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ULTRASONIC DETERMINATION OF IN VIVO CARCASS COMPOSITION OF CATTLE

BY

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SUMMARY

Fourteen Angus and 15 Friesian castrate male cattle were ultrasonically scanned at six sites with a "Scanogram". After scanning, the cattle were killed and their carcasses were dissected. Measurements were made of subcutaneous fat depth and of the cross-sectional area of the Mm. longissimi thoracis et lumborum (eye muscle) on photographs of the scans and at corresponding sites on the carcass. Prediction equations were developed relating Scanogram measurements to carcass measurements and to carcass composition.

Results showed that ultrasonic scans predicted fat depth with useful accuracy. However, the error associated with ultrasonic scans of the eye muscle area was high and it is suggested that the Scanogram is unlikely to detect significant differences in eye muscle areas when animals of similar weight, age and breed are being compared.

Multiple regression equations, incorporating live weight and the appropriate ultrasonic measurements, were developed to predict carcass composition. The results showed that, with the cattle used in this experiment, ultrasonic scanning was useful for making in vivo estimates of carcass composition in terms of muscle or fat content.

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DETERMINATION ULTRASONIQUE IN VIVO DE LA COMPOSITION DE LA CARCASSE DE BOVIN

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On a procédé à un balayage par ultra-son en six endroits différents sur quatorze bovins mâles castrés de la race Angus et quinze de la race Frisienne, en utilisant un appareil "Scanogram". Après balayage, les animaux ont été tués et leurs carcasses découpées. On a mesuré la profondeur de la graisse sous-cutanée ainsi que la section des Mm. longissimi thoracis et lumborum sur les clichés photographiques des balayages et dans les sites correspondants de la carcasse. Des équations de prédiction mettant en relation d'une part les mesures du "Scanogram", d'autre part les mesures sur la carcasse, ainsi que la composition de la carcasse ont été calculées.

Nos résultats ont montré que les balayages ultrasoniques prédisent la profondeur de la graisse avec une bonne exactitude. Néanmoins, l'erreur qui se trouve associée aux balayages ultrasoniques du muscle est élevée, et suggère qu'il est peu probable que le "Scanogram" puisse détecter des différences significatives du muscle quand on compare des animaux de poids, d'âge et de race identiques.

Des équations de régression multiple, incluant le poids vif et les mesures ultrasoniques, ont été calculées pour évaluer la composition de la carcasse.

Les résultats montrent qu'avec les bovins utilisés dans cette expérience, le balayage ultrasonique s'avère utile pour établir des estimations in vivo de la composition de la carcasse en ce qui concerne le contenu en muscle et en graisse.

ПОДВЕДЕНИЕ ИТОГОВ

Ультрасонический осмотр 14 кастрированных быков породы Ангус и Фризиан был произведен в 6 разных зонах с помощью "Сканограм'а". После осмотра ("сканирования") скот был убит и каркасы быков подверглись анатомированию. Были произведены измерения толщины подкожного сала и поперечного сечения зоны Mm. longissimi thoracis et lumborum , выявленных на фотографических снимках "сканирования", а также в соответственных зонах каркасов быков. Измерения, сделанные "сканограмом" и их соотношение с измерениями состава и размера каркасов быков были выражены в виде уравнений.

Из результатов видно, что ультрасоническое "сканирование" определяет толщину сала с точностью, которая может иметь практическую пользу. Тем не менее, ультрасоническое сканирование мускульной зоны не дает стабильных результатов и мы предполагаем, что вряд ли можно вполне положиться на "сканограм" для того чтобы точно определить разницу в зонах мускулов животных одинаковых по весу, возврасту и породе.

ZUSAMMENFASSUNG

Vierzehn Angus und 15 Friesen Ochsen wurden an 6 Körperstellen anhand eines "Scanogram" geprüft. Danach wurden sie geschlachtet und die Körper zerlegt. An Scanogram (Ultraschall) photographien, und an den entsprechenden Schlachtkörperstellen wurden die Fettdicke unter der Haut und die Schnittfläche der Mm. longissimi thoracis et lumborum gemessen. Gleichungen die die Verhältnisse zwischen den Massen am Schlachtkörper und anhand des Scanograms darstellen, wurden errechnet.

