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To the Graduate Council:

I am submitting herewith a thesis written by John Richard Swaim, III entitled "Relationships of Ultrasonic Estimates of Fatness and Muscling to Production Factors of Angus Bulls at Ames Plantation." I recommend that it be accepted for nine hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Husbandry.

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RELATIONSHIPS OF ULTRASONIC ESTIMATES OF FATNESS AND MUSCLING TO PRODUCTION FACTORS OF ANGUS BULLS AT AMES PLANTATION

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

John Richard Swaim, III

June 1965

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618320

TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION.	1
II.	REVIEW OF LITERATURE.	2
III.	EXPERIMENTAL PROCEDURE.	7
	Bull Source and Management.	7
	Scanning Procedure.	8
	Method of Somagram Interpretation	9
	Scanning Periods.	10
	Methods of Analysis	12
IV.	RESULTS AND DISCUSSION.	13
	First Analysis.	13
	Second Analysis	21
	Third Analysis.	28
	Fourth Analysis	34
V.	SUMMARY AND CONCLUSIONS	42
LITERATURE CITED.		45

LIST OF TABLES

TABLE PAGE

I. Distribution of Progeny by Sire. 14

II. Distribution of Bulls by Analysis within Scan. 15

III. Means and Standard Deviations of Production Factors and Estimated Fatness and Muscling of Bulls at the First Scan--First Analysis 17

IV. Simple Correlation Coefficients Between Estimated Fatness and Muscling and Production Factors at the First Scan Period--First Analysis. 20

V. Simple Correlation (r), Partial Regression (b), and Multiple Correlation Coefficients (R^2), and Standard Error of Estimates (S_e) for Weight, Type Score, Condition Score, and Estimated Fatness and Muscling with Age on April 5, 1964--First Analysis. 22

VI. Means and Standard Deviations of Production Factors and Estimated Fatness and Muscling of Bulls at the First and Second Scans--Second Analysis. 23

VII. Simple Correlation Coefficients Between Estimated Fatness and Muscling and Production Factors at the First and Second Scan Periods--Second Analysis 25

TABLE PAGE

VIII. Simple Correlation (r), Partial Regression (b), and Multiple Correlation Coefficients (R^2) and Standard Error of Estimates (S_e) for Type Score and Estimates of Fatness, Hide Thickness, and Muscling with Estimated Depth of Biceps Femoris Muscle--Second Analysis 27

IX. Means and Standard Deviations of Production Factors and Estimated Fatness and Muscling of Bulls at the First and Third Scans--Third Analysis. 29

X. Simple Correlation Coefficients Between Estimated Fatness and Muscling and Production Factors at the First and Third Scan Periods--Third Analysis 31

XI. Simple Correlation (r), Partial Regression (b) and Multiple Correlation Coefficients (R^2), and Standard Error of Estimates (S_e) for Age and Weight at Third Scan and Estimates of Fatness and Muscling with Weight on April 5, 1964--Third Analysis 33

XII. Means and Standard Deviations of Production Factors, Selling Price, and Estimated Fatness and Muscling of Sale Bulls at the First and Third Scans--Fourth Analysis . 35

XIII. Simple Correlation Coefficients Between Estimated Fatness and Muscling, Production Factors and Sale Price--Fourth Analysis 38

TABLE PAGE

XIV. Simple Correlation (r), Partial Regression (b) and Multiple Correlation Coefficients (R^2) and Standard Error of Estimates (S_e) for Average Daily Gain, Type Score and Estimates of Fatness with Sale Price--Fourth Analysis 40

CHAPTER I

INTRODUCTION

Since man has domesticated beef cattle, he has strived to gain knowledge to aid in selection of those animals that will transmit the most desirable characteristics to their progeny. Rate of gain, type score, and other visual or measurable characteristics have been used as selection criteria in many production testing programs.

Ultrasonic techniques also have been used as aids in selection of beef cattle, sheep, and hogs. Since there is variation between half siblings, it is difficult to accurately predict certain characteristics of breeding animals based on carcass evaluation of their sibs. The use of an ultrasonic device to estimate certain characteristics that are not always discernible to the eye shows promise, especially in the field of bull selection. The production tested Angus herd on Ames Plantation provided a set of bulls on which ultrasonic techniques could be used. The success with which ultrasonic evaluation methods have been used at this and many other stations prompted this study. The objectives were:

1. To ultrasonically determine hide, fat, and muscle thicknesses of bulls calved in the fall of 1962 and spring of 1963.
2. To compare fat deposition and muscle development patterns during the bull's growth period.
3. To determine the relationships among production factors, estimates of carcass composition and sale price.

CHAPTER II

REVIEW OF LITERATURE

Since the development of the somascope in the early 1950's, the value of ultrasonic methods of estimating certain muscle and fat characteristics of live cattle has increased because of improved techniques. In some of the earliest work in the United States, Temple (1956) found a significant correlation (r=0.39) between somascope ("A" Scan) estimates of fat thickness and actual carcass fat thickness measurements on cattle. The correlation between somascope readings and actual thickness of subcutaneous fat on each animal at several locations was highly significant (r=0.63). A low association was found between rib fat thickness and slaughter grade, carcass grade, daily gain, feed efficiency, and dressing percentage.

Stouffer et al. (1961), in a study with 327 cattle and 42 hogs, found a low but significant relationship between ultrasonic estimates ("B" Scan) and actual measurements of rib-eye area. The comparisons of repeated ultrasonic measurements on the same animals indicated a significant repeatability. However, limited data suggested that positional variation of rib-eye area and fat thickness between the 12th and 13th ribs, changes of shape and size of the longissimus dorsi muscle due to slaughtering and hanging, and variability in pressure of the transducer against the hide during probing, probably accounted for the low relationships between ultrasonic estimates and

carcass measurements. Ramsey et al. (1965b) also reported an increase in fat thickness and a change in l. dorsi configuration when chine bones of carcasses were scribed. Ultrasonic somagrams of the live animals showed that the sides chilled after being laid on a table or placed in a simulated standing position, as opposed to hanging on the rail in the usual manner, had fat and muscle configurations more closely resembling those in the live animal. Ultrasonic estimates were highly associated with actual values for fat thickness (r=0.90), l. dorsi area (r=0.90) and biceps femoris area (r=0.90). Hedrick et al. (1962) obtained similar results with 203 cattle. Ultrasonic estimations were made by the "A" scan method. The simple correlation coefficient between live estimated and carcass fat measurements was 0.63 ($P < .01$) when chine bones were not scribed. When the normal scribing process was used, the correlation between the same two variables was only 0.11. The two l. dorsi area measurements, ultrasonic estimate and actual, were significantly related ($P < .01$) in each group of cattle. Ultrasonic estimates were found to be an accurate method of measuring both rib-eye area and fat thickness.

Cole, Orme, and Kincaid (1960) found that rib-eye area was a poor predictor of total carcass muscle, accounting for only 5 per cent of the variation in total carcass muscle on a weight constant basis. However, the simple correlation coefficient between the separable muscle of the round and the separable muscle of the carcass was 0.95.

Orme et al. (1960) reported that the weights of major muscles in mature beef carcasses were useful as predictors of total carcass

muscling. On a carcass weight constant basis, the weight of the b. femoris muscle was highly associated with the weight of total separable muscle in the carcass. The standard partial regression coefficient was 0.92, and on a slaughter weight constant basis the correlation was even higher (0.97). Over 95 per cent of the variation in carcass separable muscle was accounted for by slaughter weight and b. femoris weight in a multiple regression analysis.

Ramsey et al. (1965a) found that ultrasonic estimates of the cross-sectional area of the b. femoris were significantly ($P<.01$) related ($r=0.81$) to the actual area in the carcasses of bulls, steers, and heifers grading from low good to high prime. Williams (1965) showed that area of the b. femoris made a significant contribution to the prediction of trimmed round weight or round separable muscle weight. When either carcass or slaughter weight was held constant, rib-eye area did not make a significant contribution in the prediction of round composition in any combination of independent variables tested. However, b. femoris area in combination with live or carcass weight accounted for over 85 per cent of the variation in trimmed round weight, and b. femoris area made a significant contribution in the prediction equation.

