WEIGHT-BASED ADJUSTMENTS FOR ULTRASONICALLY DERIVED CARCASS TRAITS AMONG PERFORMANCE TESTED BULLS

by

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CHAPTER I

INTRODUCTION

As the beef industry moves into the future, value-based marketing becomes increasingly important as does product uniformity. Improvement in economically important traits in beef cattle has moved forward since the implementation of national beef cattle sire evaluation programs. Seedstock and commercial producers have made directional changes in traits of interest. They have done this by utilizing sire summary information as a tool for sire selection. This is apparent in the positive genetic improvements that have been cited for growth traits in many of the breeds since the birth of genetic evaluation programs. Most breeds have programs in effect that evaluate growth and maternal traits and some are evaluating calving ease as well as carcass and reproductive traits.

The beef cattle industry has directed more attention to product evaluation and consumer attitudes toward beef (Cross et al., 1986). Changes in the wants and needs of the consumers in the past twenty years show the need to enhance our end product. Society has become increasingly health-conscious, and consumer trends have shifted toward the consumption of leaner beef products. The national consumer surveys show consumers prefer closely trimmed, leaner cuts of beef. However, at the same time a portion of the population does not want to sacrifice eating quality (Savell et al., 1987). Cost of excessive waste in trimmable fat and health conscious consumers have forced the beef industry to take a serious look at making changes. Management practices during the finishing phase and post-slaughter processing may be utilized to meet the demands of the consumer, but these changes are not long lasting and are often times not efficient. When the beef industry makes genetic improvement in carcass traits utilizing genetic evaluation programs, then they could be both advancing and permanent.

The adaptation of ultrasound technology from the field of medicine has helped defeat some of the problems faced. Ultrasound currently allows beef cattle producers and researchers to measure indicators of carcass composition (fat thickness and ribeye area) in the live animal. Ultrasound offers great potential as a valuable management tool to monitor developmental changes in carcass composition and conclude when cattle are optimal for marketing. Measurements from market and breeding animals could help in the continued development of genetic evaluation programs for carcass traits. This should help producers make adjustments in their end product, much like they have in maternal and growth traits.

CHAPTER II

REVIEW OF LITERATURE

Ultrasound Imaging of Beef Cattle

Objective Measures

Of the numerous objective methods used to determine body composition in the live animal, researchers feel ultrasound offers the greatest potential as the least vague and reasonably accurate method (Anderson et al., 1983; Stouffer et al., 1989). Ultrasound is a mechanical wave resulting from the transmission of orderly vibrations through a medium at frequencies above the range of the human ear (McDicken, 1976). These longitudinal compression waves are generated from crystalline structures. These structures contain piezoelectric (pressure-electric) properties. These elements are the basic component of ultrasonic transducers-devices capable of transforming energy from one form to another (Kossoff, 1978). Transducers are the central feature of ultrasound imaging and in most applications, the same transducer is used to generate and receive sound waves (Fleischer and James, 1980).

Ultrasound was developed in response to sinking of the Titanic in 1912. Ultrasound was used for locating objects such as icebergs at sea. Ultrasound imaging is based on measuring scattered or transmitted waves from tissue exposed to an incident ultrasound field (Leeman and Roberts, 1986). Differences in tissue density and acoustical impedance are based on how sound waves are reflected at tissue interfaces. The amount of energy reflected at soft-tissue interface is minor. This allows the incidence wave to move deeper into the tissue where it may reach another interface. The reflected energy at bone and soft-tissue interfaces is more prominent (65%) than at soft-tissue and air, therefore, virtually total reflection will occur (McDicken, 1976). Tissue dimensions are delineated by consolidating the physics of wave propagation, velocity of sound in tissue and the interaction of sound waves with tissue interfaces. Presuming a constant velocity of wave propagation in soft-tissue, distance in measured by determining the time needed for ultrasonic energy to leave the transducer and return (Fleischer and James, 1980).

Ultrasound was initially used in the livestock industry to determine density boundaries without tissue waste (Wild, 1950). These boundaries occurred in the womb of pregnant animals and at the subcutaneous fat to muscle interface. The ensuing applications were fat depth measurement and pregnancy testing (Lake, 1991). Wild and Neal (1951) illustrated that the interface between fat and muscle could be determined in live cattle. Temple (1956), in an previous study with cattle, reported that ultrasound gave a dependable and accurate indication of fat thickness.

There have been estimates of live animal composition using ultrasound technology for many years. Lake (1991) demonstrated the quality and technology of ultrasound equipment has improved drastically in the past ten years. This has resulted in real-time, linear-array scanners, designed to be used in the field of medicine. The new machines image the subcutaneous fat and provide competent detail about interfacial layers in the muscles to allow the sizes of muscles to be predicted with sufficient accuracy. These applications require a satisfactory level of operator skill to interpret the reflections when there was no imaging system used (Lake, 1991). Ferguson (1991) showed a vast number of reports have shown the ultrasound measurements taken by qualified experienced operators were highly correlated with coinciding carcass measurements.

Display Formats

There are two display formats that have been outlined for use in ultrasound imaging of livestock. They are A- and B-mode (Herring and Bjornton, 1985; Rantanen and Ewing, 1981). The amplitude mode (A-mode) is a one dimensional display of the returning echo amplitude and distance measured against time. The A-mode consists of vertical peaks that lye along a horizontal axis. The height of the peaks are proportional to the magnitude of the echo and the tissue being measured is represented by the distance between peaks. The brightness mode (B-mode) is a two-dimensional display format using dots. The transducer is moved over the surface of the body and a cross section of the area scanned is displayed. The positioning of the dots seen on the screen determined by the time it takes for an echo to return to the transducer. The dots brightness are proportional to the magnitude of the returning echoes (Herring and Bjornton, 1985; Rantanen and Ewing, 1981). Park et al. (1981) compared real-time ultrasound imaging to that of the B-mode technique used in recording the movement of internal configurations. The real-time machines display format recorded echoes continuously on a non-storage cathode ray display screen. This image could be produced instantly and then frozen that it might be recorded on videotape.

There does not appear to be a distinct advantage in the accuracy associated with using the A-mode or B-mode instruments. Researchers recognized that the B-mode instruments are easier to use and information can be obtained faster (Gillis et al., 1973; Tong et al., 1981; Tong et al. 1983). The accuracy was due to experience of the operator with a particular machine than the actual equipment (Tong et al.,1983)

Fat Thickness and Ribeye Area

Ultrasound research in beef cattle has predominantly been centered around estimating fat thickness and area of the ribeye muscle in live animals. The anatomical position that is measured on the live animal varies with researcher and geographic location, but the majority have chosen the 12-13 rib position due to its ease of location and because it corresponds to most commercial cutting and grading practices. A wide range of correlation coefficients have been reported in the literature for the relationship between measurements of fat thickness and ribeye muscle area determined ultrasonically and on the carcass. Most of the literature that addresses ultrasonic measurements on beef cattle show that measurements of fat are related to carcass fat thickness and composition of the carcass; but the correlations between actual carcass ribeye area and scan estimate of ribeye area varied from one study to another in early experiments (Anderson 1975). As ultrasound has grown in use and popularity so has the increase in its accuracy for estimating ribeye area and fat thickness. Gresham et al. (1986), Faulkner et al. (1990), and Perry et al. (1990) all agree real-time ultrasound measurements of fat thickness accurate. There have been more recent studies using the real-time ultrasound machines that have described high accuracies in ribeye area scans and subsequent carcass measurements in yearling bulls and slaughter steers (Duello et al., 1990; Waldner, 1991; Perry et al., 1990). Also some reports have shown its potential in estimating marbling scores (Brethour, 1990, Perry et al., 1990).

A review article by Houghton (1988) showed correlation coefficients between ultrasonic estimates obtained with real-time ultrasound equipment ranging from .42 to .92 and .47 to .86 for fat thickness and ribeye area. These values were difficult to compare and were related to the population size and variation of the dependent variable studied.

Smith et al. (1990) compared estimates made by an experienced live evaluator to estimates of two technicians using real-time ultrasound. Ultrasound fat thickness was highly correlated to carcass fat thickness (.82 and .81) but higher than the subjective (.60) correlations. Ultrasound ribeye area was only moderately correlated to actual ribeye area (.63) and no higher than the subjective estimates (.61) yet was within 12.5 cm^2 of the actual ribeye area 88% of the time.

Miller et al. (1988) used 50 head of cattle representing calves, feeders, yearlings, steers and cows varying in size and composition. The estimates by the real-time equipment for ribeye area , 12th rib, shoulder and rump fat thickness in the live animal were significant and high in correlation to the corresponding carcass measures (R^2 = .96, .88, .79 and .76).

Henderson-Perry et al. (1989) recorded measurements of fat thickness and ribeye area on 222 steers of various breeds, in six consecutive trials. It was found that experience increased the accuracy of the ultrasound measurements. The correlation between carcass and scanned fat thickness and ribeye area ranged from .50 to .92, and .32 to .79, respectively. Comparisons of frequency indicated that fat thickness was estimated to within .4 cm of actual carcass fat 99% of the time and ribeye area within 16.1 cm^2 of carcass ribeye area 96% of the time. Within each trial, the correlations for fat thickness and ribeye area improved.

Duello et al. (1990) found that current real-time ultrasound machines can be used to accurately predict fat thickness and ribeye area. They had correlations between carcass fat thickness and ultrasound measurements ranging from .76 to .90 on steers and from .79 to .91 on bulls. Carcass ribeye area and ultrasound correlation's ranged from .56 to .76 in steers and from .71 to .90 in bulls. The difference between carcass ribeye area and ultrasound ribeye area was less than 12.9 cm^2 92.5% of the time.

Waldner et al. (1991) reported that ultrasound measures taken on yearling bulls provided a useful index of body composition and characterized differences in groups of cattle. Duello et al. (1993) scanned 832 head of small, medium, and large framed steers and bulls over a three year period from 1990 - 1992. Calves were slaughtered at 13 to 16 months of age and the carcass parameters were fat thickness 1.27 - 40.64 mm; ribeye area 59.35 - 115.5 cm^2. The average differences measured between ultrasound and carcass in all cattle were 5.1 mm and 1.81 cm^2 for fat thickness and ribeye area, respectively correlations between ultrasound and carcass measurements were .84 for fat thickness and .77 for ribeye area for the whole population. The previous two years of 1990 and 1991 were higher than in 1992.

Duello et al. (1993) serially scanned performance tested Angus and Simmental bulls from 1989 to 1992 four times during test period. Weight, height, fat thickness, and ribeye area were measured on each animal at approximately 30 day intervals from December to April. Individual regressions of the four traits on age revealed that linear and quadratic regressions in all instances had an advantage over linear only regression. This advantage suggested that growth of these traits is curvilinear. The projected growth curves or mean best fitting lines indicated that changes in composition of these bulls were different from those of steers being finished for market.

Walder et al. (1992) looked at the experience of the technician in the use of two different ultrasound machines and their interpretation of the real-time images. They also evaluated the most accurate age at which to obtain estimates of fat thickness and ribeye area from an animal. Brangus bulls from 4 to 24 months of age were scanned by four technicians with various levels of experience in the use of two different real-time, B-mode scanners and each technician read all scan images. Fat thickness scans were found to be most accurate at 16 months of age and was within .33 cm 99% of the time, whereas ribeye area was most accurate at 12 months of age and was within 20.0 cm^2 95% of the time. Operator skill did not enhance the accuracy of fat thickness or ribeye area measurements, but the increased abilities of the scan reader did improve the accuracy of the ribeye area measurements. The accuracy of the two ultrasound scanning units was no different in estimating fat thickness or ribeye area. Therefore, it was concluded that the accuracy of ribeye area scanned at 12 months of age and fat thickness at 12 to 16 months of age was satisfactory to characterize groups of cattle.

Marbling

Ultrasonic determination of marbling has received great interest in recent years, with two clearly different methods currently being engaged. Smith et al. (1990) (1) Quantification of attenuation values obtained with real-time sector scanning and (2) subjective gray scaling of ultrasonic images generated from real-time linear array ultrasound equipment.

Perry et al., (1989) were 80% accurate in distinguishing between USDA Select and Choice carcass quality grades (slight and small marbling degrees) using attenuation values obtained with a sector scanner. The technique is based on the principle that as transmitted sound waves pass through tissue, they are reduced in intensity (Mountford and Wells, 1972). This reduction, referred to as attenuation, is due to reflection, refraction, scattering and absorption of sound in tissue (Hill, 1978).

Brethour (1989) noted similar accuracy (81%) in recognizing steers with or without adequate intramuscular fat to reach the USDA Choice quality grade. These results were acquired using ultrasonic images produced from real-time linear array scans of live cattle. The recorded ultrasound images were visually analyzed and subjectively scored according to the amount of "speckle" present in the gray-scale image.

The Instrument Grading Subcommittee of the National Cattlemen's Association proposed a multi-phase research project for the development of accurate and repeatable means of determining carcass value (Anon. 1990). Research has been conducted with ultrasound to estimate fat thickness and ribeye area of ensanguined cattle prior to hide removal (Recio et al., 1986). These researchers reported correlation coefficients lower than those generally obtained in live cattle (r=.76 and .50 for carcass adjusted fat thickness and ribeye area).

Origin of Error

Due to technological limitations the precision and accuracy of live animal, ultrasonic measurements of carcass parameters are subject to error. Also, technician technique and conformational changes that occur when the animal moves from the standing position while alive or hanging on the rail in carcass form can have an effect.

Current equipment being utilized in animal research was developed to be used for human medical needs and poses some limitations in reference to imaging capabilities in livestock (Cross, 1989). The transducer length is one such limitation because it requires the operator to overlap two images in order to make one complete image of the ribeye muscle (Moore et al., 1985). Lake (1991) efforts were being made by at least one equipment manufacturer to create ultrasound equipment specifically for use in the beef industry. The newest models of the Aloka machines have larger sized scanning head so the entire ribeye can be imaged. There is still research being pursued to employ technology that will allow automation of ribeye calculation and tracing.

Summary

A great deal of literature exist that supports real-time ultrasound use in live cattle if the information was collected by experienced technicians and the measurements correspond with the carcass measurements. With all of the current statistical and ultrasound knowledge the possibilities for improvements in the beef cattle industry is untold. Especially with the installation of ultrasonically measured traits of fat thickness and ribeye area being added to performance records of many beef breeds to be utilized by the producer. Mounting pressures for the installation of value-based marketing has been triggered by the projection that almost all beef will be closely trimmed at the plant within two years. This has brought renewed interest in carcass EPDs. As the industry takes off the outside fat, the demand is on to find a fast, accurate way of measuring differences in cutability, tenderness and palatability. Progeny testing and genetic evaluation of the carcass is very expensive. Changes occur slowly in beef cattle due to their long generation intervals. Most of the comprehensive work with the carcass EPDs has been conducted by the American Angus Association. However, several other breed associations have done similar work. Hopefully, the use of ultrasound technology can help accelerate the process. Wilson (1993) "After four years of research we feel good about measuring external fat cover and ribeye area". One problem being confronted is the ability to measure the difference between percent intramuscular fat in the live animal which may be a more reliable indicator than marbling score. Wilson (1993) stated "One problem with ultrasound on young bulls is their relatively small amount of fat, particularly intramuscular fat, but there are differences". There is still skepticism among producers as to the reliability of this new technology. Therefore, it is important to continue scientific investigations into ultrasound.