Ultraschallmasse ergaben Fettdicke mit brauchbarer Genauigkeit. Fehler bei Ultraschallschätzungen der Muskelschnittfläche waren jedoch gross und es ist wahrscheinlich dass das Scanogram keine signifikanten Unterschiede der Muskelschnittfläche feststellen kann bei Tieren von gleichem Gewicht, gleichem Alter und gleicher Rasse.

Multiple Regressionsgleichungen, die Körpergewicht am lebenden Tier und geeignete Ultraschallmasse enthielten, wurden errechnet. Die Ergebnisse zeigten dass, bei den Tieren in diesem Versuch, Ultraschallprüfung brauchbare Schätzungen am lebenden Tier für den Anteil von Muskel und Fett am Schlachtkörper ergab.

INTRODUCTION

In 1961, Stouffer *et al* reported a continuous ultrasonic scanning technique for recording, at selected sites, the depth of subcutaneous fat and the cross-sectional outline of superficial muscles of farm animals. The work has led to the development of commercial equipment called the Scanogram* which has been described in detail by Stouffer (1970).

Early work on the use of ultrasonics on live animals began in Europe and USA in the 1950's. Since then numerous papers have reported correlation coefficients between ultrasonic measurements made on live animals and corresponding measurements made on their carcasses. Some authors have investigated the precision of ultrasonic techniques, the most recent paper being by Miles, Pomeroy and Harries (1972). However, apart from the work of Hervé

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* The Scanogram was developed by Prof. J.R. Stouffer of the New York College of Agriculture, Cornell University, and his colleagues of Ithaco Inc., Ithaca, New York, USA.

and Campbell (1971), the authors are unaware of work which reports equations for predicting carcass composition of cattle from ultrasonic measurements. The results of Hervé and Campbell (1971), include only limited data on complete carcass dissection.

This paper reports relationships between Scanogram measurements on live cattle and the dissected composition of their carcasses.

MATERIALS AND METHODS

During 1971 and 1972, 14 Angus and 15 Holstein Friesian castrate male cattle were obtained from farmers in southern Victoria and moved to Mt. Derrimut Field Station, University of Melbourne.

Scanning sites

Each animal was scanned on the left side at the following sites:-

10th rib, 13th rib, 3rd lumbar vertebra, tuba coxa, femur, scapula.

These sites are described in detail in the Appendix.

Scanning procedure

The Scanogram was calibrated so that measurements of 1 cm on photographs represented 2.54 cm on the live animal; that is, a reduction ratio of 1 : 2.54. An investigation using a 1 : 1 ratio was also made but is not reported here.

Animals were scanned by two "operators" (CPL and TGT). Each operator scanned until he had obtained two satisfactory pictures at each site. At the 10th and 13th rib sites, animals were scanned both before and after removing the hair coat with surgical clippers. Also at the 10th and 13th rib sites, one operator (CPL) scanned both upwards (transducer head moving ventro-dorsally) and downwards (transducer head moving dorso-ventrally).

The distance along the dorsal midline was measured from the 10th rib site to the tuber coxa site.

Interpretation of photographs

Photographs from each animal were randomized and traced onto "Ultrafan".* Two interpreters traced each

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* Ultrafan is a transparent plastic sheet on which ink can be used; it is available at artist supply shops.

photograph twice. There was a deliberate delay of at least one day between repeated tracings (replicates) of the same photographs. After indicating appropriate anatomical boundaries on the tracings, measurements were made of subcutaneous fat depth at all sites. At the 10th rib, 13th rib and 3rd lumbar vertebra sites, the cross-sectional area of the Mm. longissimi thoracis et lumborum (eye muscle) was measured. The positions at which these measurements were made are described in the Appendix.

Procedure at slaughter

Animals were slaughtered according to commercial practice and hung by the Archilles tendon after splitting down the dorsal midline. Perirenal fat and fat in the pelvic canal ("kidney and channel fat") were left in the carcass. After the carcass had been stored at 2°C for 24 hrs, carcass measurements of subcutaneous fat depth and of eye muscle area were made on the left half carcass at sites corresponding with those made with the Scanogram on the live animal.