Brinks, Clark, and Kieffer (1962) showed that measurements of growth of cattle in the early stages of life were positively associated with measures of lean and bone and negatively associated with measures of fat on the carcass. Ultrasonic measures of fatness showed more promise than rib-eye area for predicting carcass traits.

Ramsey, Cole and Hobbs (1962), in a study with 133 steers representing seven breeds, found that fat thickness was more closely related to separable lean than was rib-eye area. When breed effects were ignored, carcass grade was negatively ($r = -.70$) related to per cent separable lean but positively related to separable fat. Simple correlations between U.S.D.A. yield grade and separable fat were highly significant ($r=0.53$), and 67 per cent of the variation in separable fat could be accounted for by one fat thickness measurement over the rib eye. Neither carcass grade nor yield grade was found to be as highly associated with carcass separable lean as was a single fat thickness measurement over the rib eye.

Hedrick et al. (1964) also found that fat measurements at six locations accounted for more variation in per cent yield of partially boneless and boneless retail cuts than did L. dorsi area at the same six locations. Fat measurements at these locations were associated with 41 to 50 per cent of the variation in per cent retail yield of the partially boneless sides of beef. L. dorsi area was associated with only 8 to 29 per cent of the retail yield.

Brown et al. (1964) found simple correlation coefficients between ultrasonic estimates and carcass measurements in bulls of 0.78 and 0.46 for rib-eye and fat thickness, respectively. However, correlations between ultrasonic measurements of fat and rib-eye area or performance traits generally were low. There was a slight tendency for faster gaining, more efficient bulls to have less rib-eye area per hundred pounds of live weight. The correlation between independent

interpretations of the ultrasonic scan by two interpreters was 0.91 for rib eye and 0.94 for fat thickness. These associations showed that these trained interpreters were obtaining repeatable results.

Sumption et al. (1964) reported a significant correlation of 0.63 between ultrasonic estimates and actual fat thickness on 770 cattle. The live weight of these cattle varied from 700 to 1500 lb.

According to Temple, Ramsey, and Patterson (1965), errors in ultrasonic evaluation of live cattle which resulted in decreased accuracy in predicting carcass composition were attributed to animal variation, tissue changes during slaughter, interpretation errors and machine manipulation. Changes in calibration ratio during operating periods also contributed to error. Very firm or fat animals were difficult to somascope.

CHAPTER III

EXPERIMENTAL PROCEDURE

Bull Source and Management

Sixty-six Angus bulls were used in this 1964 study. All bulls were in some stage of the University of Tennessee production testing program at Ames Plantation. Sixteen of the bulls were calved in September, October, and November of 1962. The remaining 50 were calved in January, February, March and April of 1963. The bulls were progeny of 10 sires.

The Ames Plantation Angus herd is included in the Animal Husbandry-Veterinary Science Department of the University of Tennessee Agricultural Experiment Station beef cattle breeding project in cooperation with the Southern Regional Beef Cattle Breeding Project (S-10). The bull testing phase of the breeding project was conducted according to the following plan. The major calving season was January, February, March and April. The calves were on their dam's milk with no creep feed during the summer. This permitted selection of bulls from cows that would raise fast gaining calves on grass alone. The calves were weaned about November 1 at seven to nine months of age, then were wintered on roughage (pasture, hay, and silage) and five pounds of concentrates per bull daily. The yearling bulls were pastured from about April 1 to July 1 on orchard grass-Ladino clover pasture with eight pounds of concentrates per bull daily. The bulls

were put on a 98-day full feed test about July 1. The ration consisted of ground ear corn, cottonseed meal, minerals, and a limited amount of hay.

The fall calves were born in September, October and November, creep-fed while on their dams, and weaned in June. They were put on pasture with eight pounds of concentrates per head daily and wintered on corn silage, hay, and five pounds of concentrates per bull daily. In April they were placed on a full feed test period of 98 days. After this test period they were fed a growing ration.

Scanning Procedure

Two ultrasonic instruments were used in this study. The Branson Sonoray Model 52, with Polaroid camera and tissue scanner ("B" scan), was used to scan the l. dorsi muscle and fat layer between the 12th and 13th ribs. The scans were made perpendicular to and just off the right side of the backbone. The angle of the scan tract bar was depressed about 20° below the horizontal. The hair over this area was clipped and mineral oil was used as a coupling agent between the transducer and the hide. The transducer was mounted on the tissue scanner and, as it travelled across the animal's back perpendicular to the long axis of the l. dorsi, synchronized signals representing hide, fat, and muscle interfaces moved across the oscilloscope.

A Polaroid land camera mounted on the console unit was focused on the oscilloscope and a time exposure was taken. This time exposure print was a cross-sectional representation (somagram) of the area scanned.

The 10-second Polaroid developing process enabled rapid visual appraisal of the somagram to determine whether or not interpretable results were obtained while the animal still was confined.

Method of Somagram Interpretation

Two interpreters (A and B) using acetate paper, traced the recorded echoes judged as representing the edge of the l. dorsi muscle from its somagram. The author was Interpreter A and Dr. C. B. Ramsey was Interpreter B. These two interpreters worked independently on the measurement of fat thickness, hide thickness, and area of l. dorsi as shown on the somagrams. The tracings of the l. dorsi muscle were measured with a compensating polar planimeter. The results were multiplied by a factor for square measure determined from calibration photographs to obtain estimated life size of the muscle. Fat and hide thickness estimates were made in millimeters by the same two interpreters from the somagram at a point three-fourths of the width of the l. dorsi from the chine end. The results were multiplied by a factor for linear measure determined from the calibration photograph to obtain estimated life size fat and hide thicknesses.

The Branson Model 12 ultrasonic instrument which measured tissue thicknesses only, was used to estimate b. femoris muscle thickness and the thickness of hide and fat over this muscle. Hide and fat thicknesses at the 12th rib over the l. dorsi also were measured. The location of the scan over the b. femoris was at a point half way and on a direct line between the posterior end of the pin bone (ischium) and the

anterior edge of the stifle joint on the right side as shown in Figure 1.

Hide thickness and fat thickness over the l. dorsi were estimated with the Model 12 at a point approximately three-fourths of the distance from the center of the back to the lateral edge of the l. dorsi muscle. These measurements were taken directly from the oscilloscope of the Model 12.

Scanning Periods

The bulls were scanned on one or more of the following dates: First scan, April 6, 1964; second scan, August 24, 1964; third scan, October 19, 1964. On these same dates, production data also were collected.

The first scan included all 66 bulls. These bulls were scanned at two locations. A direct reading was taken from the Model 12 ("A" scan) oscilloscope over the b. femoris on the right quarter. A fat thickness measurement between the 12th and 13th ribs also was taken. The Model 52 ("B" scan) was used to estimate hide thickness, fat thickness and l. dorsi area between the 12th and 13th ribs.

The second scan included only 17 bulls. These bulls were scanned between the 12th and 13th ribs with the Model 52.

The third scan included 49 bulls. Both the Model 12 and the Model 52 were used at this scan period. The Model 12 was used to estimate b. femoris thickness and hide and fat thicknesses over the l. dorsi. Estimates of l. dorsi area, hide thickness, and fat thickness at the 12th and 13th rib location were obtained with the Model 52.