CHAPTER III

WEIGHT-BASED ADJUSTMENTS FOR ULTRASONICALLY DERIVED CARCASS TRAITS AMONG PERFORMANCE TESTED BULLS

Abstract

From 1988 to 1989, five breeds of performance tested bulls were evaluated at The Oklahoma Beef Incorporated Central Bull Test Station. The breeds consisted of ten contemporary groups of Angus (n = 535) and five groups each of Brangus (n = 118), Hereford (n = 82), Limousin (n = 59) and Polled Hereford (n = 163). Data collected on 957 post weaning bulls were used to develop prediction equations to estimate final ribeye area and s.c. fat thickness. Following an initial 14-d adjustment period, bulls were serially scanned for ribeye area and backfat thickness and weighed at 28-d intervals during a 112-d performance gain test. An Aloka 210dx real-time ultrasound machine equipped with a 3MHz linear array transducer was used to obtain ribeye area and backfat thickness for each contemporary group. Among individual contemporary group equations, quadratic effects were significant ($P < .05$) for 14 of the 30 backfat thickness and 6 of 30 ribeye area equations;

however, the magnitude of change in ribeye area and backfat thickness was extremely small and was deemed unnecessary for practical application. Weight-based equations accounted for more of the variation in the traits of interest than days-based equations. Results indicate the difficulty of deriving single prediction equations across contemporary groups for s.c. fat thickness and ribeye area even within a single breed of performance tested bulls.

Introduction

As the beef industry progresses into the 90's it will become increasingly important for cattlemen to genetically enhance their product to meet the needs of the consumer. Value based marketing will hopefully become a reality; thus producers who have utilized the tools available to improve their product will be the first to reap any rewards. The beef industry must use accurate predictors of performance and carcass traits. Accurate estimates of these characteristics would allow producers to improve their breeding programs and to market cattle that reach desirable end points in the feedlot, thus improving profitability.

Ultrasound technology is becoming a more useful and accurate tool to provide information relative to carcass traits. Ferguson (1991) indicated that ultrasound measurements, taken by experienced operators, were highly correlated with corresponding carcass measurements and were useful predictors of retail meat yield. Unfortunately, many carcass traits are highly weight dependent and performance tested bulls vary greatly in off-test weight. Therefore, the objective of the current study was to derive prediction equations for backfat thickness and ribeye area using ultrasonic measurements to compare bulls of various breeds at different live weights.

Materials and Methods

Bull Management

Five breeds of performance tested purebred bulls were evaluated from 1988 to 1989 at Oklahoma Beef Incorporated Central Bull Test Station. The breeds consisted of ten contemporary groups of Angus (n = 535), and five groups each of Brangus (n = 118), Hereford (n = 82), Limousin (n = 59), and Polled Hereford (n = 163) as shown in Table 1 by test group. Bulls were placed on a 14-d warm-up period prior to starting the 112-d post weaning gain test and were approximately 12 months of age at completion of test. All bulls were fed a high protein, moderate energy diet with a NEm of 84.53 Mcal/wt and NEg of 52.82 Mcal/wt on a dry matter basis. Bulls were serially scanned and weighed at 28-d intervals from the official start of the gain test to the end of the 112-d official feeding period.

Ultrasound Determination

Bulls were scanned between the twelfth and thirteenth ribs to assess fat thickness and ribeye area (USDA, 1989) using an Aloka 210-dx real time ultrasound machine equipped with a 3 megahertz probe. Scanning site was determined by

Table 1. Number of bulls by breed and test group

Breed	Test group 001	81	82	83	84	85	86	91	92	93	94	95	96	Total
Angus	20	--	--	65	25	53	93	19	--	59	41	74	86	535
Brangus	--	--	10	38	--	--	--	18	19	33	--	--	--	118
Hereford	--	21	29	--	--	--	--	16	10	6	--	--	--	82
Limousin	--	8	6	29	--	--	--	4	--	12	--	--	--	59
Polled Hereford	--	--	15	55	--	--	--	48	13	32	--	--	--	163

physical palpation on the left side of the bull. Mineral oil was used as an acoustical couplant. Ultrasound images were obtained using the double frame display capabilities of the equipment and a transducer guide was utilized to minimize error that may occur due to animal backline curvature and the overlapping step. The image of the medial portion of the muscle was recorded on video tape first. Then, the transducer was moved ventrally and the lateral portion was recorded. The resulting ultrasound image was later viewed on a 30 cm display monitor to determine longissimus muscle area estimates. Ribeye area was interpreted by tracing the configuration of the longissimus muscle on clear plastic sheeting. Area was determined from tracings using an dot grid. Fat thickness was determined at the time of scanning by utilizing the machine's internal electronic calipers.

Statistical Analyses

First and second order polynomials were used to derive days- and weight-based prediction equations for s.c. fat thickness and ribeye area. Analyses revealed that weight-based equations accounted for more of the variation in the traits of interest than days-based equations. Therefore, days-based equations were dropped from subsequent analyses. All test groups were pooled within their respective breeds to derive individual breed linear and quadratic weight-based equations for s.c. fat thickness and ribeye area predictions. The quadratic term for weight was significant

(P < .05) for 14 of the 30 test groups for fat thickness and 6 of the 30 test groups for ribeye area. Upon plotting both the linear and quadratic equations for the groups, it was apparent that the linear equations more practically fit our needs over the 112-d period. Tatum et al. (1986) observed similar results of absolute growth being linear during 140-d finishing periods for steers. Turner et al.(1990) reported that ultrasound ribeye area measurements should be adjusted for the linear effects of age and live weight.

Differences in predicted versus actual fat thickness and ribeye area measurements were analyzed across test groups within breeds. Significant test group deviations (F-tests) made it necessary to merge similar test groups to derive additional equations to compensate for over or under estimation of ribeye area and s.c. fat thickness by the pooled equations within breeds. A general linear models procedure was used (SAS, 1985) to determine test group deviations.

A dummy variable regression technique (Weisberg, 1980), sometimes referenced as Analysis of Covariance, was used to determine differences between individual equations for slope and intercept using weight as the covariant among groups. The linear equations developed for s.c. fat thickness and ribeye area were as follows:

$$Y_{ij} = \hat{B}_{0ij} + (B_{1ij} * \text{Live Weight, kg})$$

where

Y_{ij} = s.c. fat thickness or ribeye area, $B0_{ij}$ = intercept, $B1_{ij}$ = slope, i = i^{th} breed, and j = j^{th} test group.

The equations were solved for three separate live weights (499, 544, and 590 kg) to assess s.c. fat thickness and ribeye area differences at those weights. Differences among means at the three weight end points were tested using a standard normal Z-test (Steel and Torrie, 1980). Results were analyzed to determine how much change in live weight would be required to alter s.c. fat thickness by 2.5 mm and ribeye area by 6.45 sq. cm.

Results

Breed means and standard deviations, minimums, and maximums for live weight, fat thickness, and ribeye area at 112-d are reported in Table 2. As expected, among performance tested bulls, fat thickness was the least variable trait; ribeye area varied from 70 to 139 sq cm. Of the bulls tested, Brangus tended to be the lightest in weight while Limousin tended to be the trimmest and most muscular. Arnold et al. (1991) indicated that carcass fat on slaughter steers and ultrasound measures of backfat on young breeding animals may have different relationships with growth and muscling. They suggested these relationships needed to be explored before wide scale selection based on ultrasound is implemented.

Table 2. Means and standard deviations for traits of interest[a]

Breed	Mean	SD	Minimum	Maximum
		Live wt, kg		
Angus	557.5	± 47.6	433.2	703.1
Brangus	501.2	± 42.8	425.9	581.1
Hereford	535.2	± 51.8	430.5	662.7
Limousin	562.5	± 54.1	410.0	670.4
Polled Hereford	576.5	± 52.9	449.1	737.5
		Fat thickness, mm		
Angus	10.7	± 2.54	5.08	17.3
Brangus	7.6	± 1.77	5.08	11.2
Hereford	10.7	± 2.29	5.08	19.3
Limousin	6.9	± 2.03	3.05	12.2
Polled Hereford	11.2	± 3.30	4.06	18.3
		Ribeye area, sq cm		
Angus	103.2	± 11.6	70.3	134.2
Brangus	89.0	± 7.1	71.6	101.9
Hereford	96.1	± 8.6	73.5	116.1
Limousin	120.6	± 9.2	98.1	139.4
Polled Hereford	103.2	± 8.1	76.8	127.7

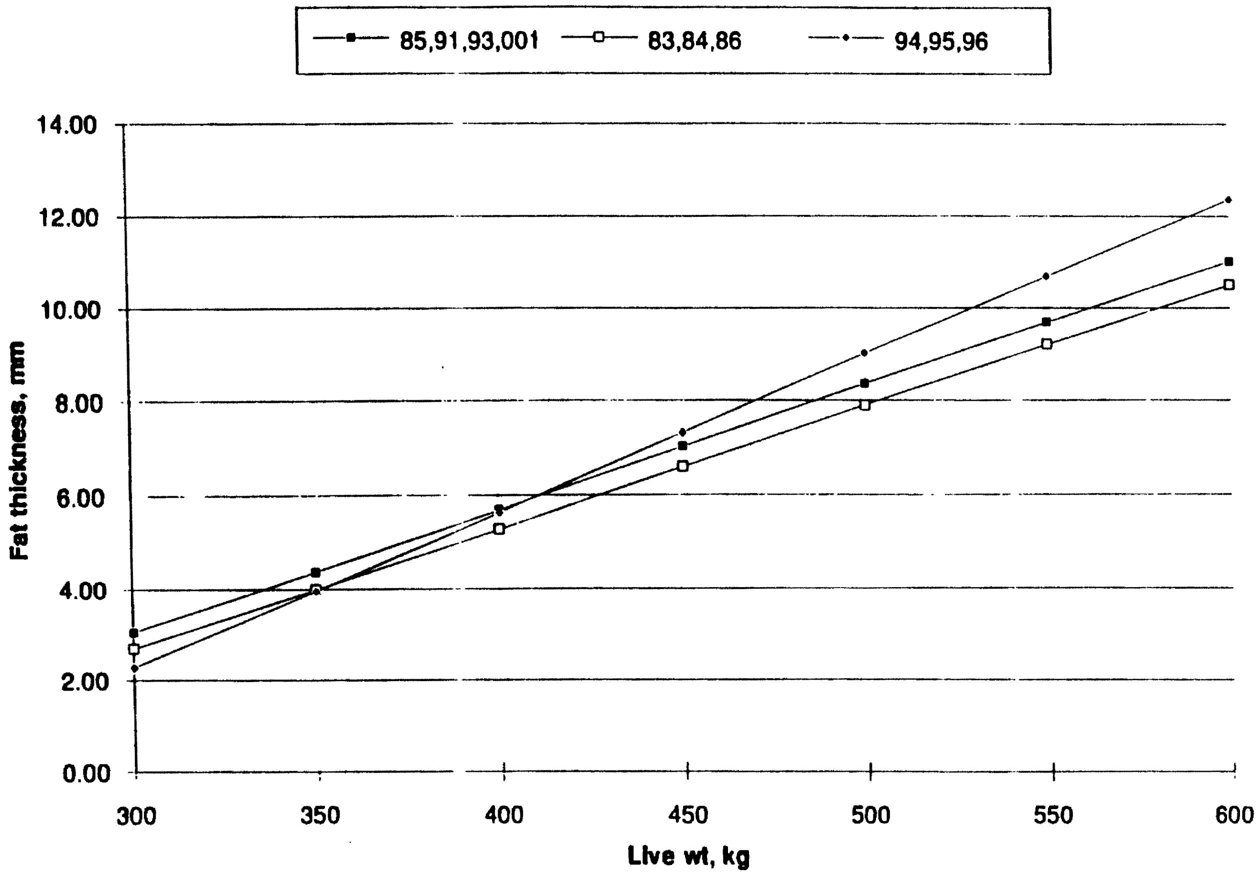
[a] Day 112 of performance test.

Fat Thickness

The pooled fat thickness equation for the 10 contemporary groups of Angus bulls resulted in significant ($P < .05$) test group deviations for predicted versus actual fat thickness. Upon closer observation, the pooled equation was either over or under estimating several of the test groups for fat thickness. Therefore, it was deemed necessary to develop two additional equations to account for these deviations. The three equations providing the best fit for s.c. fat thickness are shown in Figure 1. These three equations accounted for 60, 66, and 73% of the variation in s.c. fat thickness. Dummy variable regression analysis revealed that equation A3 differed ($P < .05$) from the other two equations for both intercept and slope. No differences ($P > .05$) were noted in intercepts and slopes between equations A1 and A2. However, when testing whether the slopes and intercepts were jointly different using a reduced F-test, the lines were judged to be significantly different.

The pooled fat thickness equation for the five contemporary groups among Brangus, Hereford and Limousin bulls resulted in non significant ($P > .05$) test group deviations for predicted versus actual fat thickness. The pooled equation was not over or under estimating the fat thickness for the respective test groups within these three breeds. Therefore, it was deemed appropriate to use the pooled equation within each of these breeds to get the best

Figure 1. Angus fat thickness across live weight



Equation (Grp)	b_0	b_1	R^2	RSD
A1 (85,91,93,001)	-4.92^a	0.026^b	.60	2.16
A2 (83,84,86)	-5.12^a	0.026^b	.66	1.74
A3 (94,95,96)	-7.82^b	0.034^a	.73	2.06

a,b = Intercepts and slopes that do not have a common superscript letter are different ($P < .05$)

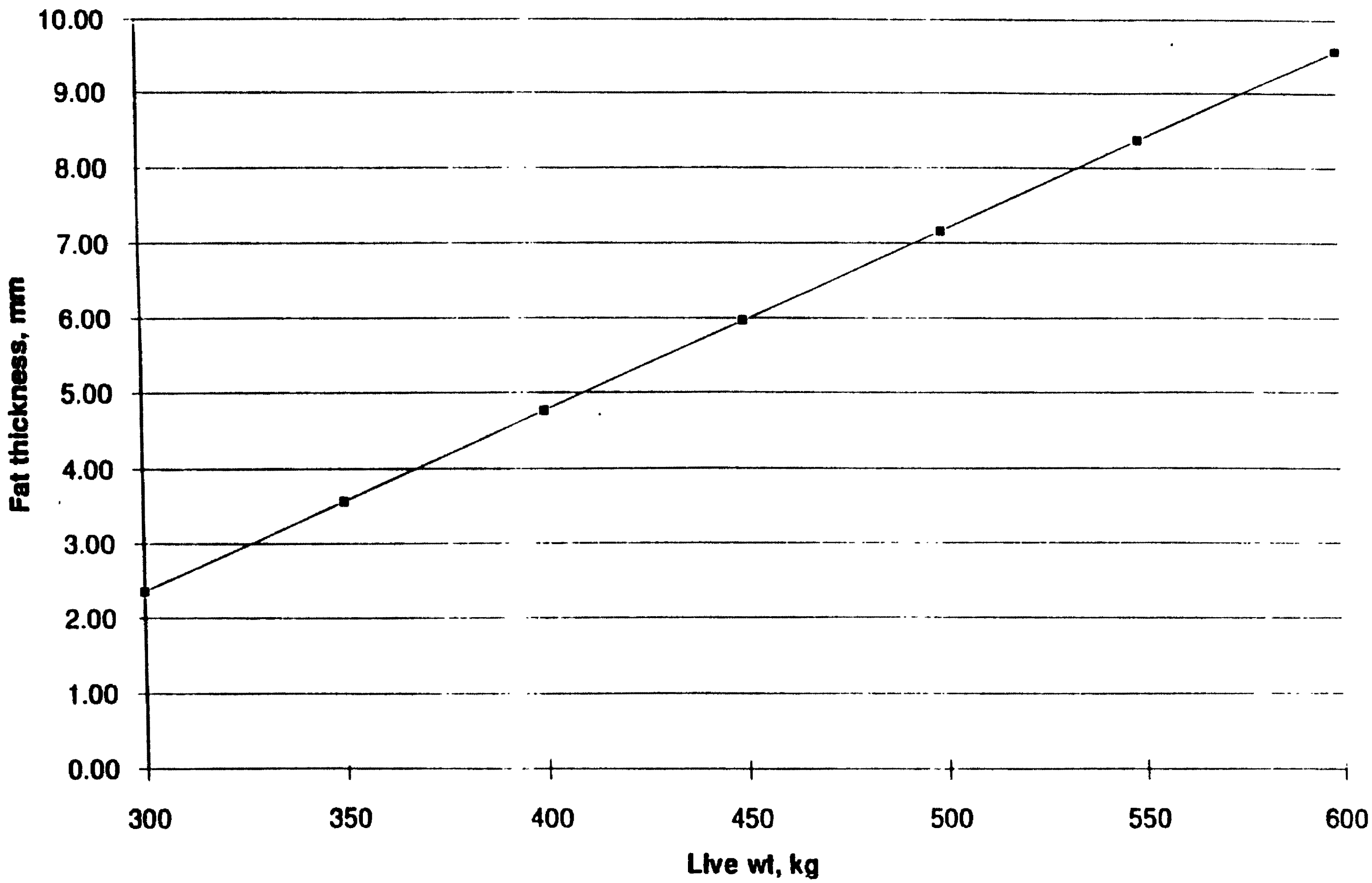
fit for s.c. fat thickness as shown in Figures 2, 3, and 4. These three equations accounted for 62, 60, and 50% of the variation in s.c. fat thickness for Brangus, Hereford and Limousin bulls, respectively.