The right half of each carcass was then dissected into individual muscles, bone, subcutaneous fat, intermuscular fat, kidney and channel fat, and fascia and tendon according to the technique of Butterfield and May (1966).

Abbreviations

TFD - Total fat depth : the sum of the three subcutaneous fat depth measurements taken at a particular site.

EMA - Eye muscle area.

Statistical techniques

Statistical techniques are described in the Appendix. To assess variability associated with each aspect of the scanning procedures, variances were calculated to compare direction of scanning, clipping the coat, operators and interpreters. To compare Scanogram measurements with carcass data, correlation and regression analyses were used.

RESULTS AND DISCUSSION

Experimental animals

The live weight and carcass weights of the experimental animals are shown in Table 1. The first four animals (2 Angus, 2 Friesian) were used to develop scanning techniques and in some instances data from these animals have been discarded. Some data from one Friesian were destroyed and the extra Friesian represents a replacement for this animal.

TABLE 1

Live weights (kg) and carcass weights (kg) of the experimental animals

Breed	No. of animals	Mean live wt. ± S.E.	Range of live wts.	Cold carcass wt. ± S.E.	Range of carcass wts.
Angus	14	433 ± 57	350 - 516	242 ± 30.9	197 - 294
Friesian	15	446 ± 45	359 - 514	243 ± 33.4	196 - 294

Live weights were chosen to spread carcass weights evenly throughout the range 200 - 300 kg, hence the relatively large standard errors shown for the mean weights.

VARIABILITY IN SCANNING PROCEDURES

The investigation of scanning procedures has been reported in detail by Tulloh, Truscott and Lang (1973). Their results showed no important effect of clipping the coat and no important differences between operators. They found that measurements for downward scans were significantly greater than for upward scans for both TFD and EMA. They also found significant differences between some measurements on tracings made by different interpreters. Differences between interpreters have also been reported by Miles *et al* (1972).

Because the scanning rail only fitted the contours of the Friesian cattle when they were scanned upwards, and because the scanning rail fitted the Angus cattle when scanned in either direction, only results from upward scans have been included in this paper.

RELATIONSHIP BETWEEN SCANOGRAM AND CARCASS MEASUREMENTS AT CORRESPONDING SITES

These relationships were examined at four sites, namely, 10th rib, 13th rib, 3rd lumbar vertebra and scapula.

The tuber coxa and femur sites were not measured in the carcass because of difficulty in identifying points on photographs which corresponded with the same positions on the carcass. Data included in this section are from one operator.

Total fat depth

The simple correlation coefficients between Scanogram and corresponding carcass measurements are shown in Table 2.

TABLE 2

Correlation coefficients (r) for total fat depth (TFD) between Scanogram and carcass measurements

Site	Angus	Friesian	Breeds combined
10th rib	0.89	0.93	0.94
13th rib	0.94	0.88	0.93
3rd lumbar vertebra	0.79	0.67	0.83
Scapula	0.24	0.67	0.56

All correlations, except for Angus cattle at the scapula site were highly significant ($P < 0.01$). These correlations are amongst the highest in the literature where they range from 0.38 to 0.90 (Davis *et al* 1964, Davis *et al* 1966, Watkins *et al* 1967, McReynolds and Arthaud 1970). The 3rd lumbar vertebra and scapula sites did not appear to be good sites in the investigation.

Because there were no interpreter differences in TFD measurements at these sites, the mean Scanogram measurements for both interpreters were used in regression analyses to predict carcass measurements. The regression equations are shown in Table 3. If the Scanogram measurements predicted carcass TFD measurements perfectly, the *b*- values in the equations would be 2.54. In fact, no *b*- value differed significantly from 2.54. This means that the accuracy of the equations was not affected by the size of TFD measurements (that is, the fatness of the animals). The Scanogram measurements were then multiplied by 2.54 and compared with corresponding carcass measurements.

