean; s_i was the true effect of the ith slaughter time; b_j was the true effect of the jth breed; t_k was the true effect of the kth trial; $(sb)_{ij}$ was the true interaction effect of the ith slaughter time with the jth breed; $(st)_{ik}$ was the true effect of the interaction of the kth trial with the ith slaughter time; and e_{ijkl} was the true effect of the lth experimental unit subjected to the (ijk)th treatment combination. It was assumed that m was constant and that the e_{ijkl} were normally and independently distributed with mean zero and variance σ^2. The s_i, b_j, and t_k effects were also assumed to be fixed. It was further assumed that

$$\sum_i^5 n_{i..}\ s_i = \sum_j^2 n_{.j.}\ b_j = \sum_k^2 n_{..k}\ t_k = 0$$

and $$\sum_i^5 n_{ij.}\ (sb)_{ij} = \sum_j^2 n_{ij.}\ (sb)_{ij} = \sum_i^5 n_{i.k}\ (st)_{ik} = \sum_k^2 n_{i.k}\ (st)_{ik} = 0$$

where $$n_{i..} = \sum_j^2 \sum_k^2 n_{ijk}\ ,\quad n_{.j.} = \sum_i^5 \sum_k^2 n_{ijk}$$

$$n_{..k} = \sum_i^5 \sum_j^2 n_{ijk}\ ,\quad n_{ij.} = \sum_k^2 n_{ijk}\ ,\quad n_{i.k} = \sum_j^2 n_{ijk}$$

Although the number of observations in each breed-slaughter time subclass were unequal, they were proportional within each trial and, hence, the straightforward computation of the various sums of squares was followed. An example of the analysis of variance for the case of proportional numbers in each subclass is shown by Snedecor and Cochran (1967).

2. The Effect of Slaughter Time or Age

A one-way classification model for age effect was considered in representing each measured component neglecting the effect of breed and trial. The linear model for the measured component was

$$Y_{ij} = m + s_i + e_{ij} \qquad 1 = 1,2,\ldots,5; \qquad j = 1,2,\ldots,n_i \qquad (2)$$

where Y_{ij} was the observed body component of the jth experimental unit in the ith slaughter time, m was the true mean effect, s_i was the true effect of the ith slaughter time, and e_{ij} were random deviations assumed to be normally and independently distributed with mean zero and variance σ^2. The s_i's were such that $\sum_i^5 n_i s_i = 0$.

After the analysis of variance was obtained for each ration using model (2) the means of each component were plotted against slaughter time. This would then show the pattern of change of the component being considered with age. For example, when the means seemed to follow a straight line pattern with age, then the linear model was

$$Y_{ij} = m + \beta(X_i - \bar{x}) + e_{ij} \qquad i = 1,2,\ldots,5; \quad j = 1,2,\ldots,n_i \qquad (3)$$

This model is still the same as model (2) except that the s_i's which were then assumed to be a function of the age X were replaced by the term $\beta(X_i - \bar{x})$'s -- the expected increase or decrease of the component Y_{ij} from the true mean effect m at the particular age X_i. The sum of squares attributable to the slope of the line and the sum of squares attributable to the deviations from the regression line were then obtained. The form of the analysis of variance table for model (2) and model (3) is shown in Table I. The expectation of mean square in this table is given by Brownlee (1965). From this table the test of significance of the deviations from linearity was done by the ratio V_1/V_0. The result of the test was used as the criterion of determining whether a higher degree of polynomial was necessary to explain the significance of the age effect. Of course, the plotted points of the component mean against age was also used to determine the type of polynomial to be fitted.

TABLE I. ANALYSIS OF VARIANCE FOR THE REGRESSION OF THE BODY COMPONENT MEAN ($\bar{Y}$) ON SLAUGHTER TIME (X)

S.V.	D.F.	S.S.	M.S.	E.M.S.
Slaughter Time	t-1	$\sum_{i}^{t} n_i(\bar{y}_i-\bar{\bar{y}})^2$	V_3	$\sigma^2+\sum_{i}^{t} n_i(s_i-\bar{s})^2/t-1$
Linear Regression	1	$\sum_{i}^{t} n_i(\hat{\bar{Y}}_i-\bar{\bar{y}})^2$	V_2	$\sigma^2+\beta^2\sum_{i}^{t} n_i x_i^2$
Deviation from Linearity	t-2	$\sum_{i}^{t} n_i(\bar{y}_i-\hat{\bar{Y}}_i)^2$	V_1	$\sigma^2+\sum_{i}^{t} n_i d_i^2/t-2$
Experimental Error	$\sum_{i}^{t} n_i-t$	$\sum_{i}^{t}\sum_{j}^{n_i} (Y_{ij}-\bar{y}_i)^2$	V_0	σ^2
Total	$\sum_{i}^{t} n_i-1$	$\sum_{i}^{t}\sum_{j}^{n_i} (Y_{ij}-\bar{\bar{y}})^2$		

where $d_i = Y_i-m-\beta(X_i-\bar{x})$

and Y_i is the population mean at the particular slaughter time X_i.

3. Estimation of the Regression Parameters

The estimation of the parameters of the various polynomial regressions was done by using the following scheme.

(a) Estimation of α and β in the Straight Line Model

$$\bar{Y} = \alpha + \beta X + \bar{e}$$

The procedure followed was to set up the following quantities:

$\bar{y}_i = (1/n_i)\sum_j^{n_i} Y_{ij}$, the mean of the measured components Y_{ij} at the slaughter time X_i,

$\bar{\bar{y}} = \sum_i^t n_i\bar{y}_i / \sum_i^t n_i$, the grand mean of the measured components Y_{ij} overall the slaughter time X,

$\bar{x} = \sum_j^t n_i X_i / \sum_i^t n_i$, the weighted mean of the slaughter time X,

$S_{11} = \sum_i^t n_i(X_i-\bar{x})^2$, the weighted sum of squares of the slaughter time X,

$S_{1y} = \sum_i^t n_i(X_i-\bar{x})(\bar{y}_i-\bar{\bar{y}})$, the weighted sum of crossproducts of the $\bar{y}_i$'s with the X_i's.

The estimate of α and β were then obtained using the formulas

$$\hat{\beta} = S_{1y}/S_{11}, \qquad \hat{\alpha} = \bar{\bar{y}} - \hat{\beta}\,\bar{x}$$

(b) Estimation of β_0, β_1, and β_2 in the Quadratic Model

$$\bar{Y} = \beta_0 + \beta_1 X + \beta_2 X^2 + \bar{e}$$

The following additional quantities were computed.

$\bar{x}^2 = \sum_i^t n_i X_i^2 / \sum_i^t n_i$, the weighted mean of the squared values of the slaughter time X,

$S_{12} = \sum_i^t n_i \ (X_i - \bar{x})(X_i^2 - \bar{x}^2)$, the weighted sum of crossproducts of the X_i's with the X_i^2's,

$S_{22} = \sum_i^t n_i \ (X_i^2 - \bar{x}^2)^2$, the weighted sum of squares of the X_i^2's,

$S_{2y} = \sum_i^t n_i \ (X_i^2 - \bar{x}^2)(\bar{y}_i - \bar{\bar{y}})$, the weighted sum of crossproducts of the X_i^2's with the $\bar{y}_i$'s.

Then the following normal equations

$$\begin{aligned} \hat{\beta}_1 S_{11} + \hat{\beta}_2 S_{12} &= S_{1y} \\ \hat{\beta}_1 S_{12} + \hat{\beta}_2 S_{22} &= S_{2y} \end{aligned} \qquad (4)$$

were obtained. The solution of the above normal equations gave the estimates of β_1 and β_2. The estimate of β_0 was then obtained by the formula

$$\hat{\beta}_0 = \bar{\bar{y}} - \hat{\beta}_1 \bar{x} - \hat{\beta}_2 \bar{x}^2$$

For the cubic and quartic models, the estimates of the regression parameters were obtained by solving the corresponding set of normal equations as was done in step (b).

In addition to the estimate of the regression coefficients, the estimate of the correlation coefficient was obtained using the following formulas.

Simple Correlation: $\hat{\rho}^2 = \hat{\beta} S_{1y} / \sum_{i}^{t} \sum_{j}^{n_i} (Y_{ij} - \bar{\bar{y}})^2$

Multiple Correlation: $\hat{R}^2 = \sum_{m} \hat{\beta}_m S_{my} / \sum_{i}^{t} \sum_{j}^{n_i} (Y_{ij} - \bar{\bar{y}})^2$

OBJECTIVES OF THE STUDY

The objectives of the study were:

1. To determine the effect of age and energy level of the ration on: (a) the rate of development of various body tissues such as muscle, bone, fat, etc., and (b) the proportional rate of development of various organs and body components in beef steers from 7 to 30 months of age.

2. To obtain the polynomial regression equation that best describes the relationship of the various measured components of the carcass of the steer to age and ration energy level.

RESULTS AND DISCUSSION

1. The Effect of Breed and Trial on Percentage Hot Carcass

The summary of the mean percentage hot carcass by breed and ration is shown in Table II.

TABLE II. MEAN PERCENTAGE HOT CARCASS BY BREED AND RATION

	Ration			
Breed	I	II	III	IV
	%	%	%	%
Angus	53.8	54.1	59.1	62.5
Hereford	55.2	55.4	60.0	63.4

For the trial means, the percentages hot carcass obtained are shown in Table III.

TABLE III. MEAN PERCENTAGE HOT CARCASS BY TRIAL AND RATION

	Ration			
Trial	I	II	III	IV
	%	%	%	%
1	55.6	56.4	60.6	64.0
2	53.4	53.2	58.4	63.6

As indicated in the analysis of variance (Table IV), there was no evidence of significant trial effect except in ration II. In all the rations, the mean percentage hot carcass in trial 1 was higher than in trial 2. The breed effect was not significant for any of the rations. However, Hereford had a consistently higher percentage hot carcass than the Angus. Callow (1961) reported average dressing percentages of

TABLE IV. ANALYSIS OF VARIANCE OF THE PERCENTAGE HOT CARCASS BY RATION

S.V.	D.F.	Ration I		Ration II		Ration III		Ration IV	
		M.S.	F	M.S.	F	M.S.	F	M.S.	F
Trial (T)	1	43.78	3.27^{NS}	92.81	9.56**	44.44	3.95^{NS}	41.40	3.36^{NS}
Breed (B)	1	18.64	1.36^{NS}	13.45	1.38^{NS}	6.76	0.60^{NS}	5.45	0.44^{NS}
Slaughter Time (S)	4	217.74	16.28**	213.01	21.94**	47.16	4.19^{NS}	88.05	7.15**
T x S	4	59.64	4.46**	41.58	4.28*	84.98	7.55**	54.58	4.43**
B x S	4	9.33	0.69^{NS}	10.74	1.11^{NS}	15.50	1.37^{NS}	4.15	0.34
Error	21	13.37		9.71		11.26		12.31	

NS - Not significant.
* - Significant at 5% level.
** - Significant at 1% level.

60.0 for Hereford, 59.9 for Dairy Shorthorn, and 59.6 for Friesian steers; all differences insignificant. One might expect greater differences among these breeds than between Angus and Herefords.

Table IV also shows the results for effect of age (slaughter time). With the exception of ration III, age had a significant effect on percentage hot carcass. The breed by age interaction was insignificant irrespective of ration, but the trial by slaughter time interaction was significant or highly significant for all rations. This can largely be explained by the unrealistically high initial mean value of 65.9% for trial one, compared with 56.9% for trial two. The latter value is much closer to the average dressing percentage usually observed for cattle of similar age, weight, and condition. The high value for trial one must have resulted from weighing error in recording the live weight before slaughter. The mean values for the two trials were not very different at the other slaughter times.

The decision was made to pool the results from the two trials and fit the regressions to the pooled data. This, of course, resulted in some distortion of the regression lines for the initial period, but should not have affected the slopes in the latter periods. Alternative procedures would have been to treat each trial separately, or to adjust the initial value for trial one to a more realistic level, neither procedure very appealing.