The pooled fat thickness equation for the five contemporary groups of Polled Hereford bulls resulted in significant ($P < .05$) test group deviations for predicted versus actual fat thickness. Upon closer interpertation, the pooled equation fit four of the five groups. Thus, we chose to eliminate the pooled equation and use the equation derived for test groups 82, 83, 91, and 92. And a separate equation for group 93. Giving us two equations to account for deviations. The two equations providing the best fit for s.c. fat thickness are shown in Figure 5. These two equations accounted for 60 and 67% of the variation in s.c. fat thickness. Dummy regression showed no differences ($P > .05$) in intercepts and slopes between equations P1 and P2. However, when testing whether the slopes and intercepts were jointly different using a reduced F-test, the lines were judged to be significantly different.

<u>Ribeye Area</u>

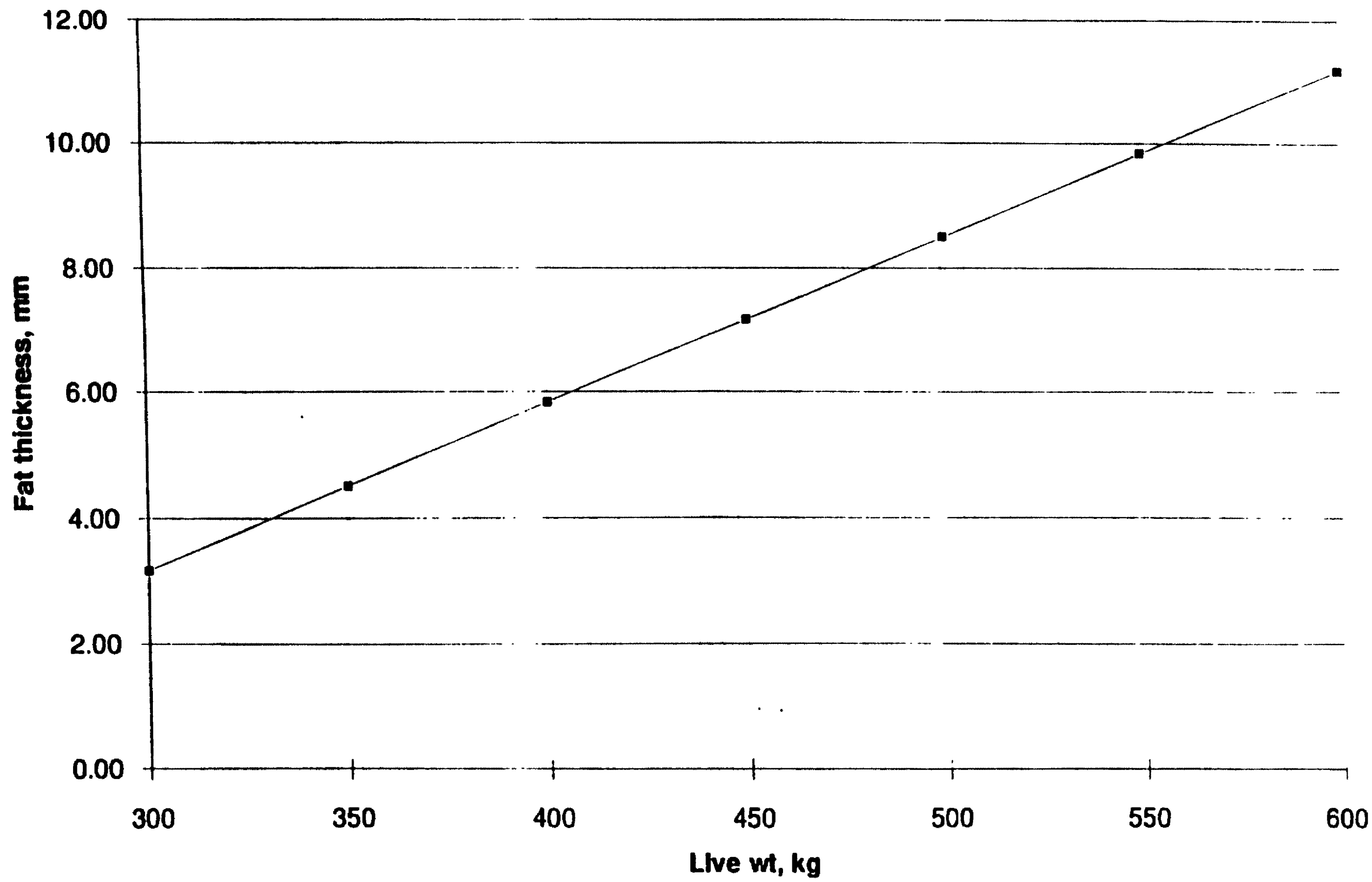
The pooled ribeye area equation for the 10 contemporary groups of Angus bulls resulted in significant ($P < .05$) test group deviations for predicted versus actual ribeye area. The pooled equation either over or under estimated several of the test groups for ribeye area. Therefore, two additional equations were developed to

Figure 2. Brangus fat thickness across live weight



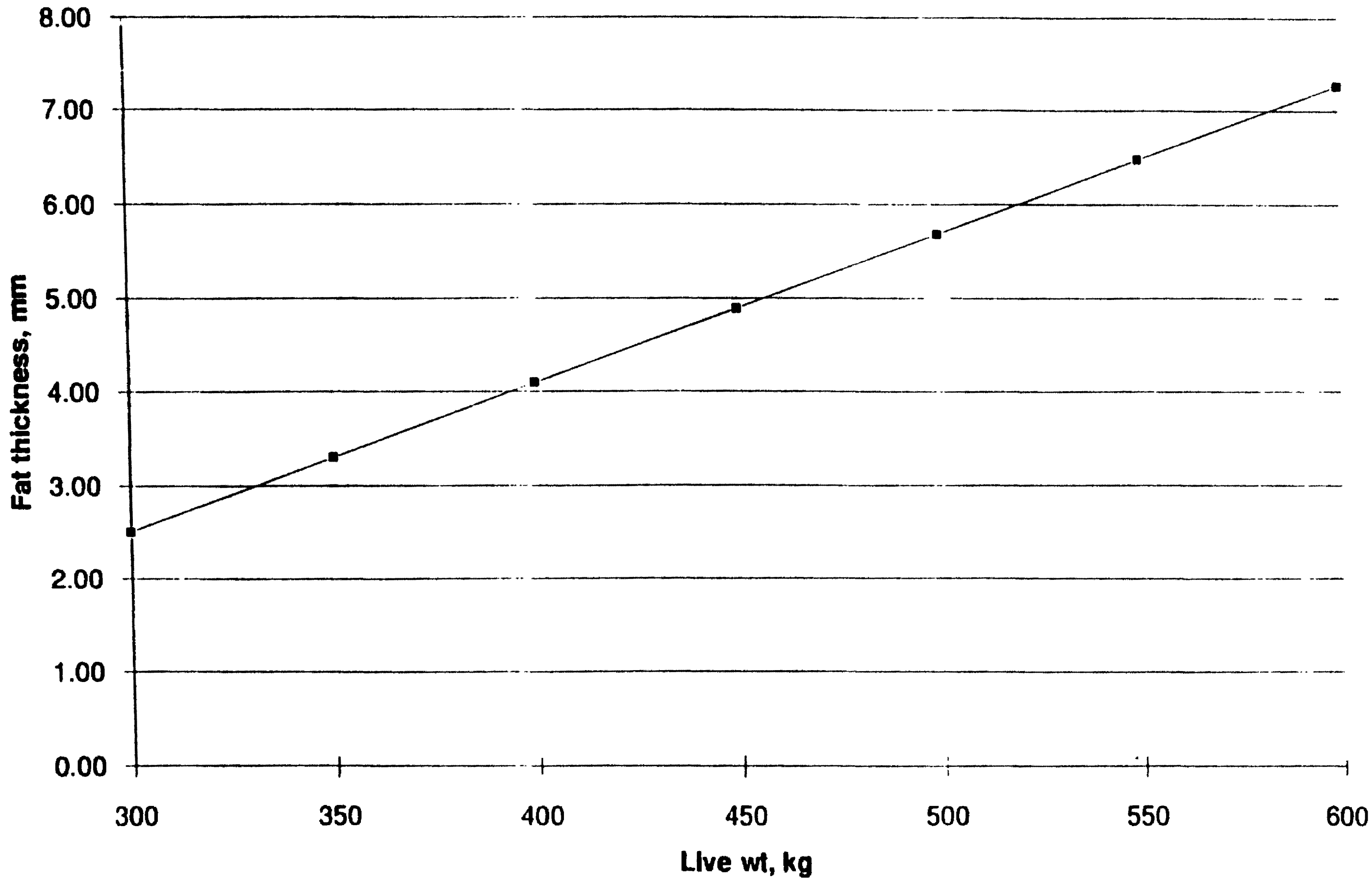
Groups	b_0	b_1	R^2	RSD
pooled	-4.86	0.024	.62	1.74

Figure 3. Hereford fat thickness across live weight



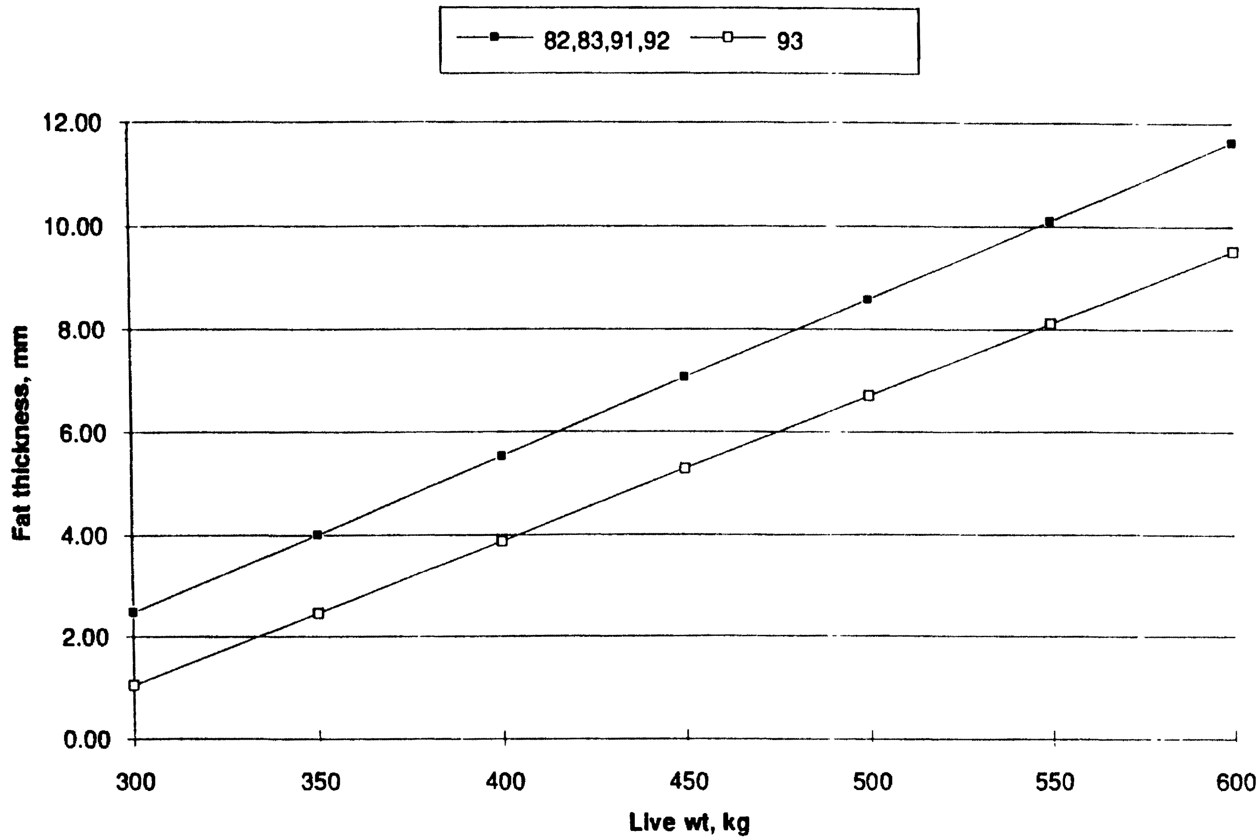
Groups	b_0	b_1	R^2	RSD
pooled	-4.83	0.027	.60	2.00