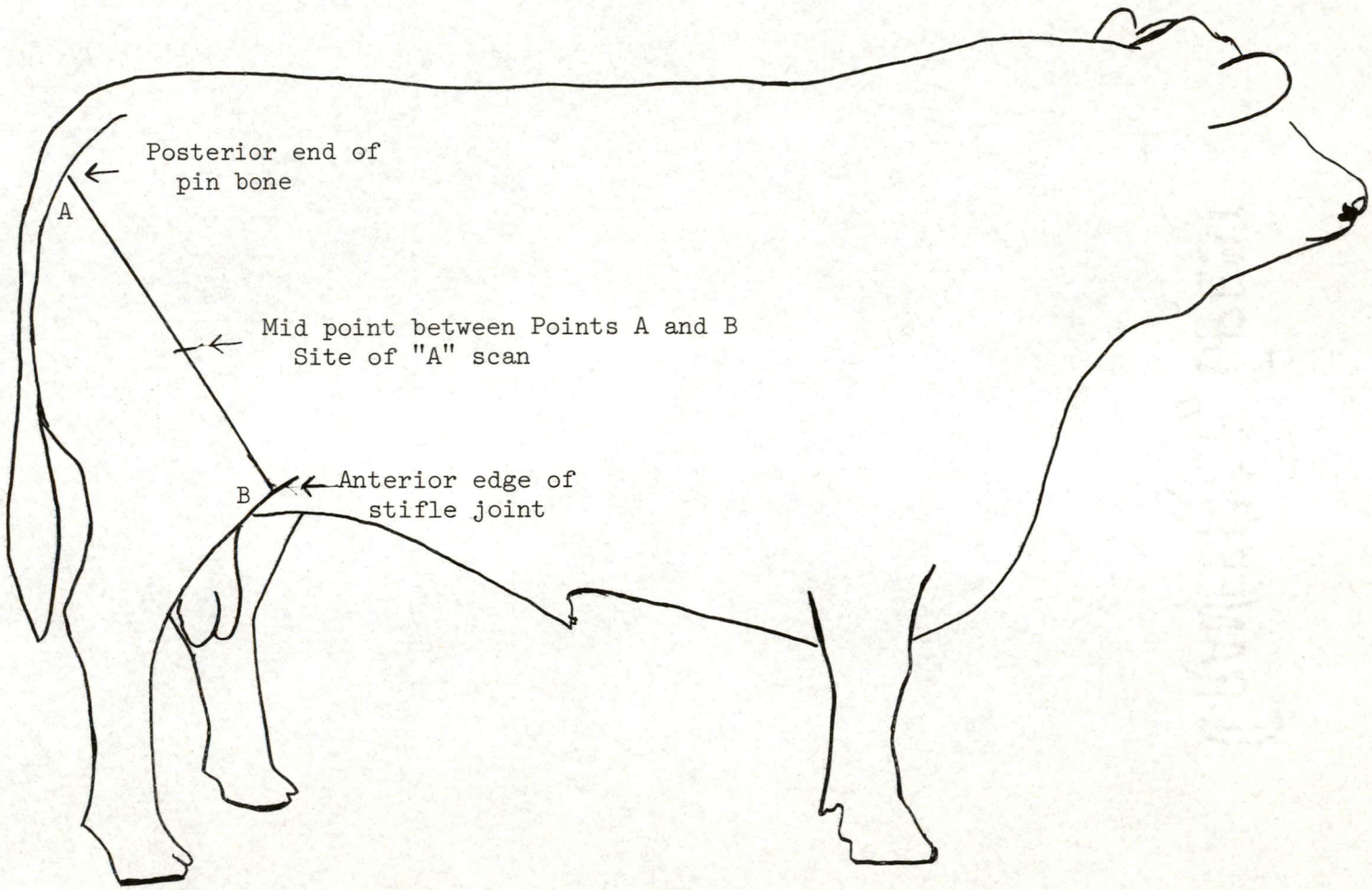

Figure 1. Location of Model 12 scanning site over the biceps femoris muscle in the beef quarter.

The bulls were weighed and scored for type and condition either one or two days prior to the scan day. Age was calculated in days from date of birth to date of scan.

Methods of Analysis

The data from these bulls were analyzed statistically in four separate combinations. The data from all 66 bulls in the first scan period only were included in the first analysis. The second analysis contained only 17 bulls which were included in both the first and second scanning periods. The 49 bulls in the third analysis were those scanned at both the first and third scanning periods. The fourth analysis contained all 32 of the bulls scanned at the first and third scan periods which went into the Ames Production Sale on December 5, 1964. No sale bulls were included in the second scan. Both simple and multiple correlation coefficients were calculated.

Predictions of selected dependent variables were obtained by the method of linear multiple regression. These were calculated using a step-wise procedure with an IBM 7040 computer. In each step, the independent variable, which had the highest partial correlation with the dependent variable, was added to the equation. This procedure continued until no additional independent variable explained a significant portion of the remaining variation in the dependent variable.

CHAPTER IV

RESULTS AND DISCUSSION

Sixty-six Angus bulls at Ames Plantation were used in a study of production characteristics and ultrasonic estimates of fatness and muscling. The bulls were scanned at three periods and production data also were collected at those times.

These sixty-six bulls were not evenly distributed among sires. As shown in Table I, the number of progeny by sires ranged from 1 to 17 in sale bulls and from 1 to 29 in all bulls. Two sires did not have any progeny in the sale.

The data from the sixty-six bulls were analyzed in four analyses. Table II shows the distribution of bulls by analysis within scan period. The three scan dates were: First scan, April 6, 1964; second scan, August 24, 1964; and third scan, October 19, 1964.

First Analysis

All sixty-six bulls were scanned at the first scan date, April 6, 1964, and data from this scan period were included in the first statistical analysis. Bulls in the first analysis averaged 15 months of age and weighed 764 lb. (Table III). These bulls had a lifetime average daily gain of 1.69 lb. to this first scan period. The standard deviations for weight and age were 119 lb. and 59 days, respectively.

The mean hide thickness estimates for Interpreters A and B on

TABLE I

DISTRIBUTION OF PROGENY BY SIRE

Code no.	Sire no.	No. of bulls in sale	Total no. of bulls
1	2642636	17	29
2	2492910	4	8
3	2747675	3	6
4	2089295	2	4
5	3154675	2	3
6	3306153	2	6
7	3309392	1	2
8	3154673	1	6
9	3153355	0	1
10	3405839	0	1
Total		32	66

TABLE II

DISTRIBUTION OF BULLS BY ANALYSIS WITHIN SCAN

Bull no.[a]	Sire code[b]	Scan: First analysis 1	2	3	4	Second analysis 1	2	3	4	Third analysis 1	2	3	4
1412	1	x	x	x			x						
1502	1	x	x				x						
1522	1	x	x				x						
1562	8	x	x				x						
1652	1	x	x				x						
1722	1	x		x	x							x	x
1752	8	x	x				x						
1762	2	x	x				x						
1772	8	x	x				x						
1812	3	x	x				x						
1882	8	x	x				x						
1942	2	x	x				x						
2022	9	x	x				x						
2142	8	x	x				x						
2192	2	x	x				x						
2272	10	x	x				x						
2282	4	x		x	x							x	x
13	4	x		x	x							x	x
23	1	x		x								x	x
33	4	x		x								x	
43	1	x		x								x	x
73	1	x		x	x							x	x
93	1	x		x								x	
113	1	x		x	x							x	x
193	1	x		x	x							x	x
233	4	x		x								x	
273	1	x		x	x							x	x
283	1	x		x	x							x	x
293	1	x		x	x							x	x
323	1	x		x								x	
333	1	x		x	x							x	x
343	1	x		x								x	
353	1	x		x	x							x	x
363	1	x		x	x							x	x
413	1	x		x	x							x	x
423	1	x		x	x							x	x
433	1	x		x	x							x	x
463	1	x		x	x							x	x
473	6	x	x				x						
593	1	x		x								x	

TABLE II (continued)

Bull no.[a]	Sire code[b]	Scan: First analysis 1	2	3	4	Second analysis 1	2	3	4	Third analysis 1	2	3	4
633	1	x		x	x							x	x
703	1	x		x								x	
723	1	x		x	x							x	x
733	1	x		x	x							x	x
813	1	x		x								x	
833	6	x		x								x	
853	3	x		x	x							x	x
883	6	x		x								x	
973	7	x		x	x							x	x
1023	5	x		x	x							x	x
1033	6	x		x	x							x	x
1063	8	x		x	x							x	x
1083	7	x		x								x	
1123	2	x		x	x							x	x
1163	3	x		x								x	
1193	5	x		x	x							x	x
1213	3	x		x								x	
1313	6	x	x				x						
1343	3	x			x							x	x
1373	5	x		x								x	
1413	6	x		x	x							x	x
1453	3	x		x	x							x	x
1463	2	x		x	x							x	x
1473	2	x		x	x							x	x
1623	2	x		x	x							x	x
1643	2	x		x								x	

[a]Last digit in bull number designates year of birth--2 = 1962, and 3 = 1963.

[b]See Table I for sire numbers.