2. <u>The Effect of Age on Percentage Hot Carcass</u>

Although the effect of age has already been included in the previous analysis, a summary of the mean percentage hot carcass classified according to age alone was constructed and the figures are shown in

Table V. The grand mean, the standard deviation, and the coefficient of variation of the original observations are also shown in the table. The numbers enclosed in parenthesis under the column slaughter time indicate the approximate age in months of the steers when they were slaughtered. The numbers enclosed in parenthesis after each mean value indicate the number of steers slaughtered.

The analysis of variance (Table VI) indicate slaughter age means differed very significantly. This table also shows that when the steers were on rations I and II, the relation of their mean percentage hot carcass with their age was quadratic. In fattening rations (rations III and IV), this relationship became cubic.

The graph of the regression equation of the mean percentage hot carcass on age is shown in Figure 1. It can be noticed from this figure that in rations I and II, the mean percentage hot carcass dropped from 60% to a low of about 48.5% when they were around 15 months from weaning time. However, the dressing percentage increased thereafter. Those steers on rations III and IV, although losing some in percentage hot carcass from weaning until about 13 months of age (6 months from weaning), progressively increased thereafter and reached an average of about 65% toward the termination of the experiment.

3. <u>The Effect of Age on Empty-Body Weight</u>

The mean empty-body weight in pounds and the standard error of the mean by slaughter time and ration are shown in Table VII. The mean empty-body weight ranged from 377.6 $\pm$ 12.9 lbs. to 430.9 $\pm$ 18.2 lbs. during the whole slaughter period for the steers on ration I. In ration II, the range was from 377.6 $\pm$ 14.7 lbs. to 664.4 $\pm$ 20.8 lbs.;

TABLE V. SUMMARY OF THE MEAN PERCENTAGE HOT CARCASS BY SLAUGHTER TIME AND RATION

Slaughter Time 1/ (mo.)	Ration			
	I	II	III	IV
	%	%	%	%
0 (7) 2/	61.4 ± 1.99 (12) 3/	61.4 ± 0.98 (12)	61.4 ± 0.97 (12)	61.4 ± 0.93 (12)
5 (12)	51.8 ± 2.81 (6)	53.7 ± 1.38 (6)	55.6 ± 1.37 (6)	58.4 ± 1.32 (6)
10 (17)	49.5 ± 2.81 (6)	49.8 ± 1.38 (6)	57.2 ± 1.37 (6)	62.7 ± 1.32 (6)
16 (23)	51.1 ± 2.81 (6)	52.1 ± 1.38 (6)	60.7 ± 1.37 (6)	66.5 ± 1.32 (6)
23 (30)	52.0 ± 2.81 (6)	50.1 ± 1.38 (6)	61.0 ± 1.37 (6)	67.6 ± 1.32 (6)
Grand Mean ($\bar{\bar{y}}$)	54.5	54.8	59.5	63.0
Standard Deviation (S.D.)	3.50	3.38	3.36	3.22
Coefficient of Variation (c.v., %)	6.42	6.17	5.65	5.12

1/ Approximate number of months after weaning.
2/ Approximate age in months of the steers.
3/ Number of steers slaughtered.

TABLE VI. SUMMARY OF THE ANALYSIS OF VARIANCE OF THE PERCENTAGE HOT CARCASS BY RATION

S.V.	D.F.	Ration I		Ration II		Ration III		Ration IV	
		M.S.	F	M.S.	F	M.S.	F	M.S.	F
Slaughter Time	4	217.74	17.74**	213.01	18.60**	47.16	4.18*	88.05	8.46**
Linear Regression	1	444.59	36.23**	586.02	51.18**	0.88	0.08 NS	257.14	24.70**
Deviation from Linear	3	142.12	11.58**	88.68	7.75**	62.57	5.55**	31.68	3.04*
Quadratic Regression	2	401.11	32.69**	388.82	33.96	48.31	4.28*	137.51	13.21**
Deviation from Quadratic	2	34.36	2.80 NS	37.21	3.25 NS	46.01	4.08*	38.58	3.71*
Cubic Regression	3	---	---	---	---	62.32	5.52**	114.58	11.01**
Deviation from Cubic	1	---	---	---	---	1.69	0.15 NS	8.43	0.81 NS
Experimental Error	31	12.27		11.45		11.28		10.41	

* - Significant at 5% level.
** - Significant at 1% level.
NS - Not significant.

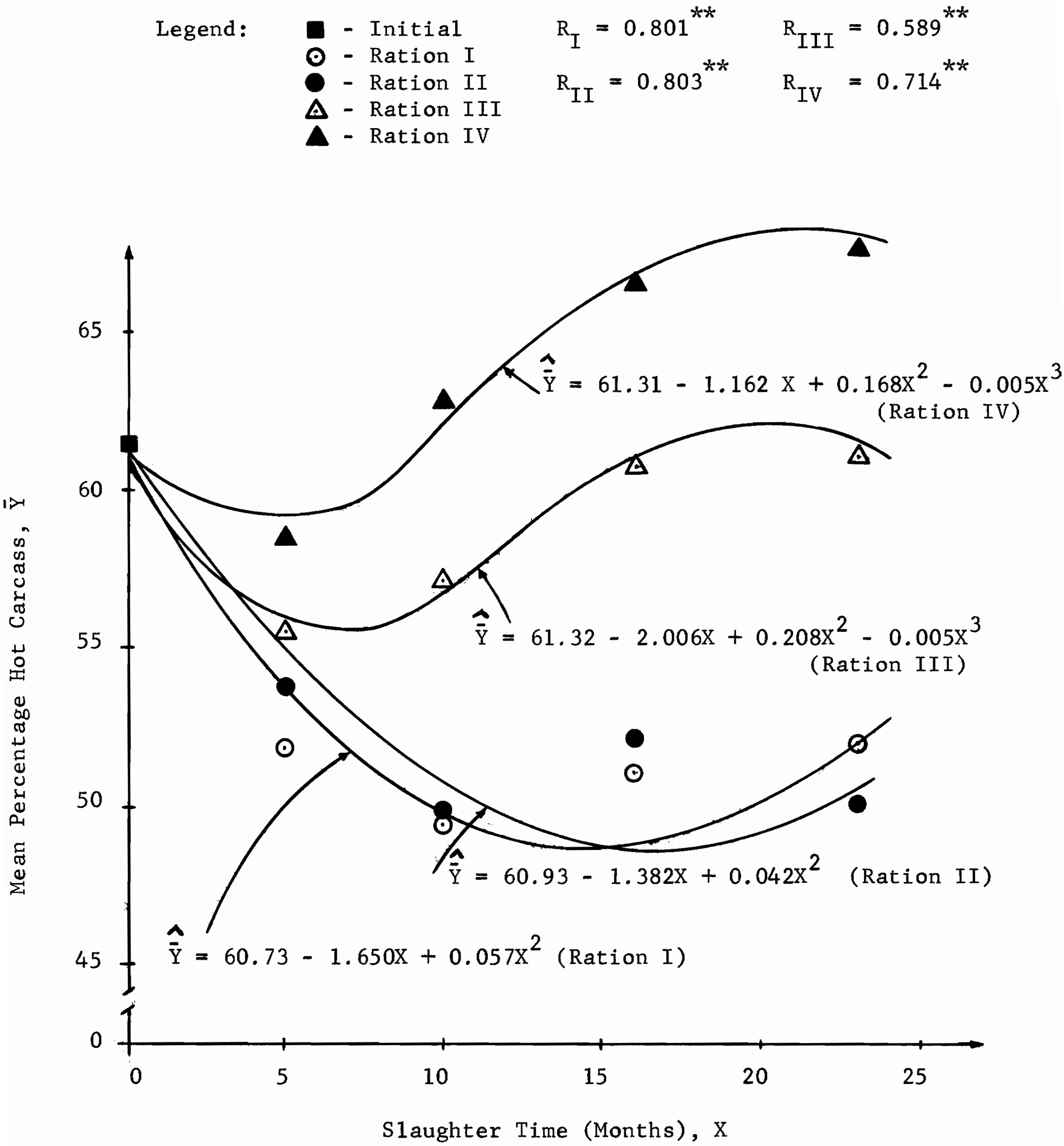

FIGURE 1. RELATION OF THE MEAN PERCENTAGE HOT CARCASS TO SLAUGHTER TIME BY RATION.

** - Significant at 1% level.

TABLE VII. SUMMARY OF THE MEAN EMPTY-BODY WEIGHT IN POUNDS BY SLAUGHTER TIME AND RATION

Slaughter Time	Ration			
	I	II	III	IV
(mo.)	lbs.	lbs.	lbs.	lbs.
0	377.6 ± 12.9	377.6 ± 14.7	377.6 ± 13.0	377.6 ± 17.2
5	396.1 ± 18.3	436.4 ± 20.8	526.6 ± 18.4	614.9 ± 24.3
10	423.8 ± 18.3	450.0 ± 20.8	705.4 ± 18.4	914.6 ± 24.3
16	421.9 ± 18.3	582.5 ± 20.8	911.0 ± 18.4	1102.4 ± 24.3
23	430.9 ± 18.3	664.4 ± 20.8	1019.7 ± 18.4	1250.9 ± 24.3
Grand Mean ($\bar{\bar{y}}$)	404.7	481.4	653.0	773.0
Standard Deviation (S.D.)	46.2	52.5	46.5	61.3
Coefficient of Variation (c.v., %)	11.4	10.9	7.1	8.0

ration III from 377.6 $\pm$ 13.0 lbs. to 1019.7 $\pm$ 18.4 lbs.; and ration IV 377.6 $\pm$ 17.2 lbs. to 1250.9 $\pm$ 24.3 lbs.

It was only in ration I that the effect of age was not significant (Table VIII). This was, of course, due to holding them to no gain. In other rations, the effect of age was broken down into regression components (Table VIII). Linear effect of age on the mean empty-body weight was found highly significant in ration II; the quadratic effect was found highly significant in rations III and IV.

When plotted against age, the mean empty-body weight behaved as shown in Figure 2. The figure clearly shows that when the steers were on a ration designed to maintain constant live body weight, the mean empty-body weight also remained essentially constant during the range of slaughter periods. However, when kept on a full feed of hay (ration II), the mean empty-body weight changed proportionately with time. More abrupt increase occurred on the fattening rations, and the trend of the change for these groups was curvilinear.

4. <u>The Effect of Age on the Percentage Meat (Muscle-Bone Ratio)</u>

This portion of the analysis on the effect of age on the percentage meat in cattle differed in approach from that of Callow (1961) who studied the effects of breed and nutritional treatment on the ratio of muscular tissue to bone. The author reported that breed or treatment had no significant effect on the ratio. He further reported that the Herefords were marginally better than the Dairy Shorthorns and Friesians with respect to the ratio.

According to Berg <u>et al</u>.(1968), weight at slaughter has an important influence on body composition. They found that in normal slaughter

TABLE VII. SUMMARY OF THE ANALYSIS OF VARIANCE OF THE EMPTY-BODY WEIGHT IN POUNDS BY RATION

S.V.	D.F.	Ration I		Ration II		Ration III		Ration IV	
		M.S.	F	M.S.	F	M.S.	F	M.S.	F
Slaughter time	4	4,322.6	2.03^{NS}	102,383.0	37.21**	557,084.1	257.75**	1,041,902.1	277.48**
Linear regression	1	---	---	395,512.2	143.74**	2,194,851.5	1,015.49**	4,035.571.0	1,074.77**
Deviation from linear	3	---	---	4,673.3	1.70^{NS}	11,161.7	5.20**	44,012.4	11.72**
Quadratic regression	2	---	---	---	---	1,108,004.4	512.64**	2,076,584.9	553.06**
Deviation from quadratic	2	---	---	---	---	6,163.8	2.85^{NS}	7,255.2	1.93^{NS}
Experimental Error	31	2,132.8		2,751.5		2,161.4		3,754.8	

NS - Not significant.
** - Significant at 1% level.