Figure 4. Limousin fat thickness across live weight



Groups	b_0	b_1	R^2	RSD
pooled	-2.25	0.016	.50	1.50

Figure 5. Polled Hereford fat thickness across live weight

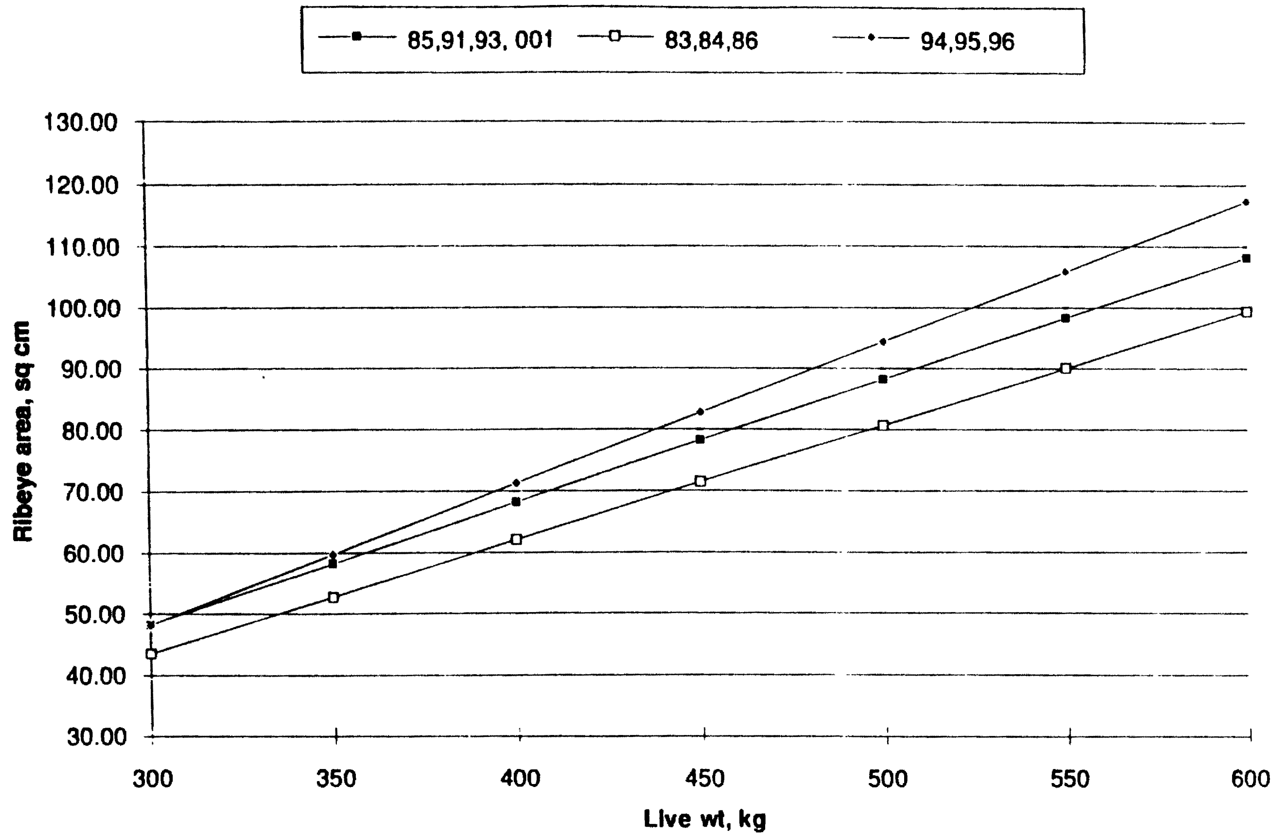


Equation (Grp)	b_0	b_1	R^2	RSD
P1 (82,83,91,92)	-6.67[a]	0.031[a]	.60	2.34
P2 (93)	-7.43[a]	0.028[a]	.67	1.90

a = Intercepts and slopes were not different (P > .05) account for these deviations. The three equations providing the best fit for ribeye area are shown in Figure 6. These three equations accounted for 80, 75, and 85% of the variation in ribeye area. Dummy variable regression analyses revealed signigicant differences (P < .05) between all three equations for slope, however, the only difference noted in intercept was that A3 was lower (P < .05) than either A1 or A2.

The pooled ribeye area equation for the five contemporary groups of Brangus and Hereford bulls resulted in significant (P < .05) test group deviations for predicted versus actual ribeye area. After closer observation, the pooled equation was found to be over and under estimating some of the test groups for ribeye area. Therefore, three additional equations had to be developed for each breed to account for these deviations. After developing these equations and plotting them, the pooled equation was observed to be very closely related to equation B2 in Brangus and equation H3 in Hereford. Therefore, the pooled equation was dropped. The three equations providing the best fit for ribeye area are shown in Figures 7 and 8. These three equations accounted for 78, 78, and 81% and 66, 73, and 84% of the variation in ribeye area among Brangus and Hereford bulls, respectively. Dummy variable regression on Brangus equations revealed no differences (P > .05) in slopes among the three equations, but equation B1 differed (P < .05) from B2 and B3 in intercepts. Despite similarities in intercepts and slopes

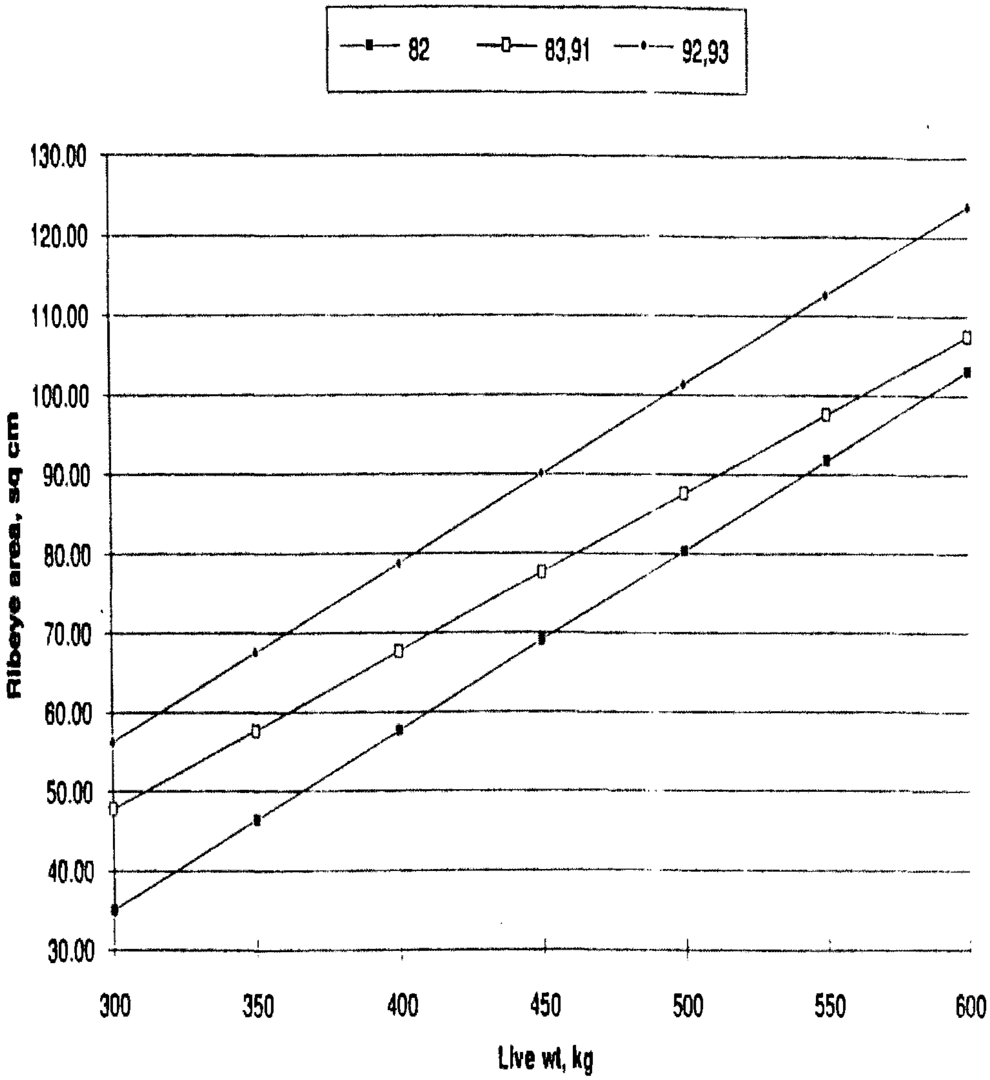
Figure 6. Angus ribeye area across live weight



Equation (Grp)	b_0	b_1	R^2	RSD
A1 (85,91,93,001)	-11.79^a	0.200^b	.80	10.00
A2 (83,84,86)	-12.37^a	0.186^c	.75	9.97
A3 (94,95,96)	-20.97^b	0.231^a	.85	9.36

a,b,c = Intercepts and slopes that do not have a common superscript letter are different ($P < .05$)

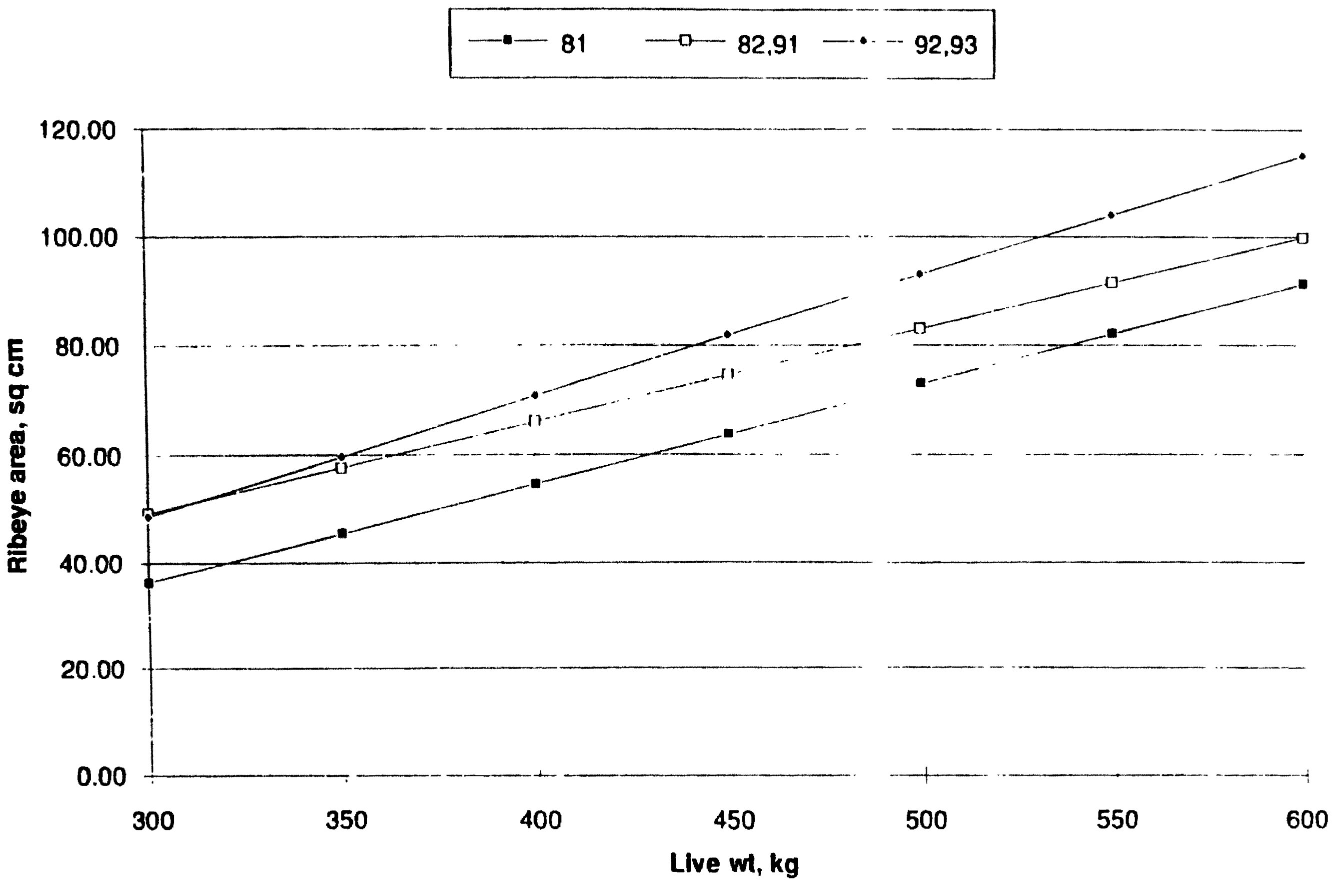
Figure 7. Brangus ribeye area across live weight



Equation (Grp)	b_0	b_1	R^2	RSD
B1 (82)	-33.05^{b}	0.227^{a}	.78	10.20
B2 (83,91)	-11.99^{a}	0.199^{a}	.78	10.11
B3 (92,93)	-11.31^{a}	0.225^{a}	.81	10.10

a,b = Intercepts and slopes that do not have a common superscript letter are different ($P < .05$)

Figure 8. Hereford ribeye area across live weight



Equation (Grp)	b_0	b_1	R^2	RSD
H1 (81)	-18.65^{b}	0.183^{ab}	.66	11.41
H2 (82,91)	-1.43^{a}	0.169^{b}	.73	9.00
H3 (92,93)	-17.96^{b}	0.221^{a}	.84	9.17

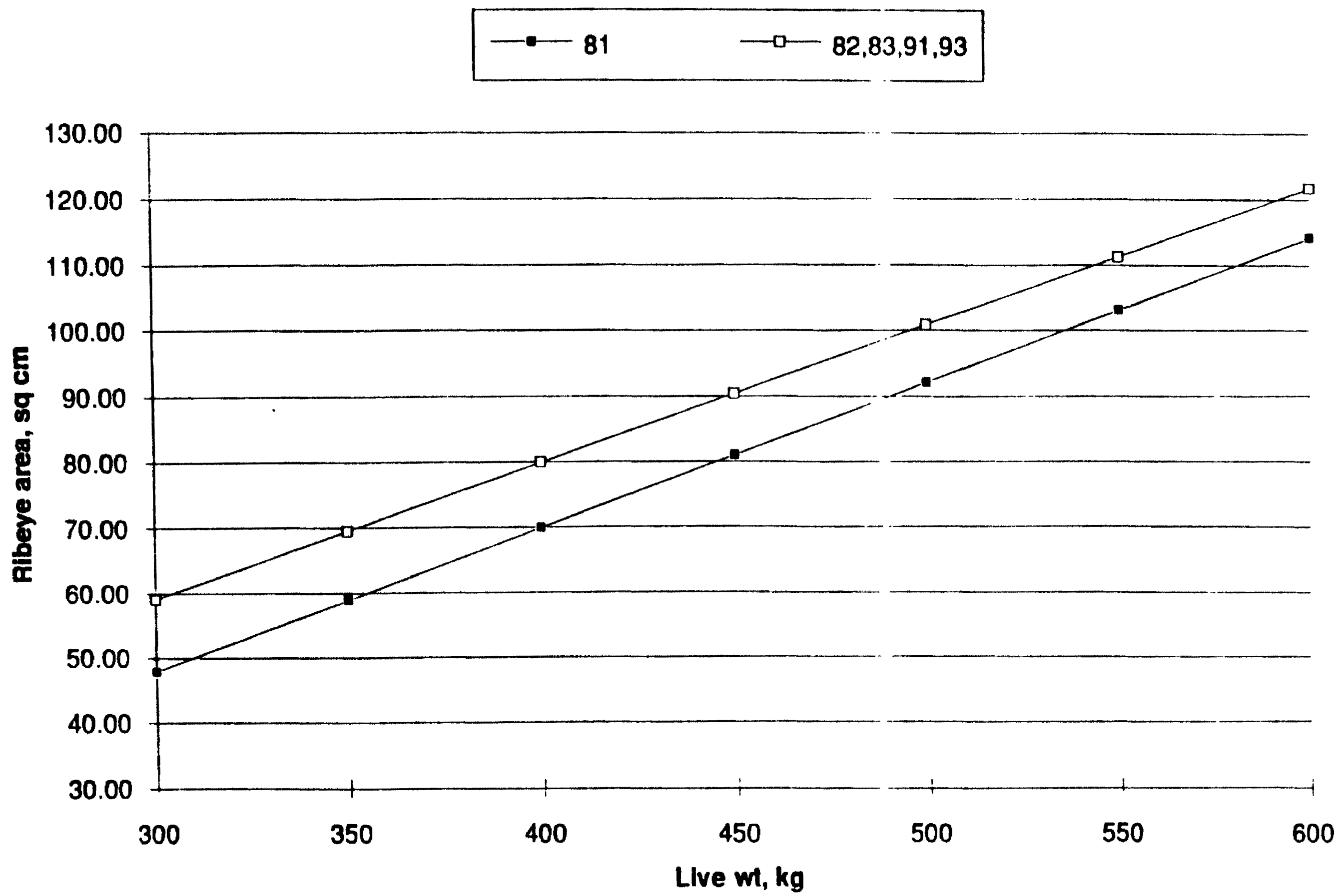
a,b = Intercepts and slopes that do not have a common superscript letter are different ($P < .05$)

between B2 and B3, their overall lines differed ($P < .05$). Among the Hereford bulls tested, equation H2 had the highest ($P < .05$) intercept and a slower rate of change than equation H3. Equations H1 and H3 were similar ($P > .05$) in intercepts and slopes. However, when testing whether the slopes and intercepts were jointly different using a reduced F-test, the lines were judged to be significantly different.