TABLE 3

Constants in regression equation of the form $y = a + bx$ and F - values in regression analyses of carcass measurements (y) against Scanogram measurements (x)

Site	Constants a	b ± S.E.	F - value	n[+]
<u>Total fat depth (mm)</u>				
10th rib	-3.63	2.90 ± 0.45	166***	25
13th rib	0.77	2.12 ± 0.34	153***	25
3rd lumbar vertebra	-0.79	3.30 ± 0.43	58***	29
Scapula	0.44	2.27 ± 1.31	12**	28
<u>Eye muscle area (cm^2)</u>				
13th rib (scan upwards)				
Interpreter A	14.9	5.08 ± 1.10	21***	25
Interpreter B	23.1	3.86 ± 0.69	31***	25
3rd lumbar vertebra				
Interpreter A	17.9	4.92 ± 1.31	14**	25
Interpreter B	19.4	4.25 ± 1.18	13**	25

[+] n = number of animals; there were no breed differences in these relationships and in these calculations, breeds have been combined.

** $P < 0.01$

*** $P < 0.001$

The mean difference between Scanogram and carcass measurements and the standard errors of prediction are shown in Table 4.

TABLE 4

Mean differences between TFD predicted by Scanogram and actual TFD measurements and standard errors of prediction

Site	n[Ø]	Mean difference ± S.E. (mm)	S.E. of prediction[+] (mm)
10th rib	25	0.4 ± 0.8	4.0
13th rib	25	1.3* ± 0.6	3.3
3rd lumbar vertebra	29	-2.4* ± 1.1	6.1
Scapula	28	0.4 ± 0.7	3.6

Ø Number of animals

\+ S.E. of prediction $= \sqrt{\dfrac{\Sigma(\text{Scanogram} - \text{carcass})^2}{n - 1}}$

* $P < 0.05$

At the 13th rib site, the significant overestimate of 1.3mm by the Scanogram included a total of three fat thickness measurements; thus, the actual overestimate for the average fat depth measurement was about 0.4 mm. Similarly, the significant underestimate of -2.4 mm at the 3rd lumbar vertebra site represented only about -0.8 mm for an average fat thickness measurement. In practice, the bias in these estimates is small enough to ignore. If it is assumed that the above differences were not real, that is, the mean difference was zero, the standard error of prediction at the 10th and 13th rib sites were 4.0 and 3.3 mm respectively,(see Table 4). These S.E. of prediction indicate that for a mean fat depth (instead of a total of three in TFD), the S.E. of prediction was only 1.3 and 1.1 mm, respectively. In this experiment, it is clear that ultrasonic scans did predict carcass fat depth with useful accuracy.

<u>Eye muscle area</u>

The same type of analyses were done for EMA as were done for TFD.

The simple correlation coefficients between Scanogram and corresponding carcass measurements are shown in Table 5. Correlations at the 10th rib site were low and not significant in all instances but one. These correlations for EMA were generally lower than those obtained for TFD, especially at the 10th and 13th rib sites.

TABLE 5

Correlation coefficients (r) for eye muscle area (EMA) between Scanogram and carcass measurements

Site	Angus	Friesian	Breed combined
10th rib			
Interpreter A	0.69*	0.16	0.37
Interpreter B	0.46	0.18	0.32
13th rib			
Interpreter A	0.71**	0.64	0.69**
Interpreter B	0.80**	0.74**	0.76**
3rd lumbar vertebra			
Interpreter A	0.29	0.82**	0.62**
Interpreter B	0.44	0.71**	0.60**

* $P < 0.05$

** $P < 0.01$

There were some difficulties in photo-interpretation at the 10th rib site when the thoracic trapesius and the spinalis dorsi muscles confused the interpreters. The lower correlations for Angus than for Friesian are thought to be due to greater difficulty in identifying the lateral edge of the eye muscle in fatter animals.

Significant regression equations for predicting EMA from Scanogram measurements were obtained with data at the 13th rib and 3rd lumbar vertebra sites; these equations are shown in Table 3. Because of interpreter differences, equations for both interpreters have been included.

If the Scanogram predicted EMA perfectly, the b-values in these equations would be 6.45 (that is, 2.54^2). The b-value for Interpreter B at the 13th rib site was significantly less ($P < 0.01$) than 6.45. When the Scanogram EMA measurements at all sites were multiplied by 6.45 and compared with carcass measurements, the mean differences (Scanogram measurement - carcass measurement) were all highly significant for Interpreter A, but not for B. The mean differences and standard errors of prediction at each site for each interpreter are shown in Table 6.