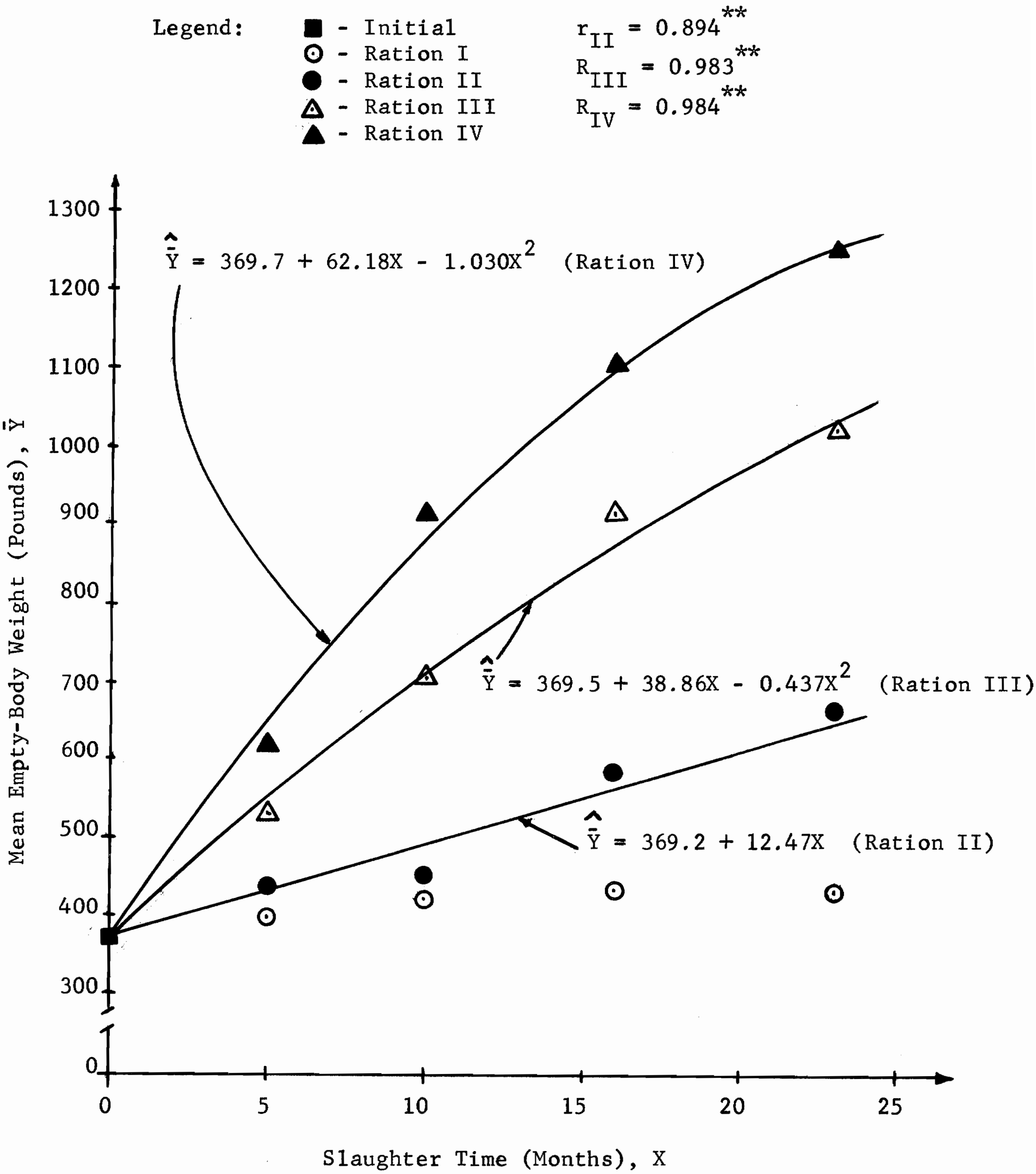

FIGURE 2. RELATION OF THE MEAN EMPTY-BODY WEIGHT TO SLAUGHTER TIME BY RATION.

** - Significant at 1% level.

ranges, as weight increases muscle percentage decreases, fat percentage increases and bone percentage decreases.

Table IX shows the summary of the mean percentage meat by slaughter time and ration. Over the slaughter range, the steers on ration I had a mean percentage of meat ranging from 72.8 $\pm$ 1.43 to 73.6 $\pm$ 2.02. The highest mean of 75.9 $\pm$ 2.02 was attained 5 months after weaning in the same group. On ration II, the mean percentage meat increased from 72.8 $\pm$ 1.44 at weaning to 77.8 $\pm$ 2.04, 23 months after weaning. For the steers in ration III, the range was 72.8 $\pm$ 1.25 to 83.7 $\pm$ 1.77, and for the steers in ration IV, 72.8 $\pm$ 1.24 to 87.9 $\pm$ 1.76.

As shown in Table X, fattening rations (rations III and IV) affected the percentage meat significantly. The pattern of change of the mean percentage meat with age was found to be quadratic. The graphs are shown in Figure 3.

5. The Effect of Age on the Percentage of Front Quarter to Total Carcass

There is lack of clear information as to how the proportion of front quarter relative to the total carcass weight in cattle behaved as the animal grows older, particularly after weaning time. In the article of Berg *et al.* (1968), the authors reported that fattening leads to an increase in proportion of those cuts which includes major fat depots, particularly ventral parts of the carcass. Luitingh (1962) concluded that ventral parts constituted a greater percentage of the carcass of the fattened steers. He further added in his conclusion that age had no influence on the proportion of ventral parts of the carcass.

The results of this investigation on the effect of age on the percentage of front quarter to total carcass weight are summarized in

TABLE IX. SUMMARY OF THE MEAN PERCENTAGE MEAT BY SLAUGHTER TIME AND RATION

Slaughter Time	Ration			
	I	II	III	IV
(mo.)	%	%	%	%
0	72.8 ± 1.43	72.8 ± 1.44	72.8 ± 1.25	72.8 ± 1.24
5	75.9 ± 2.02	77.8 ± 2.04	79.7 ± 1.77	80.9 ± 1.76
10	75.0 ± 2.02	75.2 ± 2.04	81.3 ± 1.77	84.9 ± 1.76
16	71.0 ± 2.02	74.5 ± 2.04	82.8 ± 1.77	85.8 ± 1.76
23	73.6 ± 2.02	77.8 ± 2.04	83.7 ± 1.77	87.9 ± 1.76
Grand Mean ($\bar{\bar{y}}$)	73.5	75.2	78.8	80.9
Standard Deviation (S.D.)	4.9	5.0	4.3	4.3
Coefficient of Variation (c.v., %)	6.7	6.6	5.5	5.3

TABLE X. SUMMARY OF THE ANALYSIS OF VARIANCE OF THE PERCENTAGE MEAT BY RATION

S.V.	D.F.	Ration I		Ration II		Ration III		Ration IV	
		M.S.	F	M.S.	F	M.S.	F	M.S.	F
Slaughter Time	4	22.78	0.93 NS	16.56	0.66 NS	179.66	9.56**	334.65	18.03**
Linear Regression	1	---	---	---	---	558.33	31.30**	1,142.96	61.57**
Deviation from Linear	3	---	---	---	---	43.43	2.31*	65.21	3.51*
Quadratic Regression	2	---	---	---	---	384.04	18.52**	656.51	35.37**
Deviation from Quadratic	2	---	---	---	---	12.28	.65 NS	12.29	0.66 NS
Experimental Error	31	24.44		24.89		18.80		18.56	

* - Significant at 5% level.
** - Significant at 1% level.
NS - Not significant.

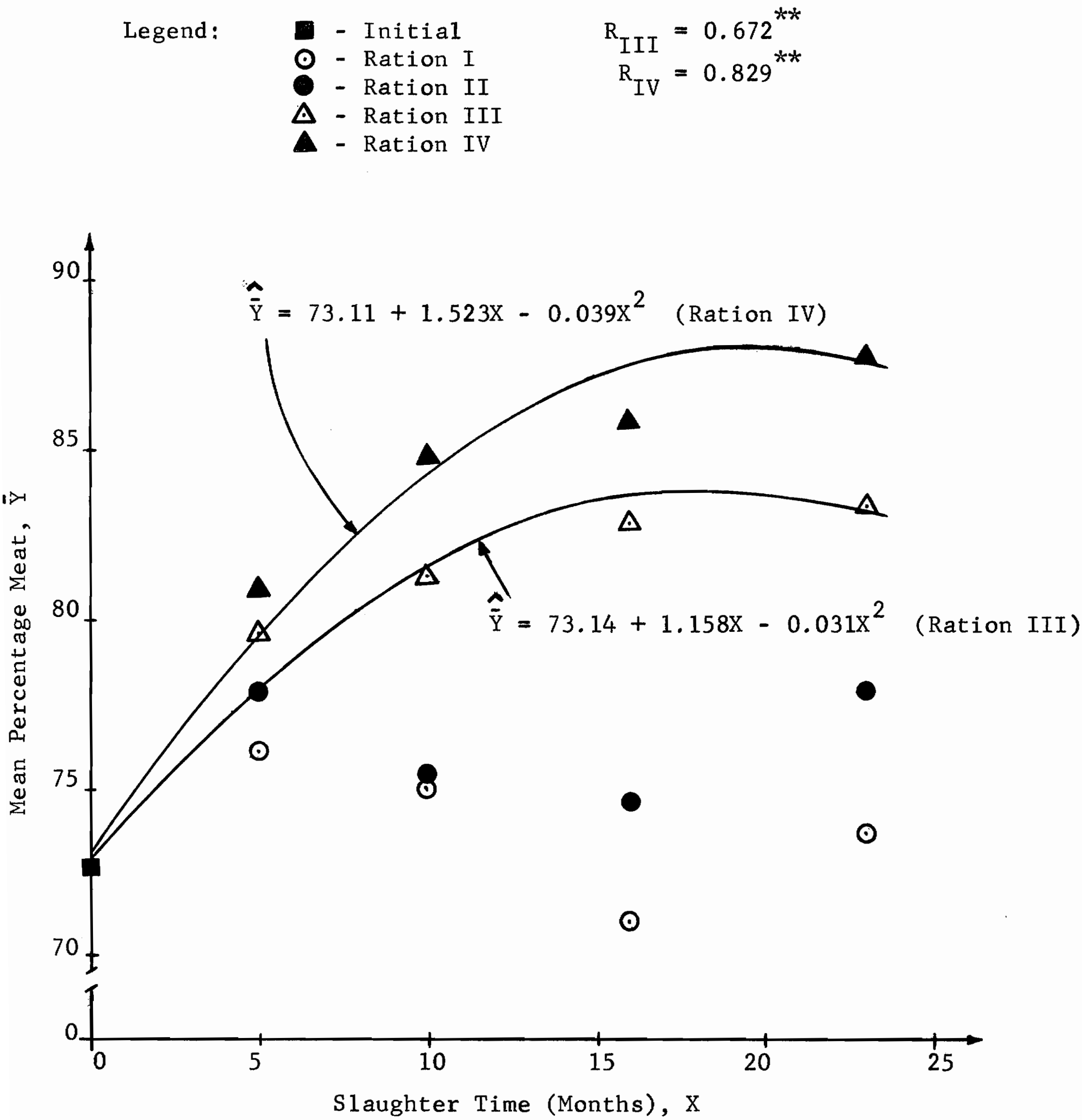

FIGURE 3. RELATION OF THE MEAN PERCENTAGE MEAT TO SLAUGHTER TIME BY RATION.

** - Significant at 1% level

Table XI. It can be noticed that the different planes of nutrition had little effect on the percentage of front quarter during the entire period of slaughter. In the maintenance group, the mean value ranged from 24.8 $\pm$ 0.25% to 26.6 $\pm$ 0.36%. The mean percentage front quarter in ration II ranged from 24.8 $\pm$ 0.23 to 26.1 $\pm$ 0.32, 24.8 $\pm$ 0.20 to 26.1 $\pm$ 0.28 in ration III, and 24.8 $\pm$ 0.19 to 26.0 $\pm$ 0.27 in ration IV. In every ration the pattern of the mean percentage of front quarter seemed to increase proportionately with age. It should be remembered that the above mean values are the weights of the right front quarter expressed as a percentage of total carcass weight. Multiplying these values by 2 would give the approximate mean percentage of both front quarters based on total weight of carcass.