The pooled ribeye area equation for the five contemporary groups of Limousin bulls resulted in significant ($P < .05$) test group deviations for predicted versus actual ribeye area. The pooled equation was over or under estimating some of the test groups. Therefore, two additional equations were developed to account for these deviations. After developing these equations and plotting them, the pooled equation was very closely related to equation L2. Therefore, the pooled equation was eliminated. The two equations used to provide the best fit for ribeye area are shown in Figure 9. These two equations accounted for 64 and 78% of the variation in ribeye area. Equations L1 and L2 were similar ($P > .05$) in intercepts and slopes. However, when testing whether the slopes and intercepts were jointly different using a reduced F-test, the lines were judged to be significantly different.

The pooled ribeye area equation for the five contemporary groups of Polled Hereford bulls resulted in significant ($P < .05$) test group deviations for predicted versus actual ribeye area. After closer observation, the

Figure 9. Limousin ribeye area across live weight



Equation (Grp)	b_0	b_1	R^2	RSD
L1 (81)	-18.46[a]	0.221[a]	.64	15.10
L2 (82,83,91,93)	-3.66[a]	0.209[a]	.78	10.42

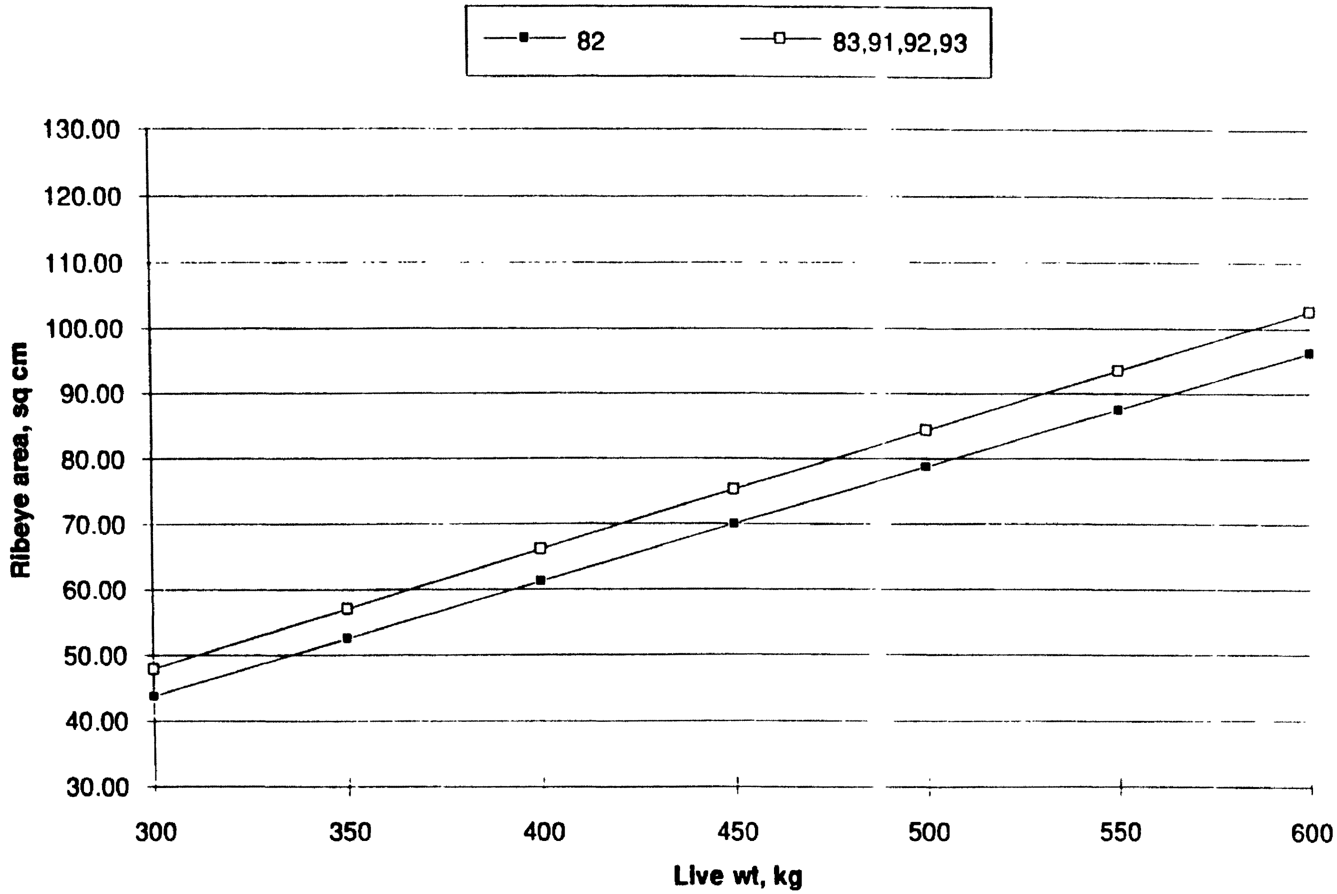
a = Intercepts and slopes were not different ($P > .05$)

pooled equation was found to be over or under estimating some of the test groups for ribeye area. Therefore, two additional equations were developed. After developing these equations and plotting them, the pooled equation was very closely related to equation P2. Therefore, the pooled equation was eliminated. The two equations used to get the best fit are shown in Figure 10. These two equations accounted for 69 and 78% of the variation in ribeye area. Dummy variable regression showed no differences ($P > .05$) for intercepts or slopes for equations P1 and P2. However, when testing whether the slopes and intercepts were jointly different using a reduced F-test, the lines were judged to be significantly different.

The 8 s.c. fat thickness and 13 ribeye area weight-based equations for the five breeds of bulls are plotted in Figures 11 and 12, respectively. The corresponding means for s.c. fat thickness and ribeye area computed at 499, 544 and 590 kg of live weight are reported in Table 3. Pairwise comparisons were made between means within each weight category to assess significance. Results indicate substantial overlap both between and within breeds in both s.c. fat thickness and ribeye area.

Among Angus bulls tested, a 45 kg change in live weight altered s.c. fat thickness approximately 1.3mm (1.2, 1.2, and 1.5 mm for equations A1, A2, A3 respectively). Brangus, Hereford and Limousin bulls tested had a change in s.c. fat thickness of approximately 1.1, 1.2, and .7mm for a 45 kg change in live weight. Among the Polled Hereford

Figure 10. Polled Hereford ribeye area across live weight



Equation (Grp)	b_0	b_1	R^2	RSD
P1 (82)	-8.79[a]	0.175[a]	.69	11.00
P2 (83,91,92,93)	-6.85[a]	0.182[a]	.78	9.15

a = Intercepts and slopes were not different (P > .05)

Figure 11. Fat thickness for breeds across live weight

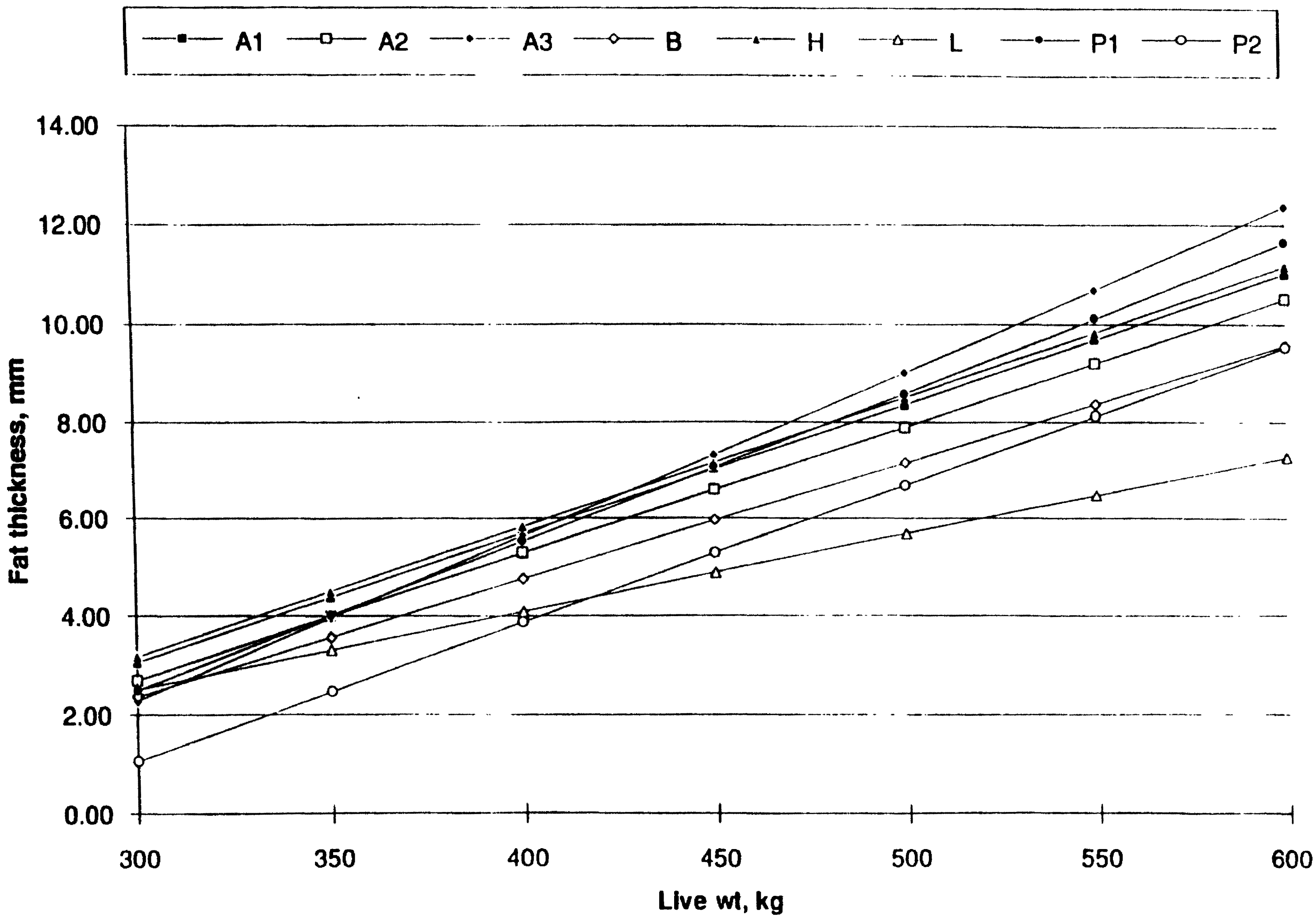


Figure 12. Ribeye area for breeds across live weight

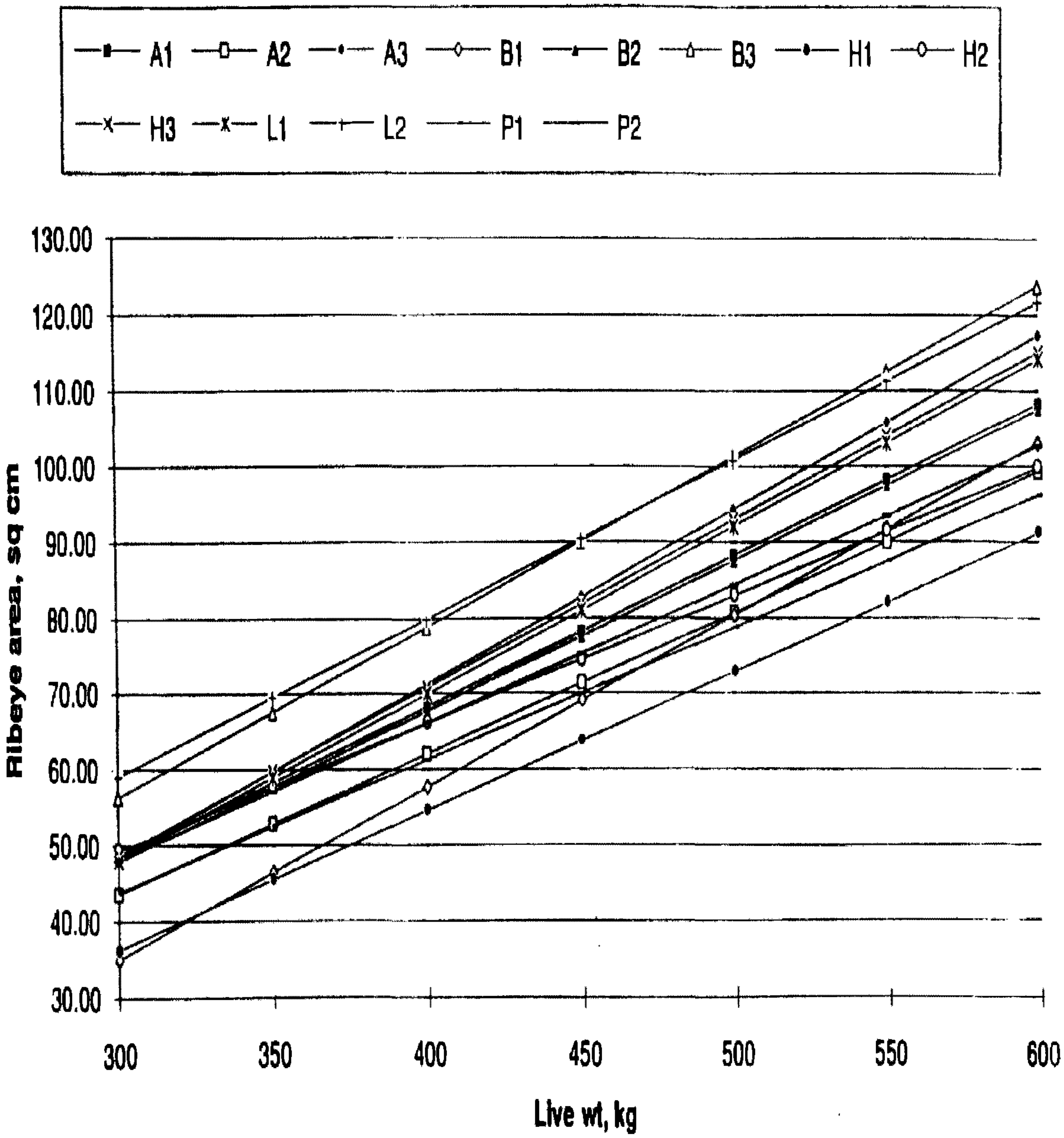


Table 3. Fat thickness and ribeye area for breeds estimated at three live weights