TABLE 6

Mean differences between EMA predicted by Scanogram and actual carcass EMA measurements and their standard errors of prediction

Site	n^+	Mean difference ± S.E. (cm^2)	S.E. of prediction (cm^2)
10th rib			
Interpreter A	25	-6.7^{***} ± 1.4	9.8
Interpreter B	25	-2.4 ± 1.3	6.9
13th rib			
Interpreter A	25	-3.1^{**} ± 0.9	5.6
Interpreter B	25	0.4 ± 1.0	5.1
3rd lumbar vertebra			
Interpreter A	29	-7.4^{***} ± 1.1	9.2
Interpreter B	29	-1.9 ± 1.1	5.8

$^+$ n = number of animals

** $P < 0.01$

*** $P < 0.001$

The table shows that the Scanogram generally underestimated EMA. The bias may have been due to a change in the relative positions of the tissues before and after slaughter. The bias is not regarded as important but the large standard errors of prediction are. If the bias is ignored, the standard errors of prediction were similar to the standard deviation associated with the total variation in EMA found in the experiment. For example, 13th rib mean EMA = 57.6 ± S.D. 6.1 cm^2; at this site, the S.E. of prediction for Interpreter A = 5.6 cm^2. If a correction is made for the significant bias of Interpreter A at this site (-3.1 cm^2), the standard deviation of the mean difference = 4.5 cm^2 (that is, S.E. x $\sqrt{n}$) which is still large.

It is concluded that the use of the Scanogram for detecting differences in EMA between individual animals of similar breed, weight and age is unlikely to be successful.

RELATIONSHIP BETWEEN SCANOGRAM MEASUREMENTS AND CARCASS COMPOSITION

Dissected carcass muscle

Correlation coefficients

TFD was not significantly correlated with dissected muscle weight either before or after the effect of live weight had been removed. However, all correlations between TFD and percentage of muscle in the carcass were highly significant ($P < 0.01$) and negative. Removing the effect of live weight had almost no effect on these correlations. The four highest partial correlation coefficient (effect of live weight removed) were as follows:-

10th rib:	-0.73
13th rib:	-0.61
Tuba coxa:	-0.65
Femur:	-0.67

The significant simple correlation coefficients between EMA measurements and dissected muscle weight were as follows:-

EMA

10th rib : 0.57**

13th rib : 0.48*

EMA x Length (where length = distance 10th rib site to tuber coxa site)

10th rib : 0.71**

13th rib : 0.82**

3rd lumbar vertebra : 0.65**

* $P < 0.05$ ** $P < 0.01$

When the effect of live weight on these correlations was removed all became non-significant except the correlation between 13th rib site EMA x length and weight of dissected carcass muscle (partial correlation = 0.50 $P < 0.05$). Hervé and Campbell (1971) and Levantin et al (1964) also found strong correlations between EMA measurements and weight of carcass muscle in mature cattle, but partial correlations with the effect of live weight removed were not presented. There were no EMA measurements which were significantly related to percentage of muscle in the carcass. Burkart et al (1967) found a weak, although statistically significant, relationship between EMA measured ultrasonically at the 11th and 12th rib site and percentage of carcass muscle.

Prediction of dissected carcass muscle

In order to predict dissected carcass composition from various combinations of measurements, a step-wise multiple regression procedure was used. The most useful prediction equations were as follows:

(i) Weight of dissected muscle

$$y = 7.31 + 0.109x_1 + 0.041x_2$$

where y = weight (kg) of dissected muscle in the half carcass

x_1 = live weight (kg)

x_2 = 13th rib EMA x Length (cm^3)

This equation accounted for 86#% of variation in weight of dissected muscle and had a residual standard deviation (Sy.x) of 3.09 kg.

(ii) Percentage of muscle

Breed differences in relationships between Scanogram measurements and percentage of dissected muscle made it necessary to compute separate equations for each breed. They were as follows:-

86% = R^2 x 100, where R is the multiple regression coefficient.