The analysis of variance (Table XII) of the percentage front quarter indicated a highly significant effect of age in all the four rations. When broken down into regression components, the effect of age was best explained by the linear relation of the percentage front quarter to age. The graph of the regression line for each ration is found in Figure 4.

The findings in this analysis indicate that the front quarter constitutes approximately one half of total carcass weight at 7 or 8 months of age, and the proportion increases with age regardless of the plane of nutrition, at least up to about 30 months of age. However, the amount and rate of change was greater on the maintenance ration than on higher planes of nutrition.

TABLE XI. SUMMARY OF THE MEAN PERCENTAGE OF FRONT QUARTER TO TOTAL CARCASS BY SLAUGHTER TIME AND RATION

Slaughter Time	Ration			
	I	II	III	IV
(mo.)	%	%	%	%
0	24.8 ± .25	24.8 ± .23	24.8 ± .20	24.8 ± .19
5	25.9 ± .36	25.8 ± .32	25.6 ± .28	25.6 ± .27
10	25.8 ± .36	25.5 ± .32	25.7 ± .28	25.5 ± .27
16	26.3 ± .36	25.8 ± .32	25.7 ± .28	26.0 ± .27
23	26.6 ± .36	26.1 ± .32	26.1 ± .28	25.4 ± .27
Grand Mean ($\bar{\bar{y}}$)	25.7	25.4	25.4	25.4
Standard Deviation (S.D.)	0.87	0.79	0.68	0.66
Coefficient of Variation (c.v., %)	3.4	3.1	2.7	2.6

TABLE XII. SUMMARY OF THE ANALYSIS OF VARIANCE OF THE PERCENTAGE FRONT QUARTER BY RATION

S.V.	D.F.	Ration I		Ration II		Ration III		Ration IV	
		M.S.	F	M.S.	F	M.S.	F	M.S.	F
Slaughter Time	4	4.32	5.67**	2.25	3.60**	2.17	4.72**	1.77	4.04**
Linear Regression	1	15.06	19.74**	6.77	10.82**	7.14	15.54**	3.32	7.56**
Deviation from Linear	3	0.74	0.97 NS	0.75	1.19 NS	0.51	1.10 NS	1.25	2.86 NS
Experimental Error	31	0.76		0.62		0.46		0.44	

** - Significant at 1% level.
NS - Not significant.

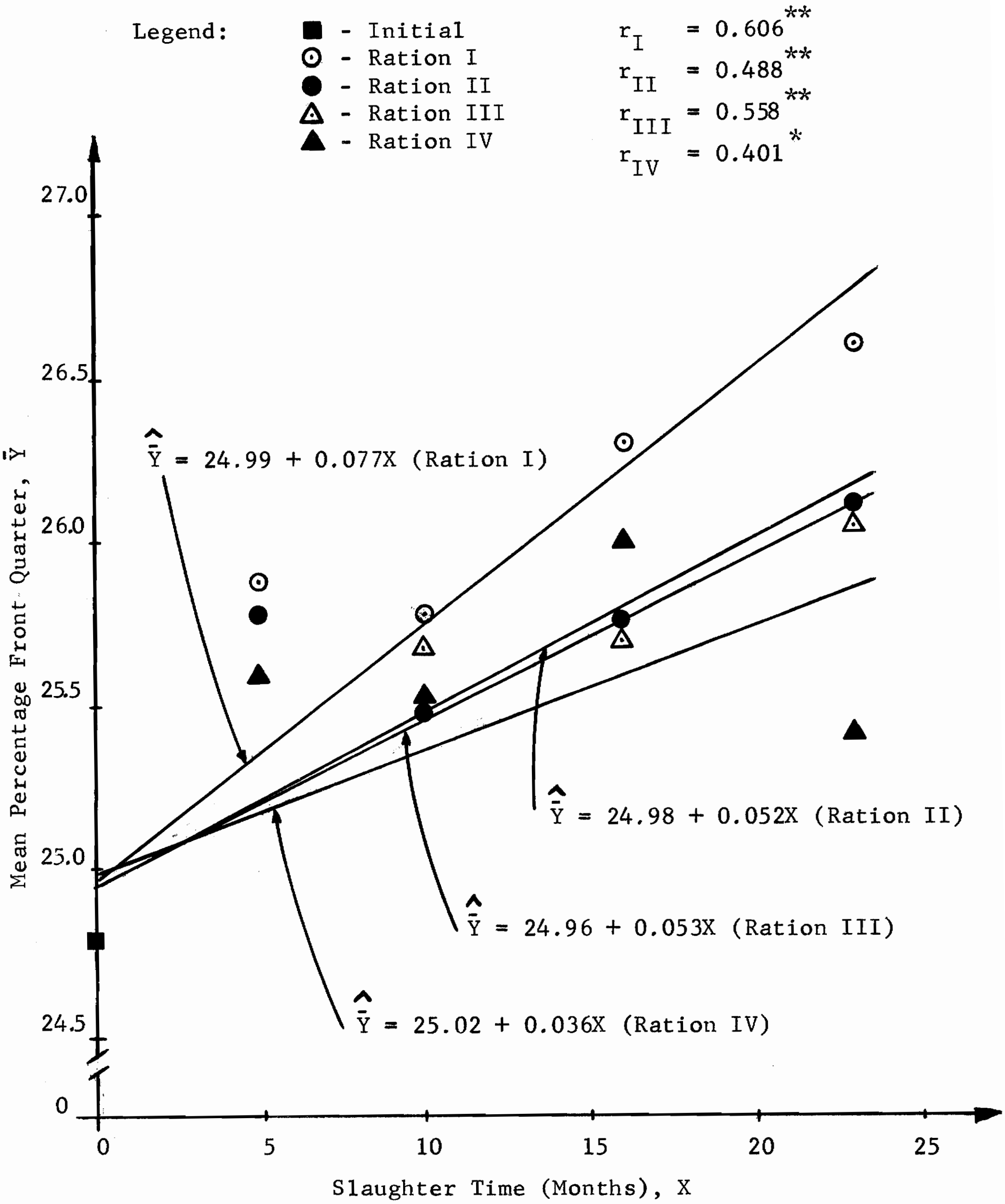

FIGURE 4. RELATION OF THE MEAN PERCENTAGE FRONT QUARTER TO SLAUGHTER TIME BY RATION.

* - Significant at 5% level.
** - Significant at 1% level.

6. The Effect of Age on the Percentage of Hind Quarter to Total Carcass

The summary of the mean percentage hind quarter values are shown in Table XIII. As can be noticed in the table, the mean percentage hind quarter did not exceed 25%. The steers in ration I had a grand mean of 24.2% over the whole slaughter period. Those steers in rations II, III, and IV had a grand mean of 24.5%, 24.4%, and 24.5%, respectively, over the same age period.

The analysis of variance (Table XIV) shows the effect of age was found to be linear. On the other hand, the differences between the means of each slaughter time in the other three rations were all insignificant.

In this study, the mean percentage hind quarter generally decreased with age (Figure 5). The results obtained from this analysis is in close agreement with that of Luitingh (1962) who reported that percentage hind quarter declined with age and fattening, particularly the animals on a maintenance ration which showed a significant downward linear trend.

7. The Effect of Age on the Percentage of Head to Live-Weight

There is little exact information as to how the proportion of head relative to live-weight changes with age, particularly in cattle. Callow (1961) reported that at market age, Herefords have a slightly, but significantly, heavier proportion of head than have Shorthorns or Friesians. Hammond (1952), in mentioning in his book the results from his previous works, stated that at younger age, the head grows rapidly and so is proportionately large then, while later other parts such as the limbs take on more rapid growth and form a larger proportion of the body weight. This is particularly true, however, in the embryo.

TABLE XIII. SUMMARY OF THE MEAN PERCENTAGE HIND QUARTER BY SLAUGHTER TIME AND RATION

Slaughter Time	Ration			
	I	II	III	IV
(mo.)	%	%	%	%
0	24.7 ± .22	24.7 ± .14	24.7 ± .14	24.7 ± .13
5	23.8 ± .31	24.3 ± .19	24.5 ± .20	24.5 ± .19
10	24.4 ± .31	24.8 ± .19	24.3 ± .20	24.4 ± .19
16	23.8 ± .31	24.8 ± .19	24.4 ± .20	24.1 ± .19
23	23.5 ± .31	24.4 ± .19	24.0 ± .20	24.3 ± .19
Grand Mean ($\bar{\bar{y}}$)	24.2	24.5	24.4	24.5
Standard Deviation (S.D.)	0.74	0.47	0.49	0.46
Coefficient of Variation (c.v., %)	3.0	1.9	2.0	1.9

TABLE XIV. SUMMARY OF THE ANALYSIS OF VARIANCE OF THE PERCENTAGE HIND QUARTER BY RATION

S.V.	D.F.	Ration I		Ration II		Ration III		Ration IV	
		M.S.	F	M.S.	F	M.S.	F	M.S.	F
Slaughter Time	4	1.99	3.70*	0.47	2.13^{NS}	0.53	2.19^{NS}	0.41	1.97^{NS}
Linear Regression	1	5.38	9.98**	---	---	---	---	---	---
Deviation from Linear	3	0.87	1.60^{NS}	---	---	---	---	---	---
Experimental Error	31	0.54		0.22		0.24		0.21	

* - Significant at 5% level.
** - Significant at 1% level.
NS - Not significant.

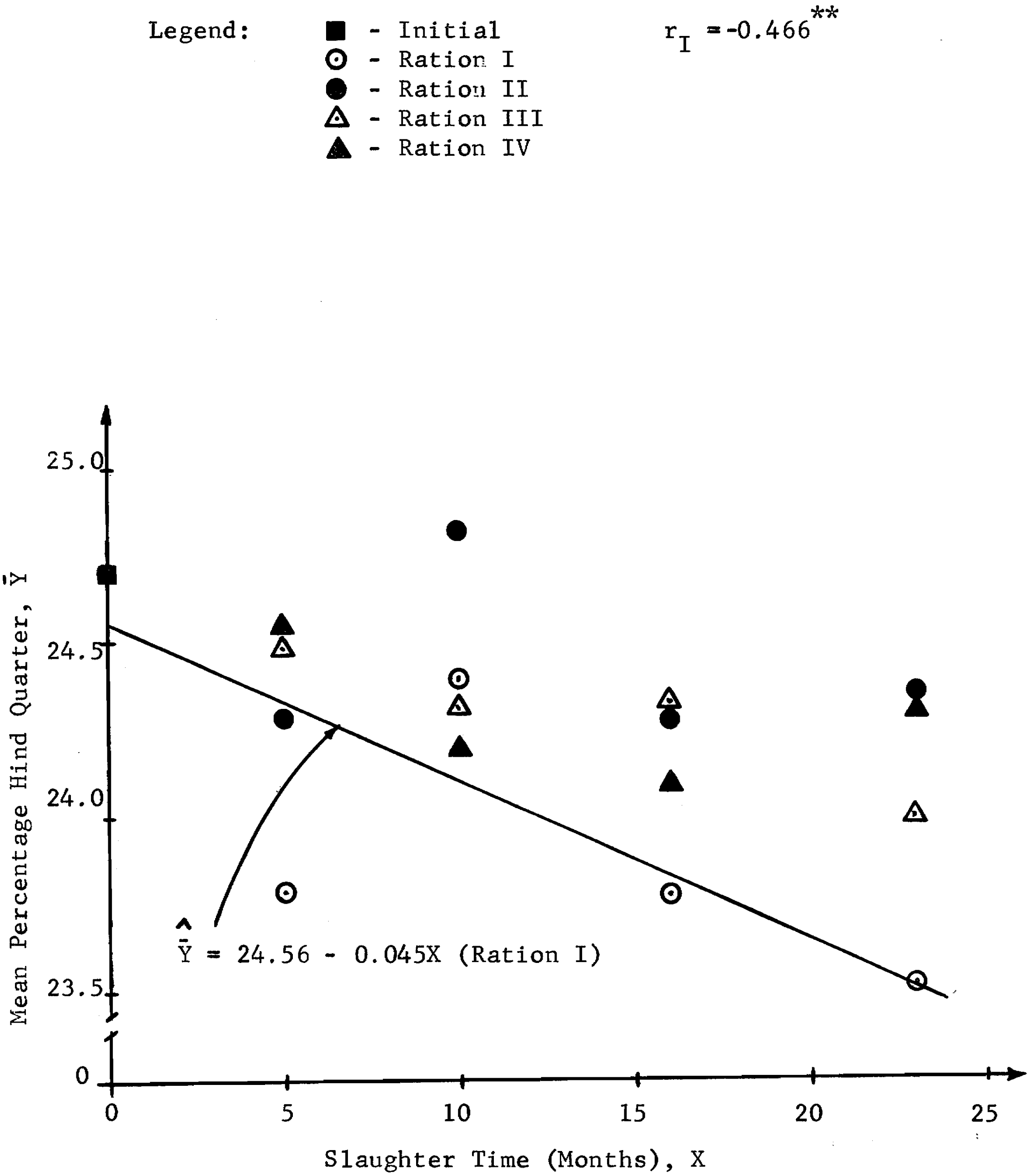

FIGURE 5. RELATION OF THE MEAN PERCENTAGE HIND QUARTER TO SLAUGHTER TIME BY RATION.