	Live wt, kg		
Breed	499	544	590
		Fat thickness, mm	
Angus[a]			
eq.1	8.05[h]	9.22[i]	10.42[i]
eq.2	7.85[i]	9.02[j]	10.22[j]
eq.3	9.15[g]	10.68[g]	12.24[g]
Brangus	7.12[j]	8.20[k]	9.30[k]
Hereford	8.64[h]	9.86[i]	11.10[i]
Limousin	5.73[l]	6.45[l]	7.19[l]
Polled Hereford[b]			
eq.1	8.80[h]	10.19[h]	11.62[h]
eq.2	6.54[k]	7.80[k]	9.09[k]
		Ribeye area, sq cm	
Angus[a]			
eq.1	88.01[i]	97.01[i]	106.21[ij]
eq.2	80.44[k]	88.81[kl]	97.37[l]
eq.3	94.30[h]	104.69[h]	115.32[h]
Brangus[c]			
eq.1	80.22[k]	90.44[jkl]	100.88[jk]
eq.2	87.31[i]	96.27[i]	105.42[ij]
eq.3	100.97[g]	111.09[g]	121.44[g]
Hereford[d]			
eq.1	72.67[l]	80.90[m]	89.32[m]
eq.2	82.90[j]	90.51[jk]	98.28[kl]
eq.3	92.32[h]	102.26[h]	112.43[h]
Limousin[e]			
eq.1	91.82[hi]	101.76[hi]	111.93[hi]
eq.2	100.63[g]	110.04[g]	119.65[g]
Polled Hereford[f]			
eq.1	78.54[k]	86.41[kl]	94.46[lm]
eq.2	83.97[j]	92.16[j]	100.53[k]

[a] eq.1 = test groups 85,91,93,001; eq.2 = test groups 83,84,86; eq.3 = test groups 94,95,96.
[b] eq.1 = test groups 82,83,91,92; eq.2 = test group 93.
[c] eq.1 = test group 82; eq.2 = test groups 83,91; eq.3 = test groups 92,93.
[d] eq.1 = test group 81; eq.2 = test groups 82,91; eq.3 = test groups 92,93.
[e] eq.1 = test group 81; eq.2 = test groups 82,83,91,93.
[f] eq.1 = test group 82; eq.2 = test groups 83,91,92,93.
g,h,i,j,k,l,m = Means with differing superscripts in same column differ ($P < .05$)

bulls rested, a 45 Kg change in live weight altered s.c. fat thickness approximately 1.4 mm (1.4mm and 1.3mm for equations P1 and P2 respectively) as reported in Table 3.

Among Angus bulls tested, a 45 kg change in live weight altered ribeye area approximately 9.4 sq cm (9.1, 8.5, and 10.5 sq cm for equations A1, A2, and A3, respectively). Of the Brangus and Hereford bulls tested, a 45 kg change in live weight altered ribeye area approximately 9.9 sq cm for Brangus (10.3, 9.1, and 10.2 sq cm) and 8.7 sq cm for Hereford (8.3, 7.7, and 10.1 sq cm). Among the Limousin bulls tested, a 45 kg change in live weight altered ribeye area approximatley 9.8 sq cm (10.1 and 9.5 sq cm for equations L1 and L2). Of the Polled hereford bulls tested, a 45 kg change in live weight altered ribeye area approximately 8.2 sq cm (8.0 and 8.3 sq cm for equations P1 and P2, respectively) as reported in Table 3.

Discussion

Using ultrasound equipment as an evaluation tool of live cattle began in 1956 (Temple, 1956). The early development and techniques used to estimate fat thickness and ribeye area have been greatly improved over the last thirty-seven years. Gillis et al. (1973) compared B-mode to A-mode and found that B-mode had greater accuracy when compared to actual carcass data than did A-mode. The early correlations between actual fat thickness and ribeye area to the scanned data showed a r = .67 to .80 for fat thickness and r = .17 to .80 for ribeye area. Turner et al. (1989) showed these correlations to be higher. Ribeye area r = .71 to .94 and r = .81 to .94 for fat thickness. This shows the improvement over time that has occurred.

In this study, we found similarities with Duello et. al (1993) in that the British breeds of cattle seemed to be the fattest. Also, the equations for the traits of interest fat for thickness (R^2 = .69) and ribeye area (R^2 = .80) in our study using linear weight-based equations for Angus cattle were accounting for a greater percentage of the variation than were the age-based equations reported by Duello et. al (1993).

In beef cattle production, most believe that ultrasonic estimates for fat thickness are more accurate than ribeye area measurements. Most generally, fat thickness is underestimated while ribeye area is overestimated. There are still doubts of how accurate ultrasound measurements are, but with the advances in technology and the advanced training and experience of technicians ultrasound is becoming a reliable tool for the Beef Cattle Industry. Knowing live weight, fat thickness, and ribeye area of a performance tested bull is very useful to the producer because it allows him to make genetic improvements in his herd. This intern generates more revenue in his operation because he can sell his cattle at a premium.

Conclusion

Among performance tested bulls, weight-based equations accounted for more of the variation in s.c. fat thickness and ribeye area than days-based equations. Single prediction equations for s.c. fat thickness were appropriate for Brangus, Hereford and Limousin bulls. However, it was necessary to use 3 equations for Angus bulls and 2 equations for Polled Hereford bulls to best explain s.c. fat thickness. Ribeye area estimates were even more variable in that two or more equations had to be used for each breed group to best explain changes over live weight. These results indicate that the difficulty in using single equations derived via ultrasound to predict fat thickness and ribeye between different breeds of bulls as well as between different contemporary groups of bulls within a breed.

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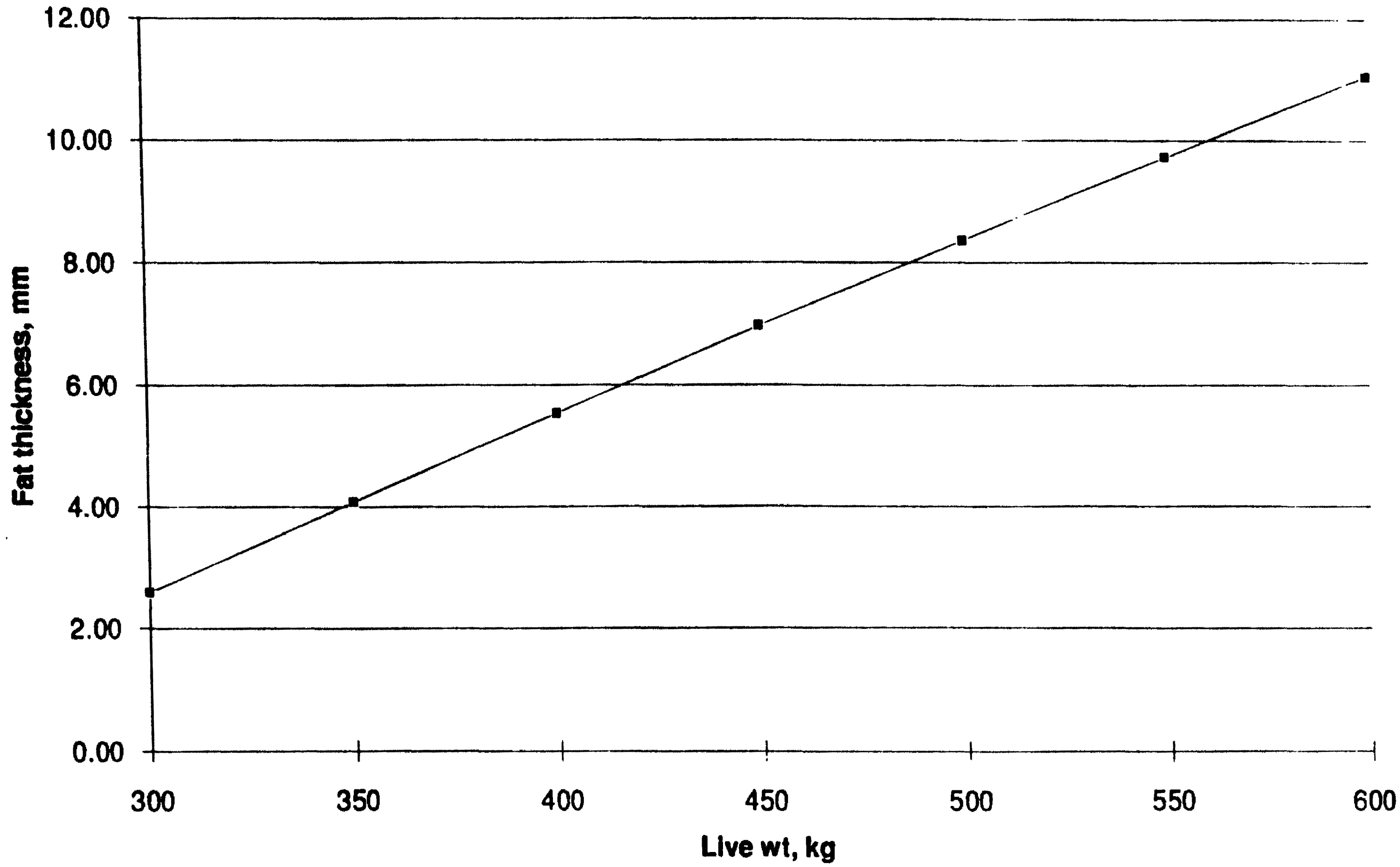
APPENDIX

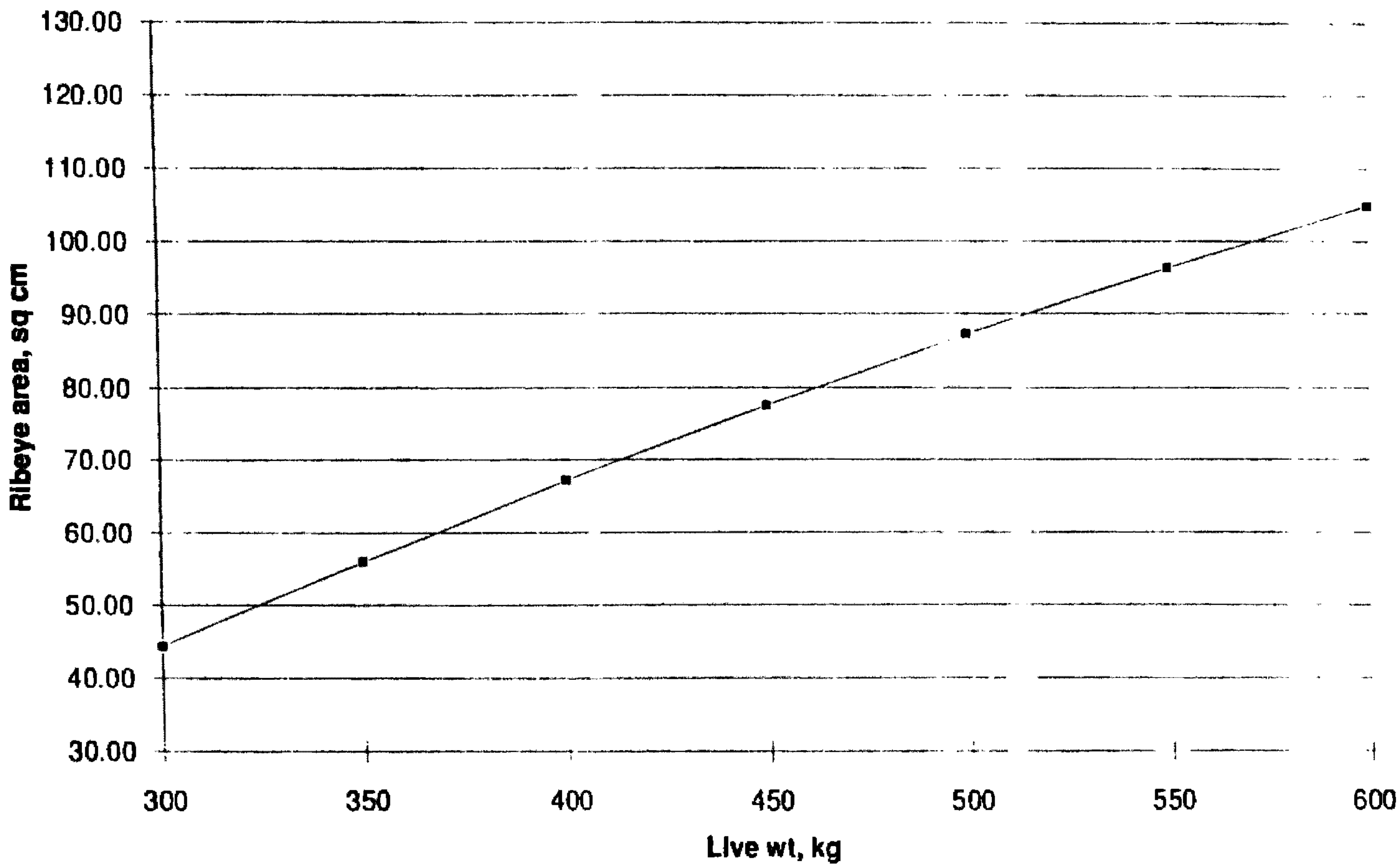
QUADRATIC WEIGHT-BASED ADJUSTMENT EQUATIONS

Figure 1a. Angus quadratic fat thickness across live weight



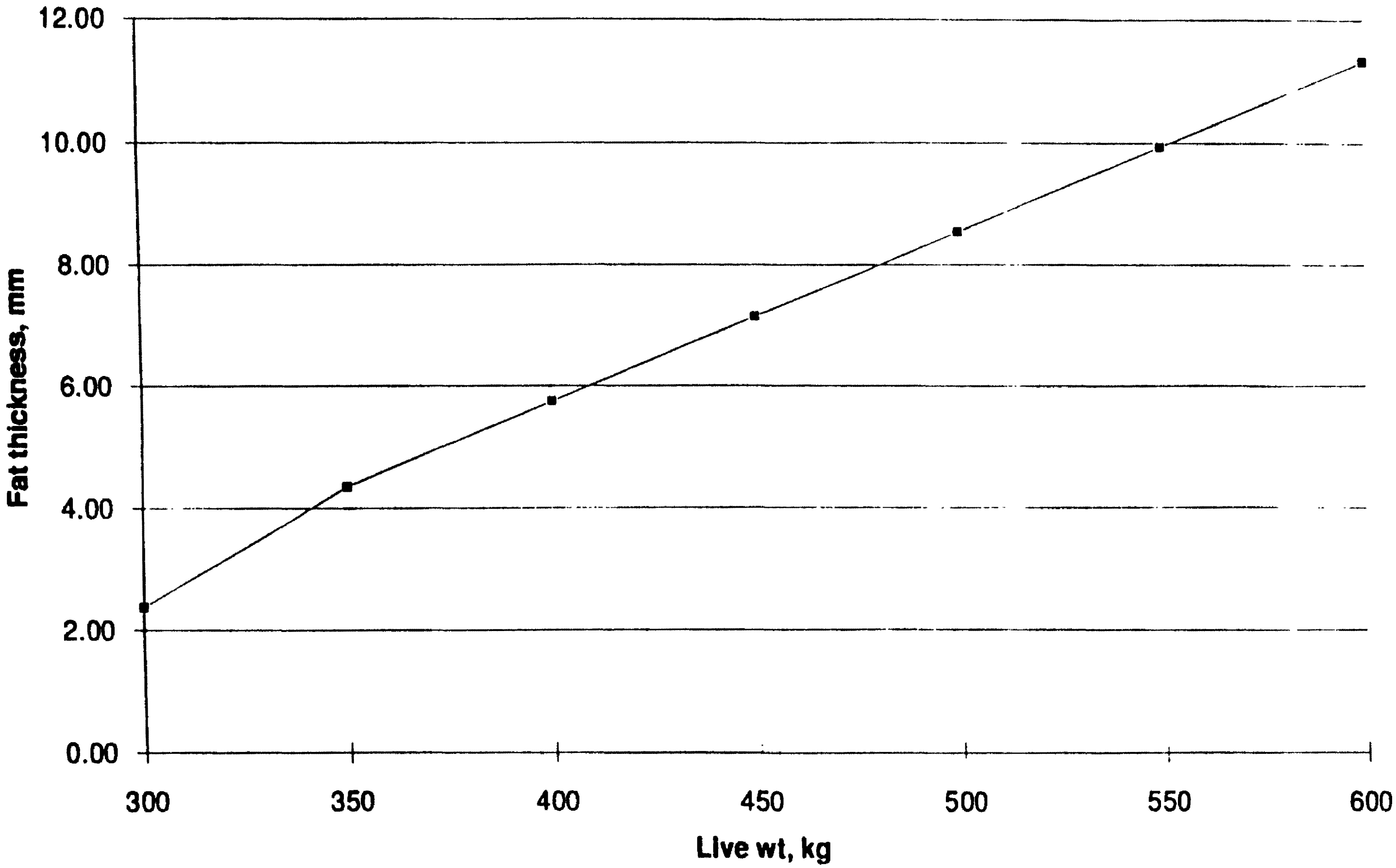
b_0	b_1	b_2	R^2	RSD
-7.06	0.034	-0.0007	.62	2.10