TABLE III

MEANS AND STANDARD DEVIATIONS OF PRODUCTION FACTORS AND ESTIMATED FATNESS AND MUSCLING OF BULLS AT THE FIRST SCAN--FIRST ANALYSIS

Variable	Mean	Standard deviation
First scan on April 6, 1964		
Age, days	450	58.7
Weight, lb.	764	118.8
Estimated hide thickness, mm.		
Model 12	7.7	0.70
Model 52, Interpreter A	5.2	0.54
Model 52, Interpreter B	5.6	0.54
Estimated fat thickness, mm.		
Model 12	4.4	0.69
Model 52, Interpreter A	3.9	1.44
Model 52, Interpreter B	4.3	1.60
Estimated *l. dorsi* area, sq. in.		
Model 52, Interpreter A	10.0	4.20
Model 52, Interpreter B	10.3	2.26
Estimated *b. femoris* depth, Model 12, cm.	9.8	0.82
Condition score[a]	7.6	0.90
Type score[b]	13.0	0.80

[a] 7 = average standard.

[b] 13 = average choice.

the Sonoray Model 52 were very close with estimates of 5.2 and 5.5 mm., respectively. The Model 12, however, gave an estimate of 7.7 mm. At this particular stage in development, hide thickness of these bulls exceeded the fat thickness. The variation in estimated hide thickness among bulls, as shown by the standard deviations, was greater for the Model 12 estimates than for the Model 52 estimates.

The difference in hide thickness estimates for the two machines probably can be attributed to the difference in pressure of the transducer against the animal. The transducer on the Model 12 was held by hand and only sufficient pressure was applied to make contact and produce satisfactory signals. The Model 52 Transducer, however, was under the standard pressure of the tissue scanning device and exceeded the pressure of the hand-held instrument. These differences occurred only in hide thickness estimates. Subsequent estimates of fat and muscle apparently were not affected.

Means of estimated fat thickness over the l. dorsi muscle ranged from 3.9 to 4.4 mm. The standard deviations indicated that estimates with the Model 12 were less variable among bulls. Interpreter A tended to give a slightly lower estimate than Interpreter B.

The mean l. dorsi area estimated by Interpreter B was 10.3 sq. in. as compared with 10.0 sq. in. by Interpreter A. The standard deviation, however, for the estimates by Interpreter A was 4.2 sq. in., while for Interpreter B it was only 2.3 sq. in. Interpreter B was the more experienced of the two.

Estimated b. femoris depth was taken with the Model 12 only,

and averaged 9.8 ± 0.82 cm. The relatively low average condition score (7.6) indicated that the bulls were carrying little finish. The fat thickness estimates substantiated the accuracy of these condition scores. Type scores averaged much higher (13.0) than condition scores.

Body weight was positively associated with age (r=0.839) in a simple correlation analysis (Table IV). Thirty-eight per cent of the variation in l. dorsi area estimated by Interpreter A was associated with the variation in age. This indicated that the older bulls tended to have larger l. dorsi areas. Older bulls also tended to have greater b. femoris depths (r=0.453). There was a positive association between b. femoris depth and type score (r=0.366). Thus, the bulls with a greater depth of this muscle in the quarter tended to receive higher type scores. Age was more highly associated with b. femoris depth than was l. dorsi area estimated by the more experienced Interpreter B. However, Interpreter A found estimated l. dorsi area more highly correlated with age than was estimated b. femoris depth. Both interpreters found the association of hide thickness estimates and age to be low and non-significant.

Condition score was significantly ($P < .01$) associated with age (r=0.621); weight (r=0.605); and fat thickness estimates with the Model 12 (r=0.509), by Interpreter A (r=0.565), and by Interpreter B (r=0.618). Only 6 per cent of the variation in condition score was associated with the variation in type score. Thus, these two scores apparently were given independently.

Those variables which had the highest association with animal

TABLE IV

SIMPLE CORRELATION COEFFICIENTS BETWEEN ESTIMATED FATNESS AND MUSCLING AND PRODUCTION FACTORS AT THE FIRST SCAN PERIOD--FIRST ANALYSIS[a]

Traits	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1) Age on April 5, 1964	1.000	0.839	-0.061	0.128	-0.120	0.373	0.435	0.487	0.664	0.366	0.453	0.621	0.039
(2) Weight on April 5, 1964		1.000	0.012	-0.035	0.016	0.466	0.544	0.602	0.613	0.415	0.590	0.605	0.238
(3) Estimated hide thickness Model 12			1.000	0.346	0.389	0.019	-0.051	0.008	0.048	0.030	0.099	0.025	0.142
(4) Estimated hide thickness Model 52 Int. A				1.000	0.419	0.127	-0.097	-0.001	0.182	0.041	0.081	0.160	-0.007
(5) Estimated hide thickness Model 52 Int. B					1.000	0.198	0.056	0.083	0.025	-0.035	-0.003	0.120	0.241
(6) Estimated fat thickness Model 12						1.000	0.714	0.682	0.330	0.215	0.509	0.544	0.269
(7) Estimated fat thickness Model 52 Int. A							1.000	0.764	0.395	0.243	0.565	0.557	0.270
(8) Estimated fat thickness Model 52 Int. B								1.000	0.438	0.296	0.618	0.650	0.273
(9) Estimated l. dorsi area, Model 52, Int. A									1.000	0.500	0.487	0.552	0.083
(10) Estimated l. dorsi area, Model 52, Int. B										1.000	0.205	0.349	0.131
(11) Estimated b. femoris depth, Model 12											1.000	0.630	0.366
(12) Condition score												1.000	0.250
(13) Type score													1.000

[a] r = 0.240 for P = .05; r = 0.339 for P = .01.

age were included in a step-wise multiple regression analysis (Table V). Weight and estimated l. dorsi area (Interpreter A) accounted for 74 per cent of the variation in age. Both independent variables made a significant ($P < .01$) contribution in the prediction equation when the other variable was held constant. Type score also made a significant contribution to the prediction of age when weight and l. dorsi area were held constant. Neither condition score nor hide thickness (Interpreter B) made significant contributions when added to the respective combinations of variables. A combination of weight, l. dorsi area, type score, condition score, hide thickness (Interpreter B), hide thickness (Interpreter A), and b. femoris depth accounted for more than 83 per cent of the variation in age. However, l. dorsi area and type score failed to make a significant contribution in the prediction equation when the other independent variables were held constant.

Second Analysis

The 17 bulls in the second analysis averaged 17 months of age and 525 lb. in weight at the first scan period and 22 months of age and 1,201 lb. in weight at the second scan period as shown in Table VI. The lifetime average daily gain was 1.68 lb. at the first scan but increased to 1.81 lb. at the second scan.

Estimated hide thickness changed very little between the first and second scans. Interpreter A found only 0.1 mm. difference while Interpreter B found 0.6 mm. difference. However, fat thickness

TABLE V

SIMPLE CORRELATION (r), PARTIAL REGRESSION (b), AND MULTIPLE CORRELATION COEFFICIENTS (R^2), AND STANDARD ERROR OF ESTIMATES (S_e) FOR WEIGHT, TYPE SCORE, CONDITION SCORE AND ESTIMATED FATNESS AND MUSCLING WITH AGE ON APRIL 5, 1964--FIRST ANALYSIS

		Independent Variable								
r or b	a	Weight on 4-5-64	Estimated *l. dorsi* area, Interpreter A, first scan	Type score, first scan	Condition score, first scan	Estimated hide thickness, Interpreter B, first scan	Estimated hide thickness, Interpreter A, first scan	Estimated *b. femoris* depth, first scan	R^2	S_e
r		0.839	0.664	0.039	0.621	-0.120	0.128	0.453		
b	134.339	0.414**							0.679	32.2
b	101.599	0.342**	8.793**						0.740	30.4
b	237.172	0.365**	8.220**	-11.367*					0.763	29.3
b	222.311	0.335**	6.458*	-12.890**	9.972				0.777	28.6
b	265.357	0.327**	6.502*	-10.805*	10.966*	-13.006			0.790	28.0
b	200.419	0.353**	4.691	-9.349*	9.104	-21.717**	20.473**		0.817	26.3
b	240.951	0.377**	5.370	-6.001	13.518**	-24.673**	22.025**	-1.367*	0.834	25.3

* $P < .05$.