** - Significant at 1% level.

There was clearly a difference among the rations in the percentage head of total body weight. In ration I, the percentage increased with time, a slight, but not significant, increase in II, and a consistent decline in III and IV with greatest rate of decline in IV. This might suggest that the head is increasing at a more or less constant rate on all rations, but that the remainder of the body is increasing at variable rates, depending on the ration. The latter is, of course, very obvious.

Of more interest to know is how the proportion of head of beef steers changed with age within a particular plane of nutrition. As indicated by the analysis of variance (Table XVI), the mean percentage of head among slaughter times differed highly significant with steers in rations I, III, and IV. Those steers on full feed of hay did not show significant differences between slaughter times with respect to percentage of head. As shown also in the analysis of variance table, the breakdown of the age effect into components indicated insignificant departure from linearity in those rations where age effects were observed significant. Thus, linear relationship between the mean percentage head and age was obtained.

The graph of the regression equation for each ration is summarized in Figure 6.

The results of the analysis of the mean percentage of head to live-weight in steers revealed that percentage head changed with age in a linear fashion. The slope of the line was positive with steers in ration I and then changed to negative value with steers in rations III and IV. However, the percentage head remained almost constant in all slaughter times with steers fed a full feed of hay ration (ration

TABLE XIV. SUMMARY OF THE MEAN PERCENTAGE HEAD BY SLAUGHTER TIME AND RATION

Slaughter Time	Ration			
	I	II	III	IV
(mo.)	%	%	%	%
0	3.7 ± .10	3.7 ± .08	3.7 ± .06	3.7 ± .07
5	4.2 ± .14	4.1 ± .11	3.6 ± .08	3.4 ± .09
10	4.4 ± .14	4.0 ± .11	3.3 ± .08	3.0 ± .09
16	4.7 ± .14	4.0 ± .11	3.1 ± .08	2.9 ± .09
23	4.9 ± .14	3.8 ± .11	3.1 ± .08	2.5 ± .09
Grand Mean ($\bar{\bar{y}}$)	4.3	3.9	3.4	3.2
Standard Deviation (S.D.)	0.35	0.28	0.21	0.22
Coefficient of Variation (c.v., %)	8.3	7.1	6.0	7.0

TABLE XVI. SUMMARY OF THE ANALYSIS OF VARIANCE OF THE PERCENTAGE HEAD BY RATION

S.V.	D.F.	Ration I		Ration II		Ration III		Ration IV	
		M.S.	F	M.S.	F	M.S.	F	M.S.	F
Slaughter Time	4	1.75	14.11**	0.17	2.26 NS	0.66	15.45**	1.83	35.36**
Linear Regression	1	6.72	54.07**	---	---	2.50	58.45**	7.03	135.74**
Deviation from Linear	3	0.10	0.79 NS	---	---	0.05	1.11 NS	0.10	1.91 NS
Experimental Error	31	0.12		0.08		0.04		0.05	

** - Significant at 1% level.
NS - Not significant.

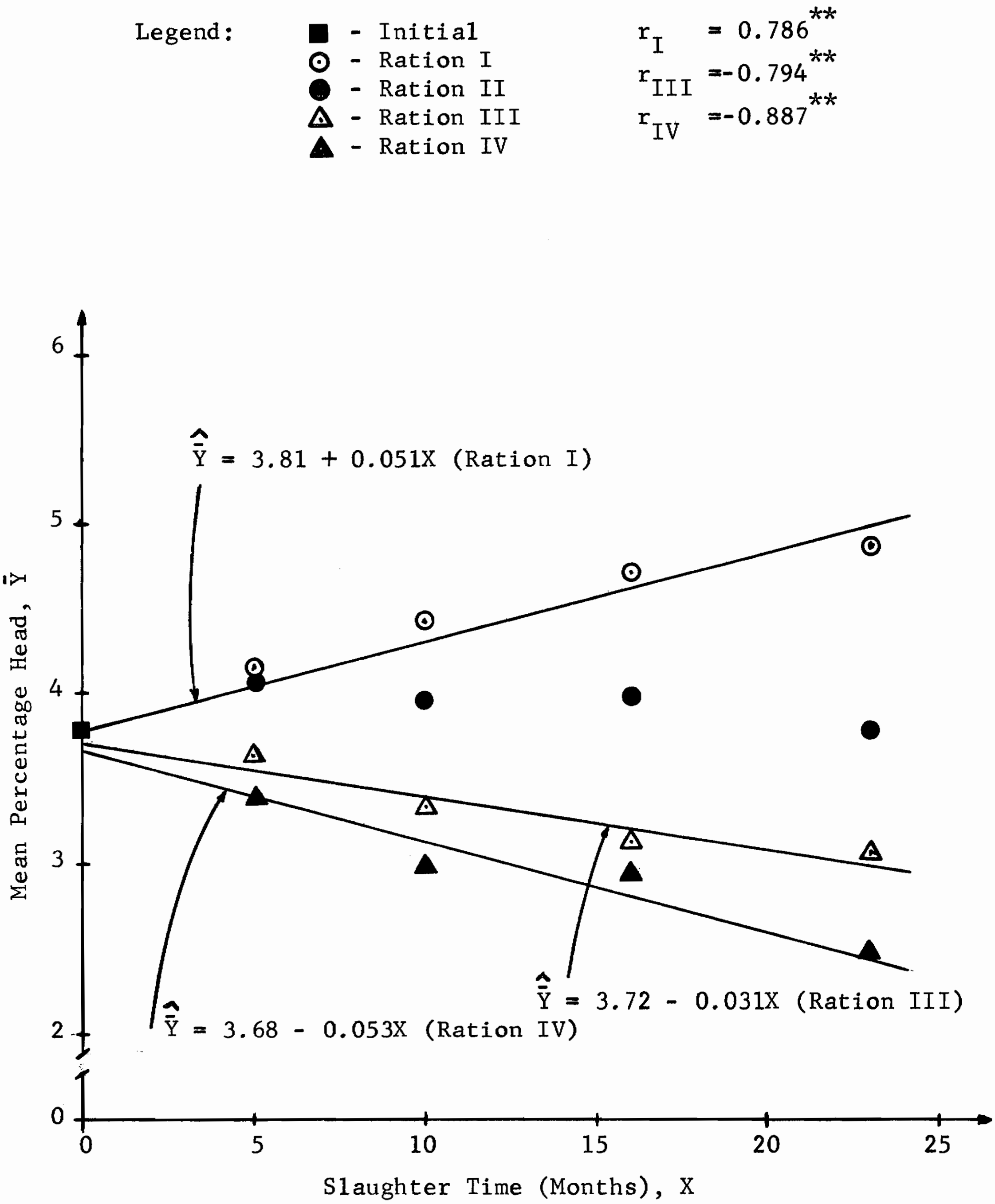

FIGURE 6. RELATION OF THE MEAN PERCENTAGE HEAD TO SLAUGHTER TIME BY RATION.

** - Significant at 1% level.

II). These results are not surprising since from the figures shown in Table XVII, it could be noticed that the weight of the head measured in pounds continuously increases from 16.1 lbs. to 25.4 lbs. in ration I, 16.1 lbs. to 30.3 lbs. in ration II, 16.1 lbs. to 35.2 lbs. in ration III, and 16.1 lbs. to 33.2 lbs. in ration IV during the period of the test. On the other hand, the pattern of change with respect to age of the empty-body weight changed from no regression to a parabolic function when ration was switched from maintenance to fattening. So with the maintenance ration, it is to be expected that the weight of head will increase proportionately with age, but on fattening rations, other portions of the animal body, particularly muscle and fat, will increase at a faster rate than the head, and so the proportion of head will tend to decline as the animal grows older and gets fatter.

TABLE XVII. MEAN WEIGHT OF HEAD IN POUNDS BY SLAUGHTER TIME AND RATION

Slaughter Time (mo.)	Feeding Ration			
	I	II	III	IV
	lbs.	lbs.	lbs.	lbs.
0	16.1	16.1	16.1	16.1
5	19.8	20.8	21.6	23.2
10	22.6	21.8	27.1	29.3
16	24.0	27.3	31.1	27.7
23	25.4	30.3	35.2	33.2

8. <u>The Effect of Age on the Percentage of Moisture in the Meat</u>

At weaning time steers were found to have 64.5% moisture in the meat (lean and fat). After weaning the percentage moisture varied with age and with ration. The mean percentages of moisture are shown in

Table XVIII. In ration I, steers had a mean of 73.3 $\pm$ 1.09% moisture five months after weaning. The mean at the same slaughter age was 71.2 $\pm$ 1.30% in ration II, 67.1 $\pm$ 1.41% in ration III, and 62.1 $\pm$ 1.27% in ration IV. The mean percentage moisture continuously increased up to 75.2 $\pm$ 1.09% in ration I when the steers were 23 months after weaning. In ration II, the mean percentage moisture declined from 71.2 $\pm$ 1.30% at 5 months after weaning to 69.4 $\pm$ 1.30% at 23 months after weaning. The decline in the mean percentage moisture was even more with steers in ration III. The figures obtained were 67.1 $\pm$ 1.41% to 54.1 $\pm$ 1.41% in the same time span. Fattening rations greatly affected the proportion of moisture in the meat. As shown in the table, the moisture content declined from the initial value of 68.5% to 45.2% on ration IV when the steers were about 31 months of age.

The effect of age was highly significant for all rations (Table XIX). Since the deviations from cubic was significant, the best fitting curve was the quartic for ration I. There was an increase in percentage moisture in the first period on all rations except IV, with continued increase in I to 16 months, a slight trend toward decrease after 5 months in II, a definite decline in III, and a greater decline in IV. The fluctuation in values on ration I were erratic and may be due to sampling error. It would be hard to suggest a biological explanation for a quartic relationship.