Figure 2a. Angus quadratic ribeye area across live weight



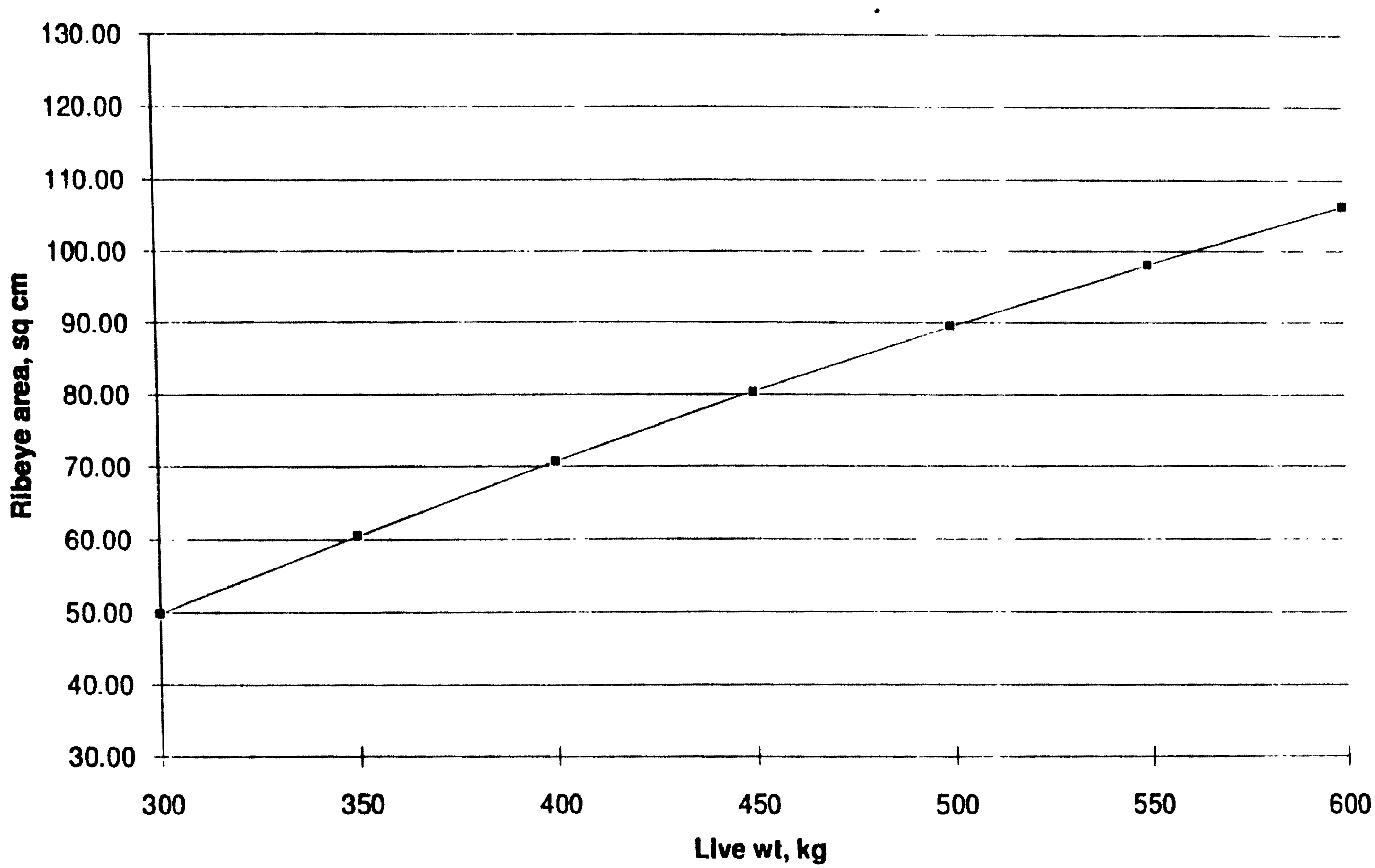
b_0	b_1	b_2	R^2	RSD
-39.57	0.319	-0.0001	.70	12.50

Figure 3a. Brangus quadratic fat thickness across live weight



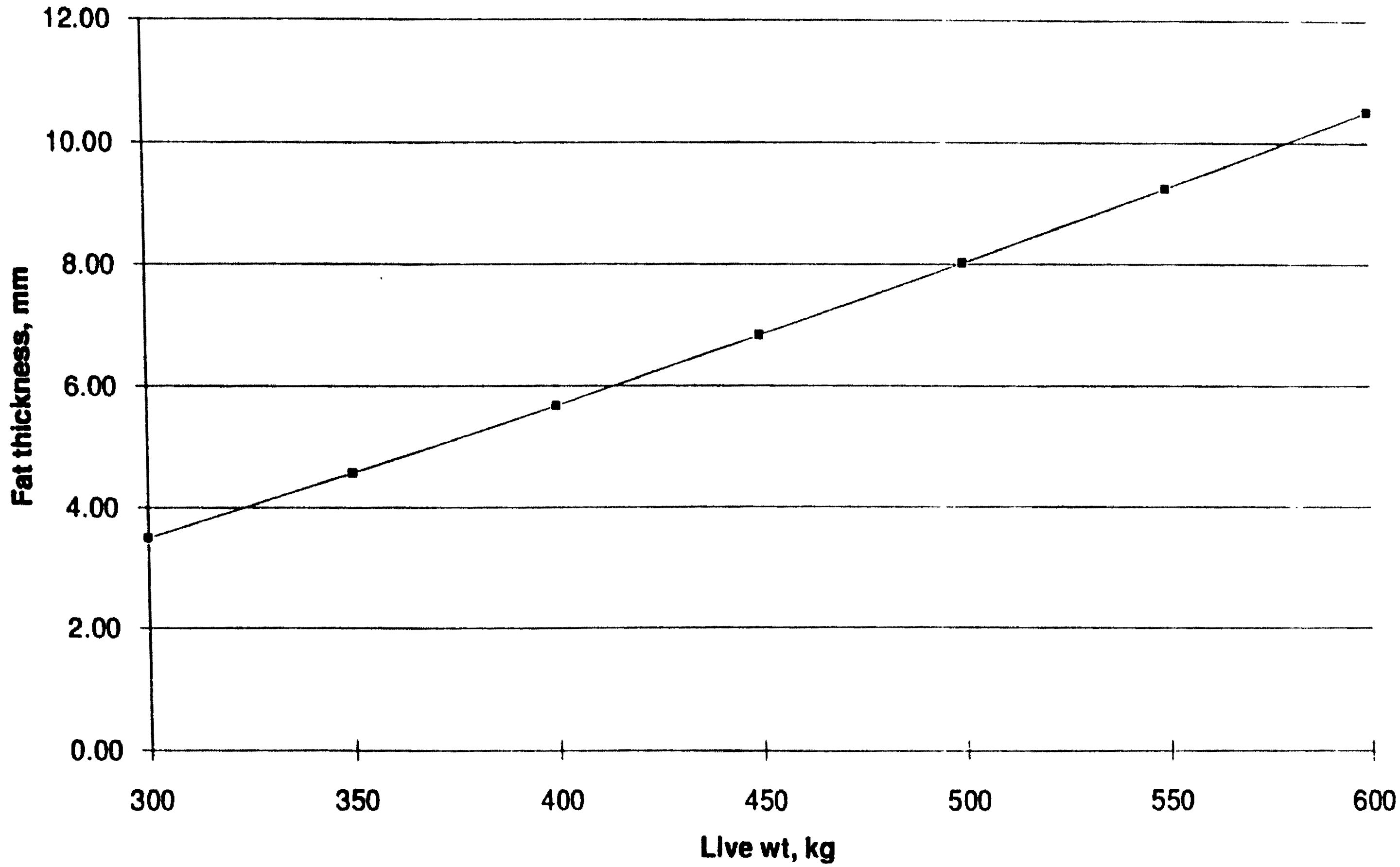
b_0	b_1	b_2	R^2	RSD
-5.42	0.028	-0.0006	.49	2.10

Figure 4a. Brangus quadratic ribeye area across live weight



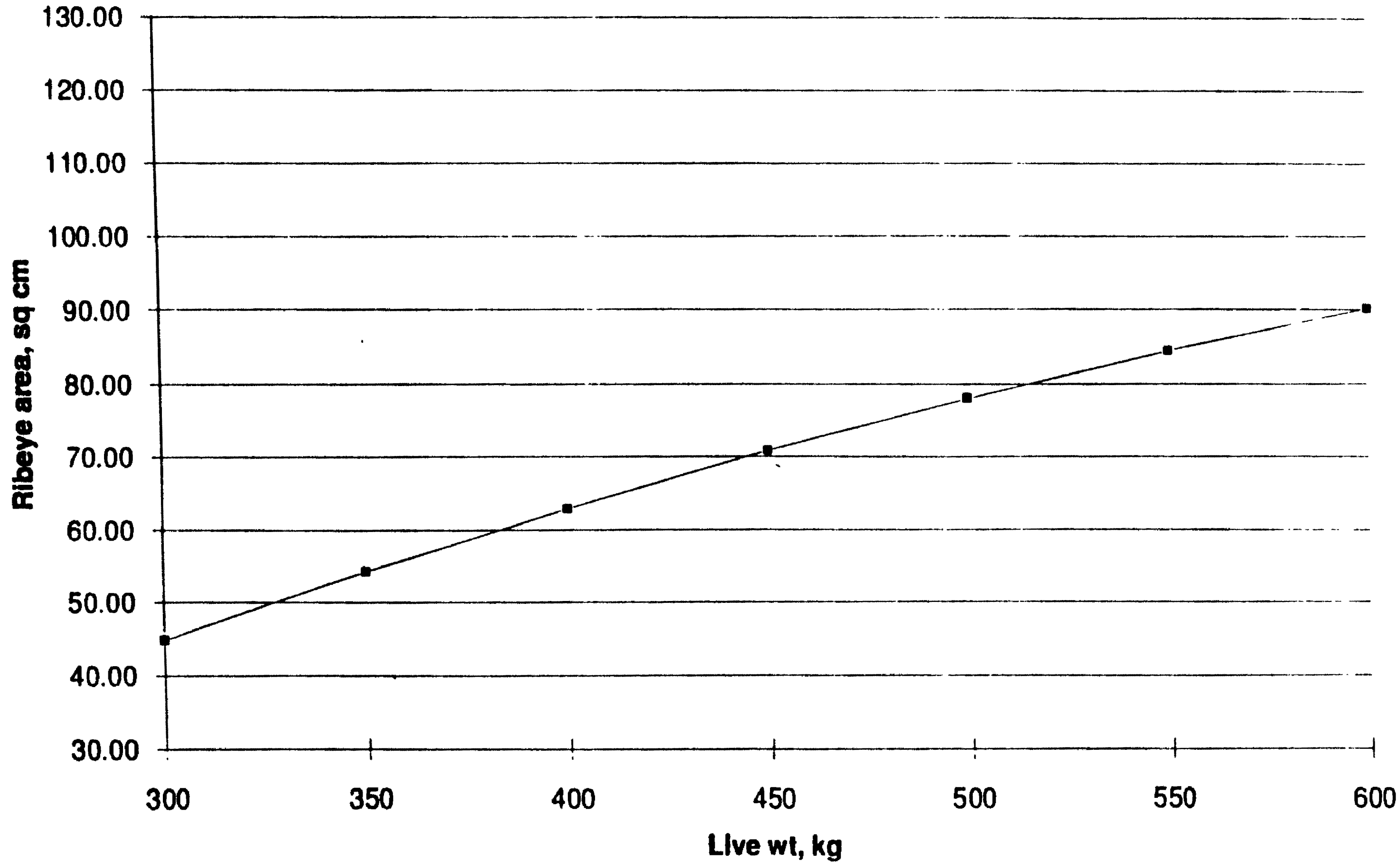
b_0	b_1	b_2	R^2	RSD
-25.13	0.281	-0.0001	.45	19.20