** $P < .01$.

TABLE VI

MEANS AND STANDARD DEVIATIONS OF PRODUCTION FACTORS AND ESTIMATED FATNESS AND MUSCLING OF BULLS AT THE FIRST AND SECOND SCANS--SECOND ANALYSIS

Variable	Mean	Standard deviation
First scan on April 6, 1964		
Age, days	525	47.0
Weight, lb.	880	99.5
Estimated hide thickness, mm.		
Model 12	7.6	1.00
Model 52, Interpreter A	5.4	0.49
Model 52, Interpreter B	5.5	0.57
Estimated fat thickness, mm.		
Model 12	5.4	2.12
Model 52, Interpreter A	4.9	1.55
Model 52, Interpreter B	5.5	1.70
Estimated *l. dorsi* area, sq. in.		
Model 52, Interpreter A	11.4	1.35
Model 52, Interpreter B	11.6	1.12
Estimated *b. femoris* depth, Model 12, cm.	10.4	0.65
Condition score[a]	8.6	0.62
Type score[b]	12.9	0.83
Second scan on August 24, 1964		
Age, days	665	48.0
Weight, lb.	1,201	131.6
Estimated hide thickness, mm.		
Model 52, Interpreter A	5.5	0.39
Model 52, Interpreter B	6.1	0.53
Estimated fat thickness, mm.		
Model 52, Interpreter A	9.6	2.00
Model 52, Interpreter B	11.2	2.56
Estimated *l. dorsi* area, Model 52, Interpreter A, sq. in.	13.5	2.94
Estimated *b. femoris* depth, Model 12, cm.	10.5	1.33
Condition score[a]	10.2	0.73
Type score[b]	13.3	0.97

[a] 8 = high standard, 10 = average good.

[b] 12 = low choice, 13 = average choice.

estimates did not remain unchanged. At the first scan both interpreters found fat thickness to average less than 6.0 mm. However, at the second scan, estimates of fat thickness by Interpreters A and B were 9.6 and 11.2 mm., respectively. Thus, during the 140 days between the first and second scans, fat thickness approximately doubled. L. dorsi area estimates by Interpreter A increased from 11.4 ± 1.3 sq. in. at the first scan to 13.5 ± 2.9 sq. in. at the second scan. Estimated l. dorsi area averaged 1.30 sq. in. per hundred pounds of body weight at the first scan as compared with 1.12 sq. in. at the second scan. These results indicate that the increase in animal weight between scans probably was due more to an increase in fat deposition than an increase in muscling. Although the l. dorsi and fat estimates showed a substantial increase between scans, the depth of b. femoris increased only slightly--10.4 cm. at the first scan to 10.5 cm. at the second scan. The standard deviation for b. femoris depth was larger at the second scan than at the first (1.3 vs. 0.7 cm.). This indicated that more variation existed among bulls at the second scan than at the first.

The mean condition score of the bulls increased from 8.5 to 10.2 from the first to the second scan. However, type score increased only from 12.9 to 13.2 during the same period.

As shown in Table VII, a negative correlation existed between condition score and type score at the first scan. However, at the second scan period there was a significant positive (r=0.479) association between condition and type scores. This indicates that, as the bulls increased in age, there was a tendency for condition to have a

RODUCTION

(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
9 0.997	0.660	-0.545	-0.393	0.072	0.413	0.036	-0.128	-0.718	-0.411
0 0.775	0.642	-0.395	-0.167	0.146	0.575	-0.239	0.039	-0.469	-0.151
0 -0.139	0.101	0.205	0.206	-0.035	0.028	-0.019	0.141	0.013	-0.009
8 -0.109	0.153	0.509	-0.135	0.268	-0.086	0.404	0.546	0.194	0.143
8 -0.185	-0.121	0.647	0.482	0.103	0.228	0.043	0.039	0.308	0.426
0 -0.309	-0.235	0.045	0.440	0.293	0.263	-0.012	0.012	0.588	-0.033
1 -0.316	-0.497	0.207	0.468	0.270	0.340	-0.433	-0.202	0.388	0.208
8 -0.247	-0.509	0.225	0.449	0.141	0.427	-0.330	-0.150	0.422	0.186
6 0.679	0.385	-0.076	-0.215	0.198	0.466	-0.109	0.065	-0.535	-0.013
5 0.320	0.156	0.062	-0.089	-0.167	0.305	-0.336	0.012	-0.177	0.300
6 -0.278	-0.301	0.119	0.107	0.367	0.065	-0.444	0.261	0.252	0.300
0 -0.011	-0.250	-0.139	-0.010	0.207	0.011	0.243	0.115	0.159	-0.120
0 -0.156	-0.163	0.363	0.476	0.215	0.249	-0.620	0.140	0.334	0.566
1.000	0.663	-0.567	-0.413	0.045	0.383	0.048	-0.134	-0.723	-0.391
	1.000	-0.322	-0.499	0.386	0.258	0.188	0.411	-0.440	-0.246
		1.000	0.321	0.157	-0.060	0.076	0.367	0.451	0.486
			1.000	-0.248	-0.043	-0.186	-0.361	0.462	0.255
				1.000	0.134	-0.223	0.611	0.126	0.214
					1.000	-0.157	-0.009	-0.189	-0.166
						1.000	0.214	0.026	-0.288
							1.000	0.278	0.266
								1.000	0.479
									1.000

positive effect on type scoring.

There was a positive association between b. femoris depth and type score at the second scan (r=0.266). At the first scan the association was higher (r=0.566), indicating that bulls with thicker quarters, as estimated by b. femoris depth, tended to receive a higher type score.

Depth of the b. femoris muscle and fat thickness were positively associated at both scan periods. This relationship seemed reasonable because the heavier bulls tended to be fatter and also have greater b. femoris depths.

Type score and animal age were negatively associated (r = -.139) at the first scan and also at the second scan (r = -.391). This indicates that the older bulls tended to be given lower type scores and that this tendency was greater at the older age.

A multiple regression analysis was performed with estimated depth of the b. femoris muscle as the dependent variable (Table VIII). Singularly, fat thickness and hide thicknesses had greater associations with estimated b. femoris depth than did two estimates of muscling and body shape--l. dorsi area and type score. The estimate of fat thickness by Interpreter A at the second scan and hide thickness at the first scan accounted for 53.1 per cent of the variation in b. femoris depth. Adding the hide thickness estimation by Interpreter B and type score at the first scan to the equation increased R^2 to 66.7, but neither of these independent variables made a significant contribution in the prediction equation. When all five independent variables were

TABLE VIII

SIMPLE CORRELATION (r), PARTIAL REGRESSION (b), AND MULTIPLE CORRELATION COEFFICIENTS (R^2), AND STANDARD ERROR OF ESTIMATES (S_e) FOR TYPE SCORE AND ESTIMATES OF FATNESS, HIDE THICKNESS, AND MUSCLING WITH ESTIMATED DEPTH OF BICEPS FEMORIS MUSCLE--SECOND ANALYSIS

		Independent Variable						
r or b	a	Estimated fat thickness, Interpreter A, second scan	Estimated hide thickness, Interpreter A, first scan	Estimated hide thickness, Interpreter B, first scan	Type score, first scan	Estimated l. dorsi area, Interpreter A, second scan	R^2	S_e
r		0.611	0.367	0.546	0.039	0.140		
b	67.375	3.862**					0.374	10.84
b	14.541	3.165*	11.044*				0.531	9.71
b	30.587	3.104*	15.019*	-6.758			0.595	9.37
b	-31,964	2.495	19.544**	-11.404	5.361		0.667	8.84
b	-145.666	3.130*	15.143*	-12.858*	10.143*	5.740*	0.787	7.38

* $P < .05$.

** $P < .01$.

included, 78.7 per cent of the variation in b. femoris depth was explained, and each independent variable exerted a significant influence when all others were held constant. The reason for the opposite signs on the partial regression coefficients for the two hide thickness estimates was not readily apparent.