9. <u>The Effect of Age on the Percentage Crude Protein in the Meat</u>

There have been no studies made before on the effect of age on the percentage of crude protein in the meat when the steers are subjected to different planes of nutrition. Maynard and Loosli (1962)

TABLE XVIII. SUMMARY OF THE MEAN PERCENTAGE MOISTURE BY SLAUGHTER TIME AND RATION

Slaughter Time	Ration I	Ration II	Ration III	Ration IV
(mo.)	%	%	%	%
0	64.5 ± 0.77	64.5 ± 0.92	64.5 ± 0.99	64.5 ± 0.90
5	73.3 ± 1.09	71.2 ± 1.30	67.1 ± 1.41	62.1 ± 1.27
10	72.3 ± 1.09	70.6 ± 1.30	62.4 ± 1.41	52.3 ± 1.27
16	76.4 ± 1.09	70.7 ± 1.30	59.4 ± 1.41	48.0 ± 1.27
23	75.2 ± 1.09	69.4 ± 1.30	54.1 ± 1.41	44.2 ± 1.27
Grand Mean ($\bar{\bar{y}}$)	71.1	68.5	62.0	55.9
Standard Deviation (S.D.)	2.66	3.18	3.44	3.11
Coefficient of Variation (c.v., %)	3.7	4.6	5.6	5.6

TABLE XIX. SUMMARY OF THE ANALYSIS OF VARIANCE OF THE PERCENTAGE MOISTURE BY RATION

S.V.	D.F.	Ration I		Ration II		Ration III		Ration IV	
		M.S.	F	M.S.	F	M.S.	F	M.S.	F
Slaughter Time	4	212.90	30.08**	74.08	7.35**	161.80	13.64**	600.02	62.19**
Linear Regression	1	588.28	83.11**	118.12	11.72**	529.72	44.65**	2,289.63	227.17**
Deviation from Linear	3	87.77	12.40**	59.38	5.89**	39.16	3.30*	27.75	2.88 NS
Quadratic Regression	2	379.30	53.59**	127.52	12.65**	301.74	25.44**	---	---
Deviation from Quadratic	2	46.49	6.57**	20.63	2.05 NS	26.86	2.26 NS	---	---
Cubic Regression	3	260.01	36.73**	---	---	---	---	---	---
Deviation from Cubic	1	71.56	10.11**	---	---	---	---	---	---
Quartic Regression	4	212.96	30.09**	---	---	---	---	---	---
Deviation from Quartic	0	a/	---	---	---	---	---	---	---
Experimental Error	31	7.08		10.08		11.86		9.65	

a/ - The value was zero within rounding error.
* - Significant at 5% level.
** - Significant at 1% level.
NS - Not significant.

tabulated the water and organic substance for various species of animals and indicated that for steers the protein content of the animal body is about 15%. They said that the figure is subject to a large variation according to age and nutritional state as well as to the differences among individuals.

Table XX shows the summary of the mean proportion of crude protein in percent. In ration I, the mean value was 17.5 $\pm$ 0.34% at weaning and 20.2 $\pm$ 0.49% at the end of the slaughter experiment. At full roughage (ration II), the highest value was 19.2 $\pm$ 0.45% which was obtained when the steers were at 10 months after weaning. In ration III the mean percentage crude protein ranged from 17.5 $\pm$ 0.39% to 17.0 $\pm$ 0.55%. A clear downward pattern of the percentage crude protein with respect to age was observed in ration IV. The mean values were 17.5 $\pm$ 0.33% at the start and 12.2 $\pm$ 0.46% at the end.

The analysis of variance (Table XXI) shows that age had a highly significant effect on the percentage crude protein on each plane of nutrition. The breakdown of the age effects into regression components showed that in each of the rations, the deviation from linearity was not significant and hence, the relation between the mean percentage crude protein and age was linear.

The graph of the regression equations of the mean percentage of crude protein is shown in Figure 8. The effect of the ration was to change the slope from positive on maintenance and all hay rations to negative on the fattening rations III and IV.

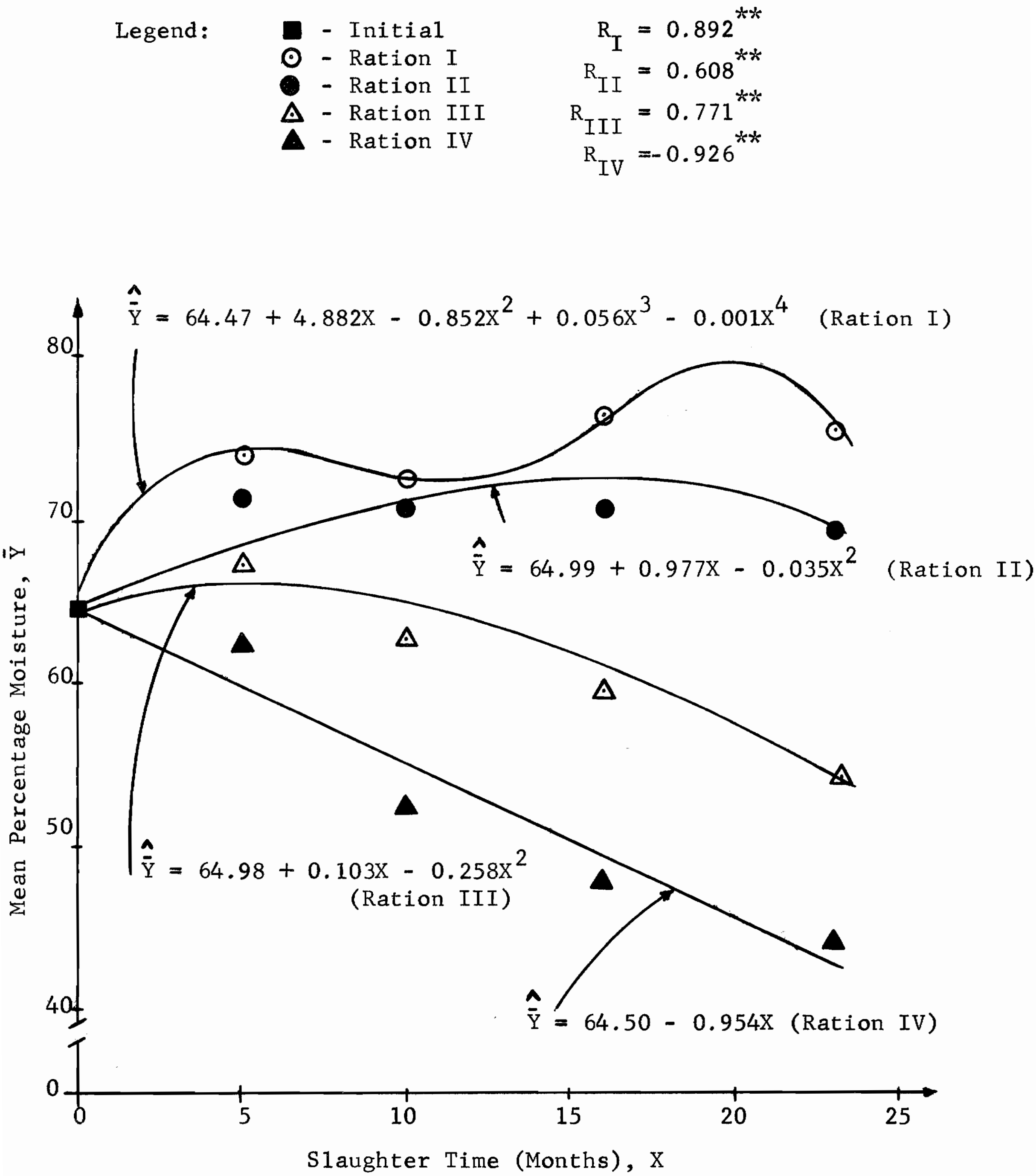

FIGURE 7. RELATION OF THE MEAN PERCENTAGE MOISTURE IN THE MEAT TO SLAUGHTER TIME BY RATION.

** - Significant at 1% level.

TABLE XX. SUMMARY OF THE MEAN PERCENTAGE CRUDE PROTEIN BY SLAUGHTER TIME AND RATION

Slaughter Time	Ration I	Ration II	Ration III	Ration IV
(mo.)	%	%	%	%
0	17.5 ± .34	17.5 ± .32	17.5 ± .39	17.5 ± .33
5	18.6 ± .49	18.1 ± .45	17.6 ± .55	17.1 ± .46
10	20.1 ± .49	19.2 ± .45	17.4 ± .55	14.2 ± .46
16	19.7 ± .49	18.9 ± .45	16.7 ± .55	14.1 ± .46
23	20.2 ± .49	18.8 ± .45	14.9 ± .55	12.2 ± .46
Grand Mean ($\bar{\bar{y}}$)	18.9	18.3	16.9	15.4
Standard Deviation (S.D.)	1.19	1.11	1.35	1.13
Coefficient of Variation (c.v., %)	6.3	6.1	8.0	7.3

TABLE XXI. SUMMARY OF THE ANALYSIS OF VARIANCE OF THE PERCENTAGE CRUDE PROTEIN BY RATION

S.V.	D.F.	Ration I		Ration II		Ration III		Ration IV	
		M.S.	F	M.S.	F	M.S.	F	M.S.	F
Slaughter Time	4	11.94	8.49**	4.15	3.36*	8.25	4.55**	37.12	29.22**
Linear Regression	1	37.86	26.93**	10.91	8.85**	25.45	14.05**	138.01	108.67**
Deviation from Linearity	3	3.30	2.34 NS	1.89	1.54 NS	2.51	1.39 NS	3.48	2.74 NS
Experimental Error	31	1.41		1.23		1.81		1.27	

NS - Not significant.
* - Significant at 5% level.
** - Significant at 1% level.

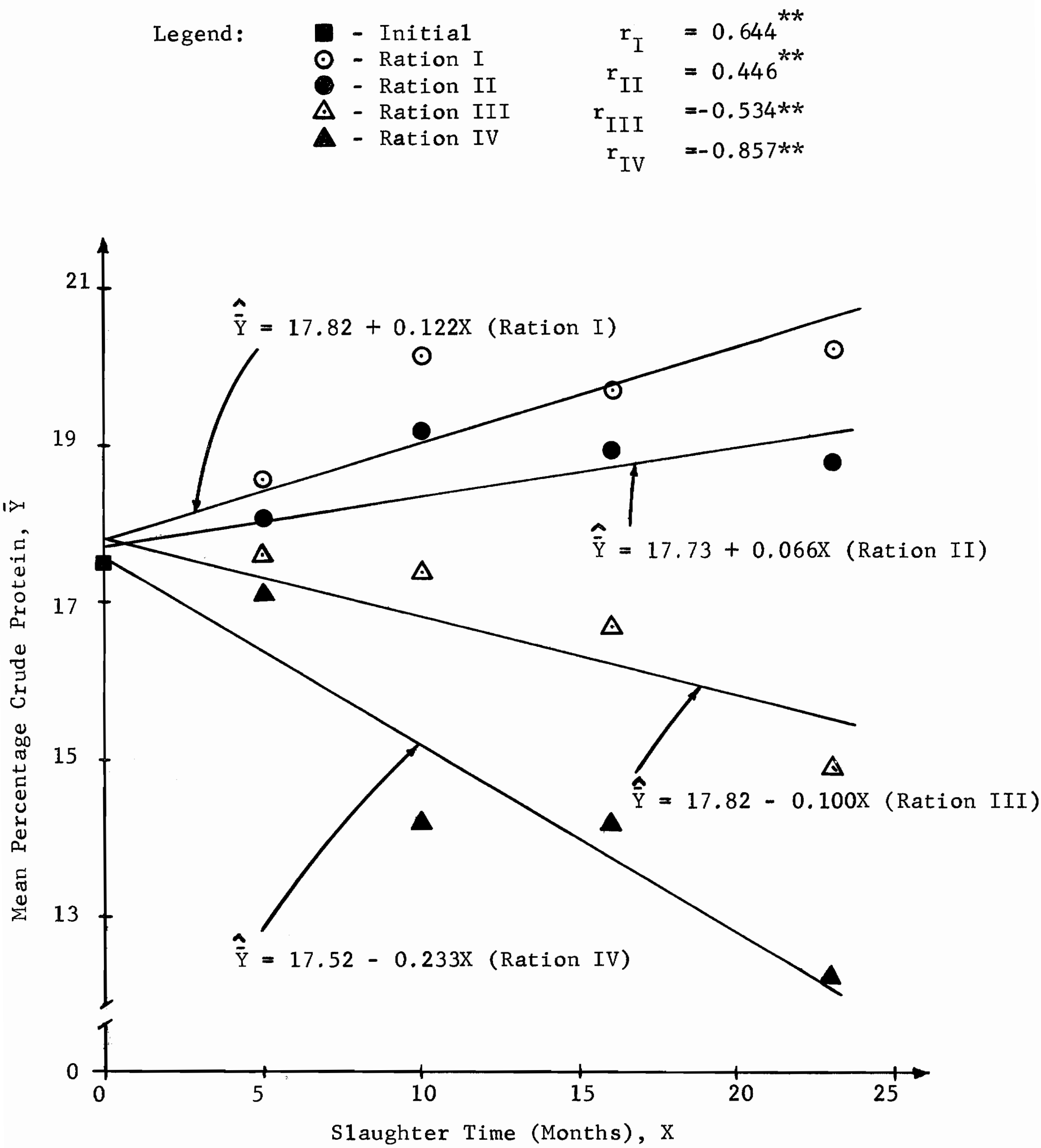

FIGURE 8. RELATION OF THE MEAN PERCENTAGE CRUDE PROTEIN IN THE MEAT TO SLAUGHTER TIME BY RATION.