Figure 5a. Hereford quadratic fat thickness across live weight



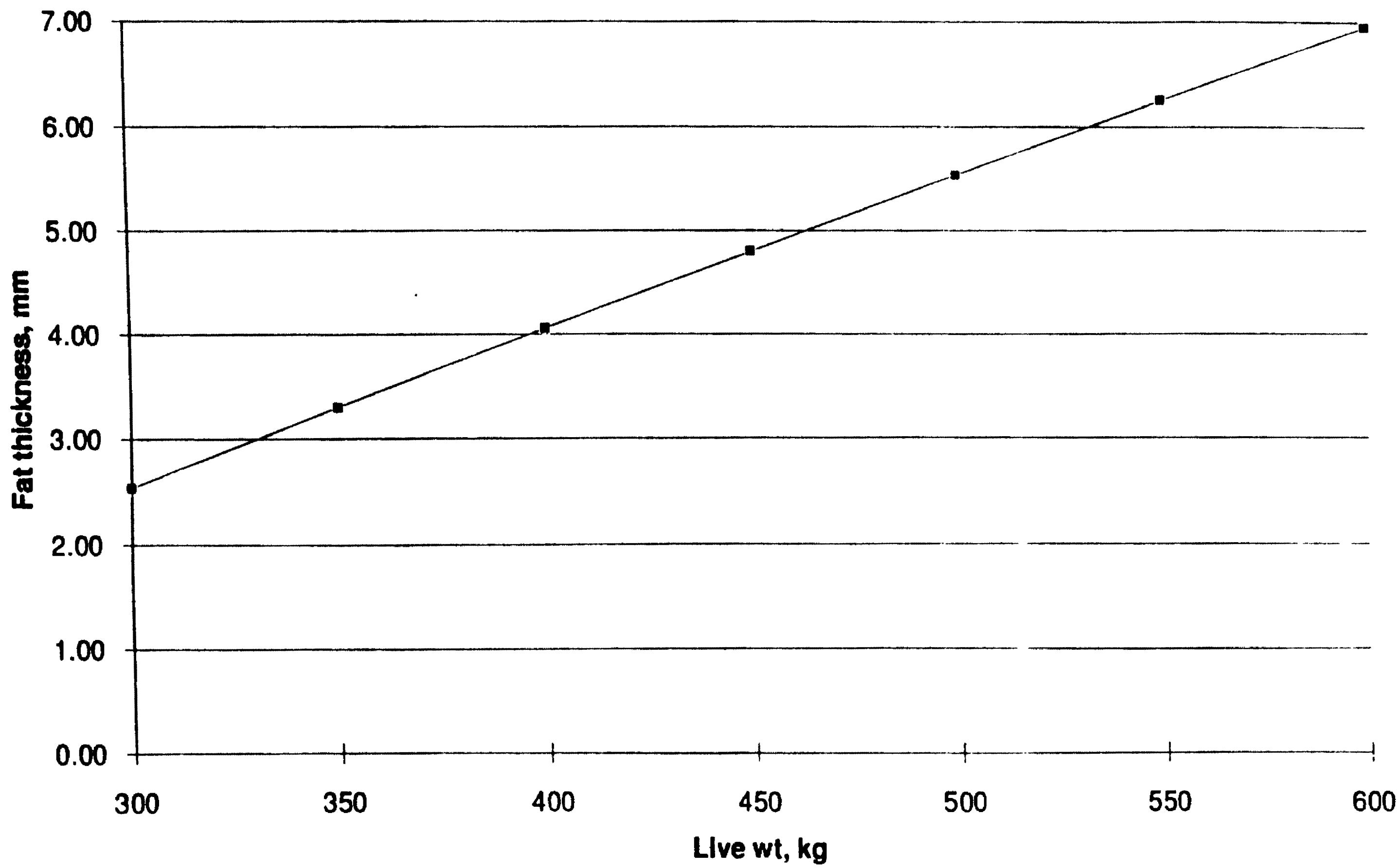
b_0	b_1	b_2	R^2	RSD
-2.12	0.016	0.0008	.41	2.50

Figure 6a. Hereford quadratic ribeye area across live weight



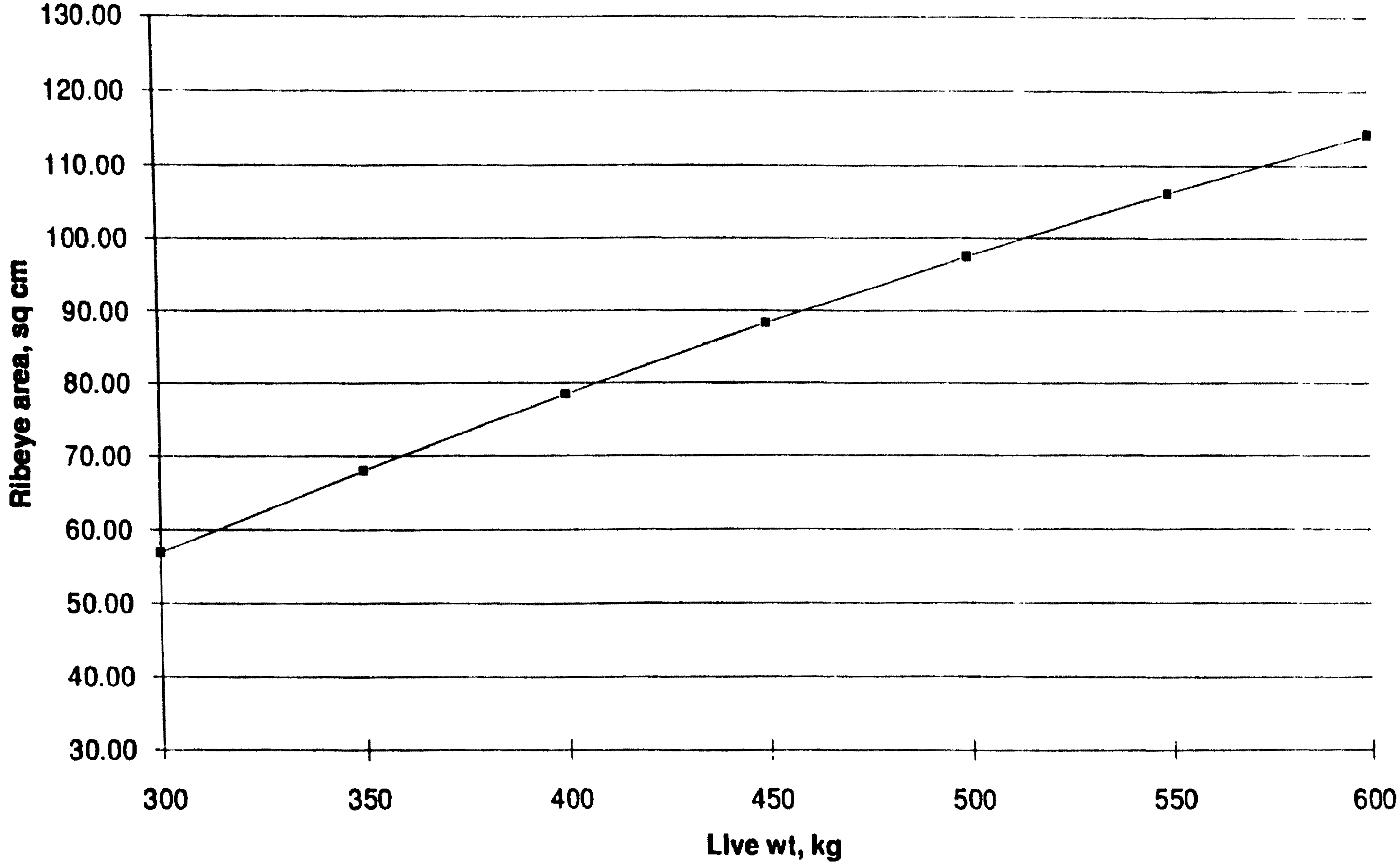
b_0	b_1	b_2	R^2	RSD
-27.49	0.286	-0.0001	.37	18.00

Figure 7a. Limousin quadratic fat thickness across live weight



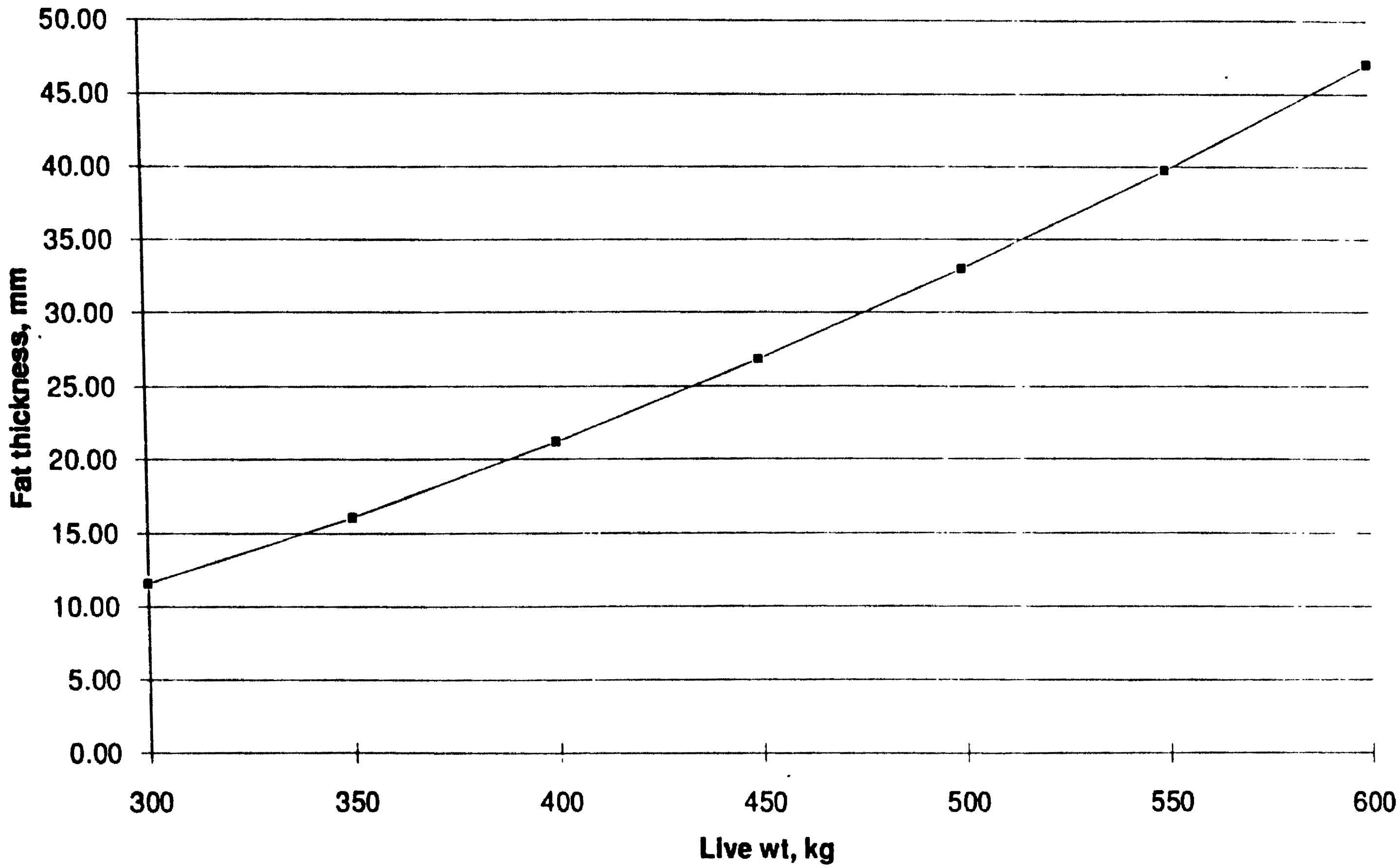
b_0	b_1	b_2	R^2	RSD
-2.34	0.017	-0.0003	.39	1.72

Firure 8a. Limousin quadratic ribeye area across live wight



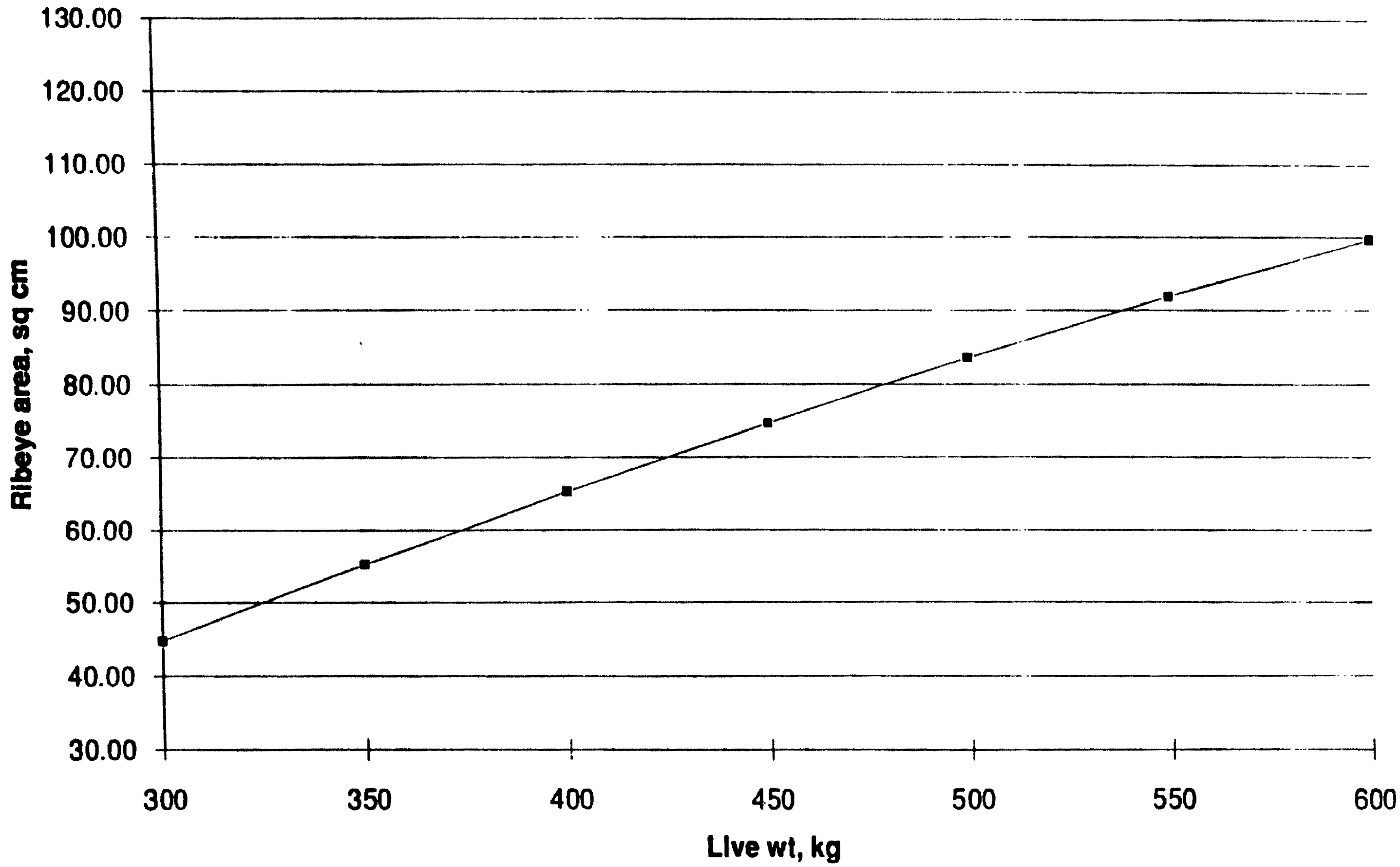
b_0	b_1	b_2	R^2	RSD
-22.00	0.299	-0.0001	.46	19.00

Figure 9a. Polled Hereford quadratic fat thickness across live weight



b_0	b_1	b_2	R^2	RSD
-3.99	0.019	0.0001	.53	2.53

Figure 10a. Polled Hereford quadratic ribeye area across live weight



b_0	b_1	b_2	R^2	RSD
-30.69	0.285	-0.0001	.61	13.00

Table 1. Days-based equations for fat thickness and ribeye area stratified by breed

Breed	b_0	b_1	R^2	RSD
Angus				
Fat	3.13	0.065	.64	2.00
Rea	49.45	0.466	.72	12.50
Brangus				
Fat	3.20	0.047	.52	2.04
Rea	57.51	0.400	.48	18.60
Hereford				
Fat	3.68	0.051	.44	2.41
Rea	48.37	.0341	.39	17.55
Limousin				
Fat	3.30	0.029	.32	1.81
Rea	66.03	0.415	.46	19.00
Polled Hereford				
Fat	3.97	0.064	.53	2.55
Rea	56.63	0.394	.64	12.60

VITA

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Master of Science

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