Third Analysis

The lifetime average daily gain at the first scan period for the 49 bulls included in the third analysis was 1.70 lb. As shown in Table IX, the mean age and body weight at the first scan were 425 days and 724 lb., respectively. At the third scan, which was 197 days after the first, mean age and weight were 622 days and 1,111 lb., respectively. As shown by the standard deviations, the weight of the bulls was more uniform at the third scan than at the first scan. Also, the bulls included in this analysis were more uniform in both age and weight than those included in the first or second analyses.

Means for hide thickness estimates by the two interpreters were closer at the first scan than at the third scan. According to Interpreter A, hide thickness decreased 0.5 mm. However, the more experienced Interpreter B detected a 0.2 mm. increase during the interval between the first and third scans.

Mean fat thickness estimates by both interpreters were within 0.3 mm. at the first scan and 0.5 mm. at the third scan with Interpreter A showing the larger increase in fat thickness (5.3 mm.) between scans. For this same period there was a 4.5 mm. increase in

TABLE IX

MEANS AND STANDARD DEVIATIONS OF PRODUCTION FACTORS AND ESTIMATED FATNESS AND MUSCLING OF BULLS AT THE FIRST AND THIRD SCANS--THIRD ANALYSIS

Variable	Mean	Standard deviation
First scan on April 6, 1964		
Age, days	425	36.6
Weight, lb.	724	97.1
Estimated hide thickness, mm.		
Model 12	7.8	0.62
Model 52, Interpreter A	5.2	0.56
Model 52, Interpreter B	5.6	0.53
Estimated fat thickness, mm.		
Model 12	4.0	1.38
Model 52, Interpreter A	3.6	1.59
Model 52, Interpreter B	3.9	1.35
Estimated l. dorsi area, sq. in.		
Model 52, Interpreter A	9.5	1.40
Model 52, Interpreter B	10.3	1.32
Estimated b. femoris depth, Model 12, cm.	9.6	0.79
Condition score[a]	7.2	0.73
Type score[b]	12.9	0.80
Third scan on October 19, 1964		
Age, days	622	34.5
Weight, lb.	1,111	83.4
Estimated hide thickness, mm.		
Model 52, Interpreter A	4.7	0.66
Model 52, Interpreter B	5.8	0.49
Estimated fat thickness, mm.		
Model 12	9.0	2.31
Model 52, Interpreter A	8.9	1.68
Model 52, Interpreter B	8.4	2.08
Estimated l. dorsi area, Model 52, Interpreter A, sq. in.	13.4	1.85
Estimated b. femoris depth, Model 12, cm.	12.0	0.98
Condition score[a]	10.2	0.54
Type score[b]	12.8	0.91

[a] 7 = average standard, 10 = average good.

[b] 12 = low choice.

fat thickness according to estimates by Interpreter B. The Model 12 reading was within 0.6 mm. of the Model 52 estimates in both scans by both interpreters. Thus, it appears that both machines were measuring the same variable.

The mean l. dorsi area estimates by Interpreter A decreased from 1.42 to 1.20 sq. in. per hundred pounds of body weight between the first and third scans. These values generally agree with those reported by Williams (1965) for Angus and Hereford bulls which were slaughtered at varying weights. Between the two scans, the bulls apparently put proportionately more of their increased weight into fat thickness than into l. dorsi muscle. However, the mean l. dorsi area estimate by Interpreter A increased from 9.5 sq. in. at the first scan to 13.4 sq. in. at the second scan. The mean depth estimates of b. femoris muscle increased from 9.6 cm. at the first scan to 12.0 cm. at the second. While there was a 20 per cent increase in b. femoris depth, there was a 35 per cent increase in body weight, suggesting again that the rate of deposition of fat was probably higher than muscle development.

Average condition score advanced from 7.2 $\pm$ 0.73 at the first scan to 10.2 $\pm$ 0.54 at the third scan. Type score decreased slightly from 12.9 $\pm$ 0.8 to 12.8 $\pm$ 0.9 during this same period.

In a simple correlation analysis (Table X) weight at the first scan period was highly related to fat thickness estimates by the Model 12 (r=0.612), and by Interpreter A (r=0.603), and Interpreter B (r=0.649) using the Model 52. This strong association was continued at the third scan period. Hide thickness estimates at one scan period

TABLE X

SIMPLE CORRELATION COEFFICIENTS BETWEEN ESTIMATED FATNESS AND MUSCLING AND PRODUCTION FACTORS AT THE FIRST AND THIRD SCAN PERIODS--THIRD ANALYSIS [a]

Traits	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
First Scan April 6, 1964																								
(1) Age	1.000	0.740	0.155	0.061	-0.009	0.480	0.460	0.516	0.425	0.472	0.448	0.362	0.180	0.990	0.245	0.209	0.077	-0.050	0.428	-0.147	0.097	0.040	-0.165	0.308
(2) Weight		1.000	0.261	-0.096	0.184	0.612	0.603	0.649	0.404	0.516	0.612	0.503	0.309	0.729	0.642	0.257	0.187	0.123	0.444	-0.112	0.286	-0.014	-0.128	0.466
(3) Estimated hide thickness, Model 12			1.000	0.333	0.374	0.200	0.194	0.322	0.140	0.293	0.282	0.285	0.158	0.178	0.194	0.420	0.287	-0.032	0.015	0.038	0.115	-0.125	-0.068	0.243
(4) Estimated hide thickness, Model 52, Int. A				1.000	0.430	0.101	-0.145	0.000	0.139	0.084	0.074	0.120	0.035	0.074	-0.020	0.266	0.415	-0.118	-0.186	0.057	-0.091	-0.049	-0.069	0.059
(5) Estimated hide thickness, Model 52, Int. B					1.000	0.248	0.025	0.086	0.093	0.029	0.112	0.371	0.190	-0.027	0.239	0.215	0.695	0.112	0.026	-0.098	0.156	0.007	-0.117	0.282
(6) Estimated fat thickness, Model 12						1.000	0.645	0.604	0.428	0.382	0.592	0.510	0.396	0.484	0.349	0.342	0.336	0.412	0.263	-0.024	0.251	0.131	0.080	0.418
(7) Estimated fat thickness, Model 52, Int. A							1.000	0.597	0.356	0.330	0.537	0.450	0.281	0.452	0.359	0.308	0.175	0.234	0.314	0.210	0.295	0.227	0.295	0.388
(8) Estimated fat thickness, Model 52, Int. B								1.000	0.370	0.441	0.603	0.579	0.259	0.519	0.299	0.301	0.293	0.162	0.450	0.097	0.537	0.265	0.135	0.376
(9) Estimated l. dorsi area, Model 52, Int. A									1.000	0.747	0.473	0.405	0.106	0.437	0.065	0.353	0.221	0.091	0.081	0.155	0.136	0.085	0.055	0.413
(10) Estimated l. dorsi area, Model 52, Int. B										1.000	0.420	0.405	0.093	0.502	0.153	0.360	0.141	0.215	0.191	-0.113	0.157	0.027	0.051	0.427
(11) Estimated b. femoris depth, Model 12											1.000	0.570	0.366	0.449	0.242	0.334	0.263	0.093	0.247	0.168	0.259	0.167	0.076	0.416
(12) Condition score												1.000	0.466	0.372	0.251	0.253	0.432	0.186	0.363	0.127	0.408	0.105	0.226	0.521
(13) Type score													1.000	0.170	0.190	0.148	0.182	-0.000	0.057	0.253	0.241	0.279	0.347	0.494
Third Scan October 19, 1964																								
(14) Age														1.000	0.225	0.270	0.079	-0.039	0.444	-0.176	0.102	0.039	-0.172	0.288
(15) Weight															1.000	0.221	0.238	0.161	0.186	0.099	0.345	-0.256	-0.117	0.298
(16) Estimated hide thickness, Model 52, Int. A																1.000	0.411	0.094	0.242	0.090	0.327	0.002	0.007	0.248
(17) Estimated hide thickness, Model 52, Int. B																	1.000	0.268	0.153	0.078	0.378	0.255	0.108	0.327
(18) Estimated fat thickness, Model 12																		1.000	0.130	-0.024	0.232	0.022	0.137	0.048
(19) Estimated fat thickness, Model 52, Int. A																			1.000	-0.240	0.571	0.146	-0.029	0.122
(20) Estimated l. dorsi area, Model 52, Int. A																				1.000	0.101	0.168	0.288	0.191
(21) Estimated fat thickness, Model 52, Int. B																					1.000	0.041	0.180	0.174
(22) Estimated b. femoris depth, Model 12																						1.000	0.495	0.170
(23) Condition score																							1.000	0.351
(24) Type score																								1.000

[a] r = 0.276 for P = .05; r = 0.376 for P = .01.

were significantly correlated ($P<.01$) with those at the other scan period. The correlation of hide thickness estimates by the two interpreters at the first scan was highly significant ($r=0.430$).