** - Significant at 1% level.

10. The Effect of Age on the Percentage Ether Extract in the Meat

The third component in the composition of the meat is the percentage ether extract. The mean values are given in Table XXII. At weaning time, the steers averaged 16.6% ether extract but from then on the mean percentage varied with age and with plane of nutrition. At maintenance (ration I), the mean percentage ether extract dropped from 16.6 $\pm$ 0.81% at weaning to 5.5 $\pm$ 1.14%, 5 months after weaning, remained steady at 3%, 10 and 16 months post weaning. At the end of the experiment, 23 months after weaning, the mean percentage ether extract was 2.8 $\pm$ 1.14, not significantly different from the 3% at 10 and 16 months.

The pattern of the mean percentage ether extract with respect to the age among the steers in ration II was markedly different from those observed in ration I. Dropping from 16.6 $\pm$ 0.82% at weaning to 8.9 $\pm$ 1.16%, 5 months after weaning, the mean values remained at around 8% between 10 and 16 months after weaning and then rose to 10.8 $\pm$ 1.16%. In ration III, although the mean value dropped to 13.5 $\pm$ 1.65, 5 months after weaning, the percentage continued to increase up to 29.1 $\pm$ 1.65% at the termination of the experiment. On the fattening ration (IV), the percentage ether extract increased from 16.6 $\pm$ 1.27% to 42.7 $\pm$ 1.80% during the entire period without any occurrence of weaning effect, as was observed in ration III.

When the differences among slaughter time means were subjected to the analysis of variance, they were found to be highly significant in each of the rations (Table XXIII). The type of polynomial regression that best explained the relation of percentage ether extract to age was

TABLE XXII. SUMMARY OF THE MEAN PERCENTAGE ETHER EXTRACT BY SLAUGHTER TIME AND RATION

Slaughter Time	Ration I	Ration II	Ration III	Ration IV
(mo.)	%	%	%	%
0	16.6 $\pm$ 0.81	16.6 $\pm$ 0.82	16.6 $\pm$ 1.17	16.6 $\pm$ 1.27
5	5.5 $\pm$ 1.14	8.9 $\pm$ 1.16	13.5 $\pm$ 1.65	19.2 $\pm$ 1.80
10	3.9 $\pm$ 1.14	7.5 $\pm$ 1.16	19.3 $\pm$ 1.65	29.3 $\pm$ 1.80
16	3.3 $\pm$ 1.14	7.9 $\pm$ 1.16	25.0 $\pm$ 1.65	34.3 $\pm$ 1.80
23	2.8 $\pm$ 1.14	10.8 $\pm$ 1.16	29.1 $\pm$ 1.65	42.7 $\pm$ 1.80
Grand Mean ($\bar{\bar{y}}$)	8.1	11.4	19.2	26.4
Standard Deviation (S.D.)	2.79	2.84	4.05	4.40
Coefficient of Variation (C.V., %)	34.5	24.9	20.3	16.7

TABLE XXIII. SUMMARY OF THE ANALYSIS OF VARIANCE OF THE PERCENTAGE ETHER EXTRACT BY RATION

		Ration I		Ration II		Ration III		Ration IV	
	D.F.	M.S.	F	M.S.	F	M.S.	F	M.S.	F
Slaughter Time	4	331.13	42.45**	131.48	16.31**	259.34	15.76**	870.63	44.87**
Linear Regression	1	920.35	117.99**	206.21	25.58**	872.63	53.15**	3,419.77	176.24**
Deviation from Linear	3	134.72	17.27**	106.57	13.22**	54.91	3.34*	20.92	1.08^{NS}
Quadratic Regression	2	618.58	79.31**	252.75	31.35**	468.78	28.55**	---	---
Deviation from Quadratic	2	43.68	5.60**	10.21	1.27^{NS}	49.90	3.04^{NS}	---	---
Cubic Regression	3	437.22	56.05**	---	---	---	---	---	---
Deviation from Cubic	1	12.86	1.65^{NS}	---	---	---	---	---	---
Experimental Error	31	7.80		8.06		16.42		19.40	

* - Significant at 5% level.
** - Significant at 1% level.
NS - Not significant.

cubic in ration I, quadratic in rations II and III, and linear in ration IV. The graphs of the regression equations were then plotted and they are shown in Figure 9.

11. <u>The Effect of Age on the Mean Percentage Ash in the Meat</u>

Ash constituted the smallest component of the meat. As shown in the summary of the mean percentage ash by slaughter time and by ration (Table XXIV), the grand mean was only 0.89% in ration I, 0.87% in ration II, 0.79% in ration III, and 0.72% in ration IV. The change in the mean value of ash with age in ration I was 0.81 $\pm$ 0.024% at weaning, 0.90 $\pm$ 0.034%, 5 months after weaning, .90 $\pm$ 0.034%, 9 months after weaning, 0.98 $\pm$ 0.034%, 15 months after weaning, and 0.97 $\pm$ 0.034%, 22 months after weaning. The steers receiving a full feed of hay (ration II) had the highest mean percentage ash, 0.96 $\pm$ 0.057%, at 16 months after weaning. However, the value dropped to 0.89 $\pm$ 0.057%, 23 months after weaning. In ration III, the steers had a mean of 0.84 $\pm$ 0.031%, 5 months after weaning, but gradually dropped down to 0.69 $\pm$ 0.031% at the last slaughter time. Fattening (ration IV) steadily decreased the proportion of ash in the meat from 0.81 $\pm$ 0.021% to 0.56 $\pm$ 0.030% from weaning to the end of the slaughter period.

Table XXV shows the analysis of variance of the percentage ash by ration. A highly significant positive linear relationship between the mean percentage ash and age was observed with steers in ration I. It was a cubic relationship in ration II, and a negative linear relationship in rations III and IV. Figure 10 shows the graphed regressions of mean percentage ash on age.

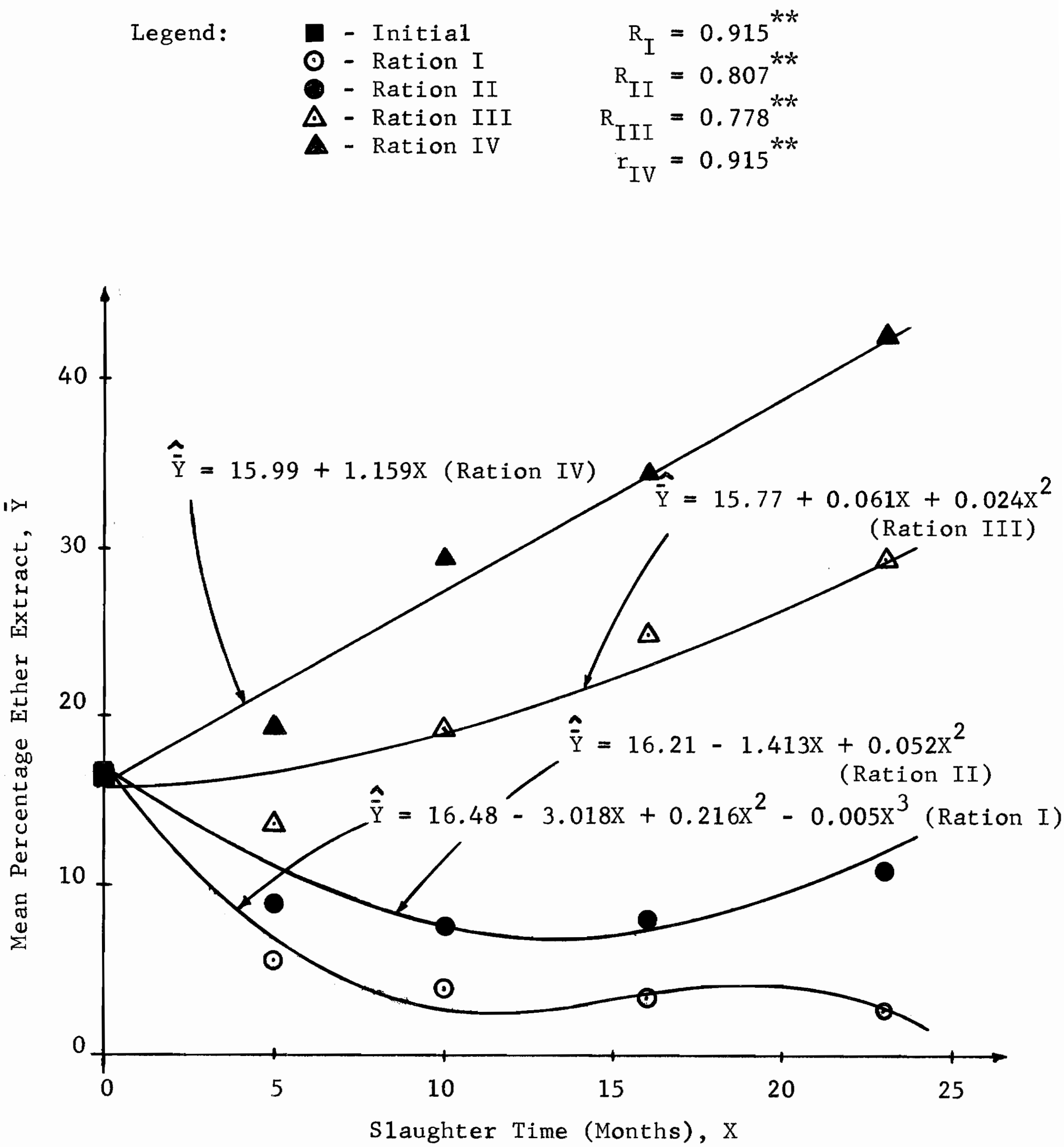

FIGURE 9. RELATION OF THE MEAN PERCENTAGE ETHER EXTRACT IN THE MEAT TO SLAUGHTER TIME BY RATION.

** - Significant at 1% level.

TABLE XXIV. SUMMARY OF THE MEAN PERCENTAGE ASH BY SLAUGHTER TIME AND RATION

Slaughter Time	Ration			
	I	II	III	IV
(mo.)	%	%	%	%
0	0.81 ± 0.024	0.81 ± 0.020	0.81 ± 0.022	0.81 ± 0.021
5	0.90 ± 0.034	0.80 ± 0.057	0.84 ± 0.031	0.80 ± 0.030
10	0.90 ± 0.034	0.93 ± 0.057	0.83 ± 0.031	0.65 ± 0.030
16	0.98 ± 0.034	0.96 ± 0.057	0.76 ± 0.031	0.65 ± 0.030
23	0.97 ± 0.034	0.89 ± 0.057	0.69 ± 0.031	0.56 ± 0.030
Grand Mean ($\bar{\bar{y}}$)	0.89	0.87	0.79	0.72
Standard Deviation (S.D.)	0.08	0.07	0.09	0.07
Coefficient of Variation (c.v., %)	9.4	8.0	10.9	10.3

TABLE XXV. SUMMARY OF THE ANALYSIS OF VARIANCE OF THE PERCENTAGE ASH BY RATION

S.V.	D.F.	Ration I		Ration II		Ration III		Ration IV	
		M.S.	F	M.S.	F	M.S.	F	M.S.	F
Slaughter Time	4	0.041	5.86**	0.034	7.02**	0.022	3.64*	0.087	15.76**
Linear Regression	1	0.142	18.90**	0.077	15.63**	0.059	10.02**	0.320	58.24**
Deviation from Linear	3	0.007	1.03 NS	0.020	4.14*	0.009	1.51 NS	0.009	1.60 NS
Quadratic Regression	2	---	---	0.053	10.71**	---	---	---	---
Deviation from Quadratic	2	---	---	0.017	3.53*	---	---	---	---
Cubic Regression	3	---	---	0.043	8.84**	---	---	---	---
Deviation from Cubic	1	---	---	0.008	1.55 NS	---	---	---	---
Experimental Error	31	0.007		0.005		0.006		0.006	

* - Significant at 5% level.
** - Significant at 1% level.
NS - Not significant.