Angus: $y = 69.7 - 0.702x_1 - 0.283x_2$

where y = % of dissected muscle in the half carcass

x_1 = 10th rib TFD (mm)

x_2 = Femur TFD (mm)

This equation accounted for 88% of the variation in percentage of dissected muscle and had a Sy.x of 1.1%

Friesian: $y = 65.9 - 0.713x$

where y = % of dissected muscle in the half carcass

x = Tuber coxa TFD (mm)

This equation accounted for 60% of the variation in percentage of dissected muscle and had a Sy.x of 1.7%

Dissected carcass fat

Correlation coefficients

TFD measurements were highly correlated ($P < 0.01$) with both weight and percentage of dissected carcass fat. When the effects of live weight were removed, the correlation coefficients showed very little change. These correlations are shown in Table 7.

TABLE 7

Simple and partial* correlation coefficients between Scanogram TFD measurements and weight or percentage of dissected carcass fat

Site	Weight of dissected fat		% of dissected fat	
	Simple correlation	Partial correlation	Simple correlation	Partial correlation
10th rib	0.79	0.80	0.84	0.81
13th rib	0.76	0.74	0.79	0.75
3rd lumbar vertebra	0.76	0.79	0.80	0.77
Tuber coxa	0.80	0.85	0.88	0.86
Femur	0.80	0.75	0.79	0.75
Scapula	0.68	0.73	0.75	0.73

* - Partial correlation coefficient : variability due to live weight removed.

The correlations between live weight and weight or percentage of dissected carcass fat were 0.70 and 0.39, respectively. Thus, a TFD measurement at any of the sites, except the scapula, was more highly correlated with carcass fat content than was live weight. Although comparative data are not included in this report, it should be noted that Scanogram TFD measurements were as well or better correlated with dissected carcass fat content than were corresponding TFD measurements made on the carcasses.

Correlations between EMA measurements and carcass fat content were low and are not reported here.

Prediction of dissected carcass fat

(i) Weight of fat

TFD at the tuber coxa site had the highest correlation with weight of dissected carcass fat and the multiple regression incorporating this measurement with live weight was as follows:-

$$Y = -14.58 + 0.070x_1 + 1.038x_2$$

where y = weight (kg) of dissected fat in the half carcass

x_1 = live weight (kg)

x_2 = tuber coxa TFD (mm)

This equation accounted for 86% of variation in weight of dissected fat and had a Sy.x of 2.88 kg.

(ii) Percentage of fat

The best equation was as follows:-

$$Y = 12.4 + 0.500x_1 + 0.495x_2$$

where y = % dissected fat in the half carcass

x_1 = tuber coxa TFD

x_2 = 10th rib TFD

This accounted for 82% of variation in percentage of dissected fat and had a Sy.x of 1.7% (representing 2.10 kg at the mean half carcass weight of 121.6 kg).

These two equations for predicting percentage of dissected fat contained no significant breed bias.

The correlation (r) between live weight and weight of dissected carcass muscle was 0.91; that is, live weight alone accounted for 82% (r^2) of variation found in this carcass component. By using Scanogram measurements in a multiple regression equation, the amount of variation accounted for was increased from 82% to 86%. this 4% increase seems small, but it represents 22% of the variation left after the effects of live weight have been removed. This improvement in prediction may be worthwhile.

Information on the amount of dissectable fat in a carcass may be as useful to the meat industry as information on amount of dissectable muscle. The correlation (r) between live weight and weight of dissected fat was 0.70, indicating that live weight accounted for only 49% (r^2) of variation in weight of dissected fat. By using a multiple regression including live weight and tuber coxa TFD, the amount of variation in weight of dissected fat accounted for increases to 86%. It is clear that, at constant live weight, big variations occur in TFD and, presumably, they are related to major changes in the fat content of the carcass.

Although carcass components were calculated as percentages of carcass weight, prediction of components as percentages were not generally as good as when prediction was based on weights.

It is concluded that with the cattle used in this investigation, ultrasonic scanning was useful for making *in vivo* estimates of carcass composition.

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APPENDIX

SCANNING SITES

The scanning sites were as follows:-

<u>10th rib:</u> A transverse section, dorso-ventral to the estimated position of articulation of the 9th and 10th thoracic vertebrae. The position was established by following the curvature of the 10th rib towards the vertebral column.