There was a positive relationship ($r=0.747$) between l. dorsi area estimates by Interpreter A and Interpreter B at the first scan period. The correlations between both of these estimates and body weight at the same scan period were significant ($P<.01$). However, at the third scan period, Interpreter A found the association between estimated l. dorsi area and body weight to be low and positive ($P>.05$). B. femoris depth at the first scan was positively associated ($r=0.612$) with body weight, but at the third scan this association was negative. This further points out the higher degree of association found between fat thickness and body weight as compared to muscle development and body weight as the bulls increased in age.

There was a significant ($P<.01$) relationship between estimated b. femoris depth and both l. dorsi area estimates by both interpreters at the first scan period. This was not true at the third scan period.

There was a positive ($P<.01$) correlation between estimated b. femoris depth and type score and between condition score and type score at the first scan. At the third scan, only condition score and estimated hide thickness by Interpreter B were significantly ($P<.01$) associated with type score. Bulls with deeper b. femoris muscles tended to be rated higher in condition score ($r=0.495$).

Table XI shows the variables which had the highest association with body weight on April 5, 1964, in a step-wise multiple regression

TABLE XI

SIMPLE CORRELATION (r), PARTIAL REGRESSION (b), AND MULTIPLE CORRELATION COEFFICIENTS (R^2), AND STANDARD ERROR OF ESTIMATES (S_e) FOR AGE AND WEIGHT AT THIRD SCAN AND ESTIMATES OF FATNESS AND MUSCLING WITH WEIGHT ON APRIL 5, 1964--THIRD ANALYSIS

		Independent Variable							
r or b	a	Age on 4-5-64	Weight on 10-19-64	Estimated depth b. femoris, first scan	Estimated hide thickness, Interpreter A, first scan	Estimated hide thickness, Interpreter B, first scan	Estimated l. dorsi area, Interpreter B, first scan	R^2	S_e
r		0.740	0.642	0.612	-0.096	0.184	0.516		
b	-111.490	1.963**						0.548	66.0
b	-609.525	1.645**	0.571**					0.773	47.2
b	-757.353	1.342**	0.526**	33.92**				0.832	41.1
b	-639.448	1.358**	0.518**	35.05**	-24.49*			0.852	39.0
b	-691.055	1.412**	0.472**	33.65**	-35.93**	27.283*		0.869	37.2
b	-692.676	1.282**	0.470**	29.20**	-37.23**	27.849*	10.279	0.884	35.6

* $P < .05$.

** $P < .01$.

analysis. Age at the first scan accounted for almost 55 per cent of the variation in weight. When weight at the third scan was added, this combination was associated with more than 77 per cent of the variation in weight at the first scan period. The addition of estimated b. femoris depth at the first scan made a highly significant contribution to the prediction equation. The contribution of estimated hide thickness at the first scan by Interpreter A was significant ($P < .05$) when the other three variables (age, weight, and estimated b. femoris depth at the first scan) were held constant. Estimated hide thickness at the first scan by Interpreter B was significantly ($P < .05$) related to weight at the first scan when the other variables were held constant. The addition of estimated l. dorsi area by Interpreter B at the first scan to the multiple regression analysis enabled the prediction equation to account for more than 88 per cent of the variation in weight at the first scan.

Fourth Analysis

The 32 sale bulls scanned at the first and third scan periods were included in the fourth analysis. They averaged 14 months in age and 730 lb. in weight at the first scan with an average daily gain of 1.71 lb. (Table XII). At the third scan period the average age was 21 months and the average weight was 1,117 lb. The lifetime average daily gain had increased to 1.79 lb.

Hide thickness estimates by Interpreter A and Interpreter B were very close, averaging 5.3 $\pm$ 0.50 and 5.6 $\pm$ 0.43 mm., respectively, at the first scan. However, at the third scan Interpreter A estimated

TABLE XII

MEANS AND STANDARD DEVIATIONS OF PRODUCTION FACTORS, SELLING PRICE, AND ESTIMATED FATNESS AND MUSCLING OF SALE BULLS AT THE FIRST AND THIRD SCANS--FOURTH ANALYSIS

Variable	Mean	Standard deviation
First scan on April 6, 1964		
Age, days	426	38.7
Weight, lb.	730	91.4
Estimated hide thickness, mm.		
Model 12	7.8	0.64
Model 52, Interpreter A	5.3	0.50
Model 52, Interpreter B	5.6	0.43
Estimated fat thickness, mm.		
Model 12	4.0	1.20
Model 52, Interpreter A	3.7	1.68
Model 52, Interpreter B	3.9	1.23
Estimated l. dorsi area, sq. in.		
Model 52, Interpreter A	10.0	1.22
Model 52, Interpreter B	10.6	1.19
Estimated b. femoris depth, Model 12, cm.	9.6	0.71
Condition score[a]	7.3	0.72
Type score[b]	13.0	0.76
Third scan on October 19, 1964		
Age, days	623	37.2
Weight, lb.	1,117	79.2
Estimated hide thickness, mm.		
Model 52, Interpreter A	4.9	0.64
Model 52, Interpreter B	5.9	0.42
Estimated fat thickness, mm.		
Model 12	8.9	2.29
Model 52, Interpreter A	8.8	1.55
Model 52, Interpreter B	8.7	2.04
Estimated l. dorsi area, Interpreter A, sq. in.	13.7	1.71
Estimated b. femoris depth, Model 12, cm.	11.9	1.07
Condition score[a]	10.2	0.59
Type score[b]	13.0	0.72

TABLE XII (continued)

Variable	Mean	Standard deviation
Sale information		
Condition score[a] when sold	10.8	0.60
Selling price, dollars	528.44	202.05
Lifetime average daily gain, lb.	1.79	0.12

[a] 7 = average standard, 10 = average good.

[b] 13 = average choice.

hide thickness to be 4.9 ± 0.64 mm. while Interpreter B estimated hide thickness to be 5.9 ± 0.42 mm. Means for fat thickness varied little among the three estimates. The greatest difference in mean estimates within scan periods was only 0.3 mm.

The l. dorsi area of 10.6 ± 1.10 sq. in. estimated by Interpreter B at the first scan was an average of 1.45 sq. in. of rib-eye area per hundred pounds of body weight. Interpreter A found 10.0 ± 1.22 sq. in. of rib-eye area or 1.37 sq. in. per hundred pounds of body weight. There was an increase in rib-eye area found by Interpreter A between the first and third scans to 13.7 ± 1.71 sq. in. while the rib-eye area per hundred pounds of body weight dropped to 1.22 sq. in.

The b. femoris depth estimates averaged 9.6 ± 0.71 cm. at the first scan and 11.9 ± 1.07 cm. at the third scan. These estimates were obtained with the Model 12.

There was a 35 per cent increase in body weight between the first and third scan periods while l. dorsi area estimates and b. femoris depth estimates increased only 27 and 20 per cent, respectively. During this same time fat thickness estimates increased 56 per cent. Mean condition scores increased from 7.3 at the first scan to 10.2 at the third scan. Type score was 13.0 at both scans with standard deviations of 0.76 and 0.72 for the first and third scans, respectively. The mean sale price for all bulls was $528.44 ± $202.05, ranging from $275 to $975.