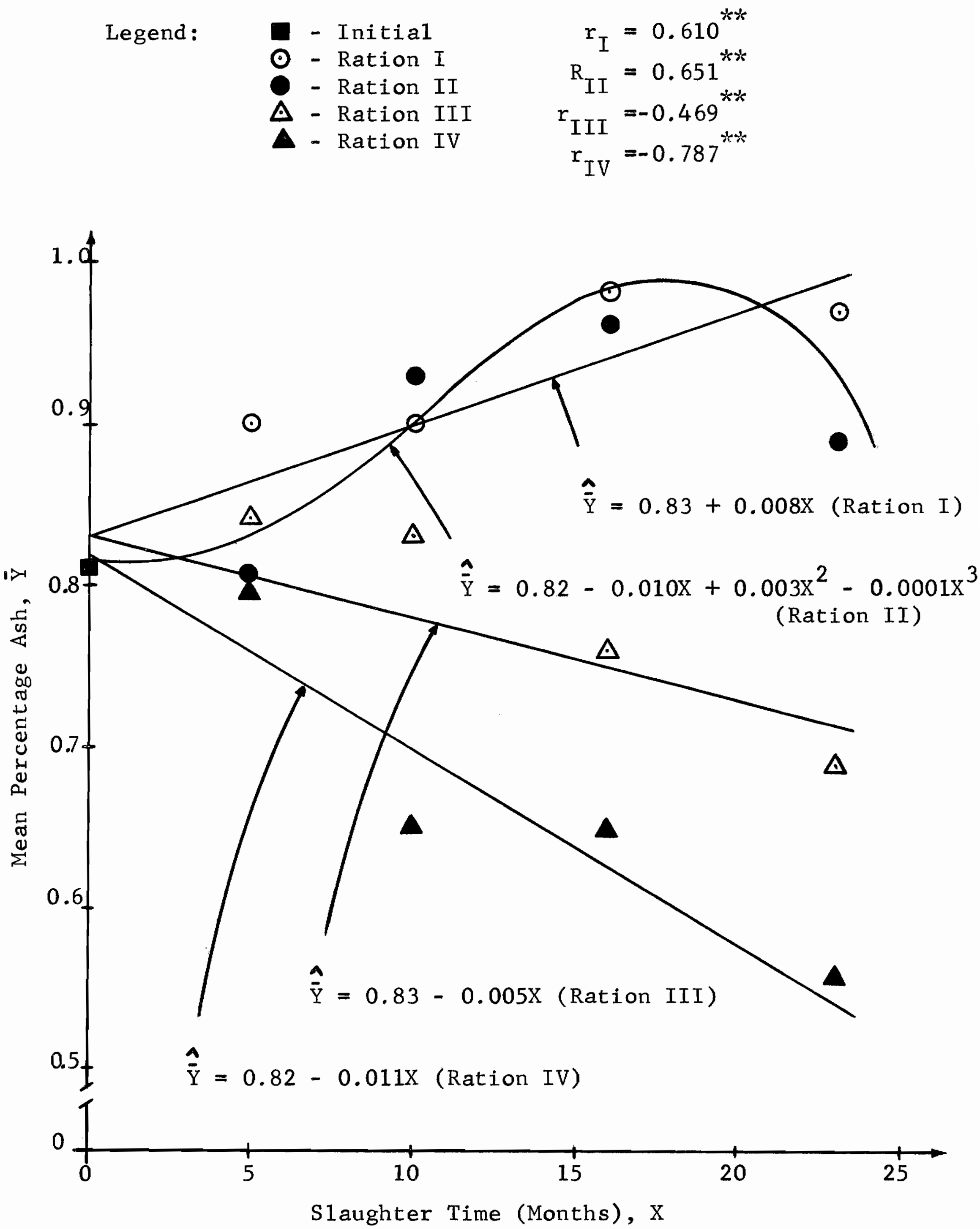

FIGURE 10. RELATION OF THE MEAN PERCENTAGE ASH IN THE MEAT TO SLAUGHTER TIME BY RATION.

** - Significant at 1% level.

SUMMARY AND CONCLUSIONS

An investigation of the growth pattern of various body and carcass measurements was carried out using slaughter data on beef steers reported by Kelly et al. (1968). The main objective of their study was to determine how various measured body and carcass components of the steers changed with time when the animals were subjected to four planes of nutrition. The nutritional regimens used were: Ration I - maintenance; Ration II - full feed of hay; Ration III - full feed of hay plus limited concentrates to provide about 1.3 lbs. gain per day; Ration IV - full feed of a fattening ration.

The slaughter data were obtained by slaughtering some steers immediately at weaning time to obtain initial carcass composition. Then some steers from each ration were slaughtered after they had been on test approximately 5, 10, 16, and 23 months. A total of 108 steers in two trials were used. The steers consisted of 54 Herefords and 54 Angus.

The various body and carcass components considered in this study were:

1. Percentage hot carcass weight of live body weight before slaughter (dressing percent).

2. Empty-body weight -- live weight less the blood and contents of the digestive tract.

3. Percentage meat, lean plus fat, of chilled carcass weight (meat:bone ratio).

4. Weight of head as percent of live weight.

5. Percent front quarter and hind quarter of chilled carcass weight.

6. Percentage moisture, crude protein, ether extract and ash of the meat.

The methods of statistical analysis followed to assess the pattern of growth of the various body or carcass component were as follows. First, the significance of the effect of age or slaughter time on the various traits was tested. When the effect of age was found significant, a polynomial regression model was fitted to the means of the components and the corresponding regression equation obtained by least squares.

The effects of breed and of trial were found insignificant with respect to percentage hot carcass. However, the percentage hot carcass for Herefords was consistently higher in every ration than that of the Angus. Trial 1 also had a higher percentage hot carcass than trial 2 at every nutritional level.

Age had a highly significant effect on the percentage hot carcass. For steers on rations I and II, the pattern of the change in percentage hot carcass was quadratic and the curve was concave upward. The lowest hot carcass percentage of around 48.5% occurred at about 15 months after weaning. On the other hand, a cubic relation between the percentage hot carcass and age was obtained in rations III and IV. For these two groups of animals, the lowest percentage points occurred at about 5 months after weaning and a highest percentage point at about 20 months after weaning. The mean percentage hot carcass observed on ration IV was always higher than that observed on ration III, but the shape of the curves were the same.

Fattening increased the mean empty-body weight from weaning to the end of the slaughter period. The mean empty-body weight was always higher on ration IV than on ration III. The relationship obtained between the mean empty-body weight and age was quadratic for both rations III and IV. The shape of the curve was slightly concave downward. The effect of age on the mean empty-body for the steers on ration II was linear with an intercept value of 369.2 lbs. and a rate of increase of 12.5 lbs. per month. The steers on the maintenance ration did not have any significant gain in empty-body weight during the entire period of the experiment.

The mean percentage meat behaved in a parabolic way with age when the steers were on fattening rations (III and IV). In both cases, the rate of increase in the mean percentage meat decreased steadily until about 18 months after weaning at which time the percentage meat in ration III was around 84% and in ration IV around 88%. For the steers on rations I and II, the percentage meat was not affected by age, although the values fluctuated about their general mean of 73.5% for ration I and 75.2% for ration II.

In all the rations, the percentage front quarter increased proportionately with age. In ration I, the mean percentage front quarter at weaning was 25.0% and increased at the rate of 0.077% per month. The rate of increase for ration II was 0.052%. Rations III and IV had a rate of increase of 0.053% and 0.036%, respectively.

In ration I, the percentage hind quarter decreased linearly with age. With an initial value of 24.6% at weaning, the rate of decrease was -0.046% per month. No age effect was found among the steers on rations II, III, and IV.

The percentage head increased proportionately with age when the steers were on a maintenance ration. No age effect was found in ration II. When the steers were given fattening rations (III and IV), the proportion of head was found to be linearly related to age but negatively.

Age affected the percentage moisture in a curvilinear fashion. The age effect was explained by a significant quartic regression on ration I. On ration II, age showed a quadratic effect on the percentage moisture with decreasing rate of increase. A quadratic relation between the proportion of moisture and age was also obtained in ration III but in this case, the curve showed a more rapid rate of decrease (dropping negatively). For steers on ration IV, the proportion of moisture decreased proportionately at the rate of -0.95% per month from a mean value of about 65% at weaning.

The percentage of crude protein in the meat was about 18% at weaning. On ration I, it increased proportionately with age at a rate of 0.12% per month. For steers on ration II, the relation of the percentage crude protein to age was also found to be linear with a rate of increase of 0.07%. When the steers were kept on fattening rations, the relationship was still linear, but negative. On ration III, the rate of decrease was -0.10% per month and on ration IV, -0.23%.

Fattening showed a positive linear relationship between the percentage ether extract and age. At weaning, the percentage ether extract was around 16%. On ration IV, the rate of increase was 1.16% per month. With less rapid fattening ration (III), the pattern was quadratic and the curve was slightly concave upward. The same type of curve, but with a perfect concave shape upward was obtained with steers on ration II.

A cubic relation between the mean percentage ether extract and age was obtained on ration I. The curve declined from weaning until about 10 months after weaning and then it rose again to a maximum of around 4% at age of about 20 months after weaning.

The proportion of ash in the meat was only about 0.83% at weaning. With the maintenance ration, the mean percentage had a linear relationship with age. The rate of increase was 0.008% per month. With full feed of hay ration, the relation became cubic. With a moderate fattening (ration III) the pattern observed was linear with the rate of decrease of -0.005% per month. When the fattening ration was full fed (IV), the mean percentage ash decreased proportionately with age with the rate of -0.011% per month.

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Mariano B. de Ramos

THE GROWTH PATTERN OF VARIOUS BODY AND CARCASS PARTS AND PROPORTIONS OF BEEF STEERS AS INFLUENCED BY DIFFERENT PLANES OF NUTRITION

By

Mariano Bauyon de Ramos

ABSTRACT

Ten attributes representing various body and carcass measurements of beef steers were considered for statistical analysis. The slaughter data were obtained from an experiment conducted at Blacksburg, Virginia, by members of the Animal Science Department of the Virginia Polytechnic Institute, described by Kelly _et al_. (1968). The objective of the study was to obtain estimates of the effects of slaughter time (age), and of the energy level of the ration fed, on the body proportions and carcass composition of beef steers from approximately 7 to 30 months of age. The nutritional regimens used were: Ration I - maintenance; Ration II - full feed of hay; Ration III - limited concentrate plus full feed of hay; Ration IV - full feed of a fattening ration. According to the design of the experiment, the linear model included the general mean, the effects of slaughter time, breed, trial, slaughter time by trial interaction and slaughter time by breed interaction, and an error term. The first part of the investigation dealt with the analysis of variance of the percentage hot carcass to determine whether the effects of breed and trial were significant. In the second part, only the general mean, the slaughter time effect, and an error term were included in the model. When the slaughter time was found significant or highly significant, the sum of squares due to slaughter time was divided into regression components to determine which polynomial regression model best described the relationship between the body component mean and age.

The results of the statistical analyses were as follows:

1. Breed and trial effects on the percentage hot carcass were insignificant in all but ration II, in which trial was significant.

2. Slaughter time by trial interaction effect was significant in all rations; slaughter time by breed was not.

3. The percentage hot carcass behaved in a parabolic manner with age, which was concave upward at lower planes of nutrition; the pattern changed to cubic at higher planes.

4. Age had no effect on the mean empty-body weight with steers on ration I; the effect was linear on ration II; quadratic on rations III and IV. Similar growth pattern was obtained for the percentage meat.

5. The percentage of front quarter to total carcass increased proportionately with age in all rations; the opposite trend was obtained for the percentage hind quarter.

6. The relationship of weight of the head, expressed as percentage of the live weight, with respect to age or slaughter time was linear with positive slope on rations I and II and negative on rations III and IV.

7. The percentage moisture in the meat showed a quartic regression with age on ration I presumably due to random fluctuation of the means. For rations II and III, the relationship was quadratic and concave downward; for ration IV, it was linear with negative slope.

8. The percentage crude protein and the percentage ash behaved similar to that of the percentage head, while opposite pattern was obtained for the ether extract.