<u>13th rib:</u> A transverse section, dorso-ventral to the estimated position of articulation of the 12th and 13th thoracic vertebrae. The position was found by following the curvature of the 13th rib towards the vertebral column.

<u>3rd lumbar vertebra:</u> A transverse section, dorso-ventral to the estimated position of the mid point of the 3rd lumbar vertebra. The position was found by palpating the lateral process of the 3rd lumbar vertebra.

<u>Tuber coxa:</u> A transverse section, dorso-ventral to a line joining the cranial edges of the left and right tuber coxae.

<u>Femur:</u> A section at right angles to the posterior surface of the leg, crossing the femur at a point midway between the hip and stifle joints.

<u>Scapula:</u> A section, across the scapula at right angles to its spine at a point midway between the ventral surface of the proximal extremity of the humerus and the dorsal border of the cartilage of the scapula.

MEASUREMENT OF PHOTOGRAPH TRACINGS

10th and 13th Rib

a) the area of the transverse section of the Mm. longissimi thoracis et lumborum (eye muscle area) was measured with a compensating polar planimeter.

b0 subcutaneous fat depth was measured at right angles to the fat layer at points marking 0.25, 0.5 and 0.75 of the width of the eye muscle.

3rd Lumbar Vertebra

Eye muscle area and subcutaneous fat depth were measured as described for the 10th and 13th ribs.

Femur

Subcutaneous fat depth was measured at right angles to the fat layer at 3 points; they were as follows:-

a) over the biceps femoris muscle at a point 3 cm from the interface of the biceps femoris muscle and the semitendinosis muscle.

b) over the semitendinosis muscle 1.5 cm from the same interface.

c) over the dorso-ventral groove of the biceps femoris muscle.

Scapula

Subcutaneous fat depth was measured at right angles to the fat layer at 2 points; they were as follows:-

a) 1 cm cranial to the spine of the scapula.

b) 2 cm caudal to the spine of the scapula.

Tuber coxa

Subcutaneous fat depth was measured at right angles to the surface at 3 points; they were as follows:-

a) over the midpoint of the section of the middle gluteal muscle.

b) at a point level with the lateral edge of the middle gluteal muscle.

c) over the tuber coxa at the point where it is closest to the surface.

STATISTICAL PROCEDURES

The relationship between Scanogram and carcass measurements

Correlation and regression analyses were done to relate Scanogram measurements to carcass measurements of the same parameter. The data used were from one operator (CPL) and were the mean measurements of interpreters A and B. The regression coefficient (b) was tested against 2.54 for TFD and aginst $(2.54)^2$ for EMA by a t-test. A non-significant test indicated that the Scanogram predicted the carcass measurement with the same accuracy irrespective of the size of the EMA or TFD.

To test whether the Scanogram gave biased estimates of the carcass measurements, the scaled up Scanogram measurements were compared with carcass measurements, using a t-test for paired comparisons.

The "standard error of prediction" of carcass measurements from Scanogram measurements was calculated on the assumption that there was no real difference between predicted carcass measurements (i.e. Scanogram measurements multiplied by the appropriate scaling factor - 2.54 for TFD and $(2.54)^2$ for EMA) and the actual carcass measurement. The "standard error of prediction" was then calculated as

$$\sqrt{\frac{\Sigma D^2}{n - 1}}$$

where D = deviation of predicted from actual

n = number of animals

The relationship between live animal measurements (including carcass measurements and carcass composition.

A step-wise multiple regression technique was used to relate live animal (including Scanogram) measurements to carcass composition. Independent variables were entered until

a) the inclusion of the next variable explained no significant extra variation in the dependent variable

or b) the variable being entered caused a normalized regression coefficient to exceed unity.

Regression lines within breeds relating TFD measurements to composition were analysed for difference in slope (b-value) and difference in intercept (a-value) by normal least squares covariance procedures. The accuracy of the computed multiple regression equations was also compared in this manner by substituting the predicted composition as the independent variable. The Scanogram data used were from one operator (CPL) and were the mean measurements from interpreters A and B.

(1956) Texts by Sokal and Rohlf (1969) and Snedecor were used as references for statistical procedures.