The simple correlation coefficients in Table XIII show the association between sale price and weight at the first scan (r=0.645)

(6)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)
.210	-0.341	-0.336	-0.011	0.082	0.020	-0.092	0.306	0.097	0.593	0.989	0.415
.400	0.467	0.455	0.220	0.179	0.016	0.324	0.139	0.448	-0.108	0.057	0.591
.087	-0.248	0.702	-0.093	-0.134	0.247	0.031	-0.111	0.261	-0.297	-0.202	-0.064
.068	0.992	0.302	0.354	0.103	-0.208	0.421	-0.024	-0.061	0.002	-0.353	0.288
.176	0.803	0.590	0.270	-0.065	-0.053	0.529	-0.022	0.132	-0.130	-0.331	0.334
.131	0.244	0.248	0.362	0.226	-0.074	0.046	0.135	0.016	-0.180	-0.116	0.292
.075	0.196	0.126	0.230	0.288	-0.253	-0.109	-0.000	-0.174	-0.186	-0.109	-0.075
.000	0.065	0.150	-0.027	0.488	0.137	-0.097	-0.373	-0.026	-0.253	-0.233	0.015
.141	0.507	0.275	0.226	0.075	0.235	0.222	-0.033	0.075	-0.050	-0.031	0.129
.086	0.433	0.270	0.246	-0.081	0.088	0.302	0.238	0.101	0.234	0.175	0.255
.027	0.494	0.302	0.232	0.068	-0.124	0.473	0.312	0.450	0.191	0.030	0.284
.054	0.608	-0.029	0.363	-0.009	0.151	0.111	0.180	0.024	0.191	0.080	0.209
.018	0.513	0.073	0.362	0.088	0.263	0.350	-0.074	0.094	0.137	0.046	0.225
.306	0.448	0.237	0.385	0.018	-0.179	0.254	0.278	0.148	0.056	0.003	0.256
.354	0.439	0.269	0.144	0.238	0.010	0.374	0.076	0.308	-0.044	0.114	0.485
.000	0.068	0.104	0.068	-0.090	-0.352	0.056	0.227	0.145	0.154	0.214	0.383
	1.000	0.281	0.420	0.129	-0.186	0.448	-0.043	-0.032	0.006	-0.338	0.265
		1.000	0.223	0.113	0.055	0.260	0.052	0.321	-0.328	-0.301	0.104
			1.000	0.275	-0.057	0.294	-0.055	0.354	-0.007	-0.000	-0.090
				1.000	0.221	0.074	-0.079	0.293	0.151	0.043	0.030
					1.000	0.133	-0.182	0.193	-0.137	0.021	-0.215
						1.000	-0.157	0.534	0.142	-0.086	0.133
							1.000	0.082	0.268	0.316	0.125
								1.000	-0.003	0.120	-0.006
									1.000	0.577	0.217
										1.000	0.441
											1.000

to be highly significant; but when sale price and weight at the third scan were compared, the relationship was positive but not statistically significant. Sale price and type score were significantly correlated at the first scan ($P < .05$) and at the second scan ($P < .01$). Type score and condition score were significantly associated ($r=0.441$) only at the third scan period. Except for estimates with the Model 12 and by Interpreter A at the third scan, all fat thickness estimates were positively associated ($P < .05$) with sale price. Fat thickness estimates with the Model 12 and by Interpreter B were significantly ($P < .05$) related to condition score at the first scan period. At the third scan, the estimated depth of b. femoris muscle had a higher association ($r=0.577$) with condition score than with any of the other variables. In the first scan the relationship of estimated b. femoris depth ($r=0.563$) to condition score ($r=0.563$) was second in magnitude only to the association between condition score and selling price ($r=0.633$).

Estimated b. femoris depth was significantly ($P < .05$) associated with type score only at the third scan period. There was a low and non-signficiant relation between estimated l. dorsi area and b. femoris depth except as found by Interpreter B at the first scan. Estimated l. dorsi area was not significantly associated with type score.

In a step-wise multiple regression analysis (Table XIV), weight at the first scan had the highest association with the dependent variable, sale price, accounting for more than 41 per cent of the variation. When type score at the third scan was added, this combination of variables was associated with over 57 per cent of the

TABLE XIV

SIMPLE CORRELATION (r), PARTIAL REGRESSION (b), AND MULTIPLE CORRELATION COEFFICIENTS (R^2), AND STANDARD ERROR OF ESTIMATES (S_e) FOR AVERAGE DAILY GAIN, TYPE SCORE, AND ESTIMATES OF FATNESS WITH SALE PRICE--FOURTH ANALYSIS

		Independent Variable							
r or b	a	Weight on 4-5-64	Type score, third scan	Estimated fat thickness, Interpreter B, third scan	Estimated fat thickness, Interpreter A, third scan	Estimated fat thickness, Interpreter B, first scan	Lifetime average daily gain	R^2	S_e
r		0.645	0.591	0.448	0.324	0.440	0.210		
b	-512.293	1.43**						0.416	157.02
b	-1834.839	1.11**	119.0**					0.574	136.31
b	-2158.824	0.98**	125.26**	38.86**				0.725	111.55
b	-2136.056	1.36**	122.98**	55.66**	-46.94			0.789	99.38
b	-2332.040	1.58**	130.83**	63.86**	-46.87	-34.89		0.813	95.38
b	-1875.010	1.85**	125.41**	74.31**	-542.31**	-47.89*	-301.24	0.833	92.03

* $P < .05$.

** $P < .01$.

variation in sale price. Estimated fat thickness at the third scan by both Interpreter B and Interpreter A was next in importance in the multiple analysis. The addition of these two variables to the equation allowed this combination of variables to account for almost 79 per cent of the variation in sale price. Adding estimated fat thickness (Interpreter B, first scan) and lifetime average daily gain to the analysis enabled this combination of variables to account for 83.3 per cent of the variation in sale price. All of the independent variables in each of the combinations made a significant contribution to the prediction of sale price when the other dependent variables were held constant. These results indicate that heavier, typier, fatter bulls with higher average daily gains tended to bring higher prices in the sale. Neither measure of muscling, l. dorsi area or b. femoris depth, had as much value in the prediction of sale price as the above variables.

CHAPTER V

SUMMARY AND CONCLUSIONS

Ultrasonic estimates of fat and hide thickness were made between the right 12th and 13th ribs with a Branson Model 12 animal tissue scanner on 66 production tested bulls at Ames Plantation. Estimates of biceps femoris depth on the right quarter also were made. The Branson Sonoray Model 52 with Polaroid camera was used to scan the cross section of the hide, fat layers, and longissimus dorsi muscle at the 12-13th rib location. Production data including weight, type score, condition score, and age were collected.

These data were analyzed to determine their relationships and also the relationship between these traits and the sale price for 32 of these bulls at the Ames Production Sale on December 5, 1964.

In the first statistical analysis of data from all 66 bulls scanned only at the first scan period (April 6, 1964), type score was positively associated with condition score, fat thickness and estimated b. femoris depth. Age tended to have a lowering effect on type scores. B. femoris depth estimates increased as fat thickness, body weight, age and estimated l. dorsi area increased. Weight was positively associated with fat thickness, condition score and estimated l. dorsi area. Over 75 per cent of the variation in age was accounted for in a multiple regression analysis by a combination of estimated l. dorsi area, type score, and condition score.

The second analysis of data from 17 bulls scanned at the first and second (August 24, 1964) scans showed that condition score, hide thickness estimates, weight, and age were positively associated with type score. In combination, estimated fat thickness, hide thickness, l. dorsi area, and type score accounted for 79 per cent of the variation in b. femoris depth. Age and estimates of fat thickness and b. femoris depth were the traits most associated with weight changes.

In the third analysis, data were analyzed from 49 bulls which were scanned at both the first and third (October 19, 1964) scan periods. Weight, condition score, fat thickness estimates, and estimated b. femoris depth were most highly correlated with type score. Traits having the highest associations with weight were estimates of fat thickness, b. femoris depth, age, and l. dorsi area. In combination, 88 per cent of the variation in weight could be accounted for by age, b. femoris depth, hide thickness, and l. dorsi area.

The fourth analysis was performed on data from 32 bulls scanned at the first and third periods which were sold in the Ames Production Sale in December, 1964. The trait most affecting type score was condition score. The traits most closely associated with b. femoris depth estimates were condition score, age, weight and fat thickness estimates. Age was closely associated with sale price (r=0.467). A multiple regression analysis of that combination of factors most affecting sale price showed that weight, type score, fat thickness estimates, and average daily gain accounted for over 83 per cent of

the variation in sale price. Thus, in this study the heavier bulls with higher type scores, greater fat thickness, and higher average daily gains tended to bring the higher price in the sale.

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14