The value of ultrasound in assessing the leg muscling of lambs

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ABSTRACT

Rib-eye muscle (M. longissimus lumborum) area (REA) and depth (B) at the 12th rib were ultrasonically measured on 89 ram lambs from 3 sire breeds. The lambs were then slaughtered and these live measures plus carcass weight were evaluated as predictors of the corresponding carcass measures and the following two measures of muscling, based on four muscles surrounding the femur bone and the femur itself: 1. Muscle:Bone ratio (M:B), and 2: Muscularity (MUSC), defined as an index of muscle depth (square root of the weight of the four muscles per unit femur bone length) relative to a skeletal dimension (femur length). Prediction of carcass REA and B from ultrasonic REA and B, after adjusting for carcass weight, was more effective for B (partial r= 0.40) than REA (partial r= 0.18). The main problems with prediction arose with higher values (B>33mm), when ultrasonic values underestimated actual carcass values. REA and B (ultrasonic live and direct carcass) significantly ($p<0.001$) improved the prediction of MUSC or M:B over carcass weight alone, but did not account for the highly significant ($P<0.001$) breed effect on these traits. It is concluded that ultrasonic and carcass measures of REA and B provide useful but limited information on lamb leg muscularity.

Keywords Ultrasound, carcass muscularity, lambs, sheep selection, breed differences.

INTRODUCTION

Consumer preference for lean meat cuts has provided the NZ sheep industry with a strong incentive to increase lean yield from lamb carcasses. Much trial work has been carried out which has established that simple measurements of fat depth provide a good indication of carcass lean-meat yield (Kirton *et al.*, 1983; Wood *et al.*, 1980). A further selection objective is to improve carcass "muscularity" or "conformation", parameters which are judged to be commercially important by the meat industry, as animals of good conformation "are claimed to produce carcasses with more lean meat and a higher proportion of joints and lean meat in the more expensive cuts" (MLC Sheep Yearbook 1987). To date muscularity has mainly been subjectively assessed (Kirton *et al.*, 1983; Williams *et al.*, 1989) due to the absence of suitable objective measure/s which adequately describe muscularity and which are applicable industry wide.

Purchas *et al.*, (1991) proposed an objective measure of muscularity that assessed the ratio of the average muscle depth of a group of muscles surrounding a bone relative to bone length. Average muscle depth was indirectly assessed as the square root of the weight of a group of muscles per unit length of an adjacent bone. In this trial muscularity of the leg was assessed from dissection of the main muscles surrounding the femur, and a leg muscle to bone ratio was also calculated.

The measure of muscularity proposed above is based on carcass measurements. In a sheep breeding programme, direct assessment of carcass traits is not possible on individual live sheep, so some means of indirectly assessing these traits is needed. Ultrasonic equipment has been used since the 1950's (Stouffer and Westerveld, 1976) to measure fat depths on live animals, and the advent of real-time B-mode ultrasonic scanners in the 1980's has made the possibility of measuring muscle depths and areas as well as fat depths available to sheep breeders.

This trial was designed, therefore, to investigate the ability of real-time ultrasound to predict on live sheep carcass muscle depths at the 12th rib, rib eye area and the index of leg muscularity and muscle to bone ratio. Although several breeds of sheep were involved, breed differences will not be discussed in detail here.

MATERIALS AND METHODS

Sheep and Ultrasonic Measurements

The trial was conducted on 89 ram lambs, comprising 3 sire-breed crosses. Breed crosses used, numbers of animals scanned per breed, their age at scanning and the scanning dates are given in Table 1. The 40 purebred Romneys were from a Manawatu stud farm, with all Coopworth crosses (Romney, Texel and Oxford Down) being from a second stud farm. For the purposes of analysis the Romney and Romney x Coopworth data were combined. Ultrasonic measurements were made using a Dynamic Imaging XLP real-time scanner with a 3.5 MHz transducer. Any wool present was parted and the transducer was held directly onto the skin, using soya bean oil as an acoustic couplant. Ultrasonic measurements taken on the right side of the animal at the 12th rib were: Fat depth C and the depth (B) and cross sectional area of the longissimus muscle (Rib-eye area or REA) (Palsson, 1939).

TABLE 1 Breed Information and Trial Scanning Dates

Sire x Dam	Number	Age (months)	Date Scanned
Romney x Romney	20	9	May 1989
	20	12	Aug 1989
Romney x Coopworth	11	13	Nov 1990
Texel x Coopworth	16	6	Mar 1990
	11	13	Nov 1990
Oxford Down x Coopworth	11	13	Nov 1990

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Carcass Measurements

The lambs were slaughtered within 48 hours of scanning and the hot carcass weight taken. Carcasses were then chilled, and the same measures which had been made ultrasonically on the live animals were also made on each side of the chilled carcasses, together with tissue depth GR (Kirton, 1989). The right hindquarter was removed between the last and second to last lumbar vertebrae and separated into lean, fat, bone and scrap. Individual muscles weighed were the semimembranosus, semitendinosus, biceps femoris and quadriceps femoris; and individual bones weighed and measured were the femur and tibia. A leg muscularity index was calculated as proposed by Purchas *et al.*,.(1991) as the ratio of an index of muscle depth (the square root of the total weight of the above four muscles per unit length of the femur) to the length of the femur.

Statistical Analysis

Statistical analysis of the data was carried out using the general-least-squares computer program (REG) (Gilmore 1985). The predictive ability of the ultrasonic measures on live sheep to determine their carcass counterpart were assessed by determining the stepwise reduction in appropriate residual standard deviations, and the increase in the coefficients of determination, when the different components of the model were included in the prediction equation.

RESULTS

Ultrasonic and Carcass Measurements

Means and pooled within-group standard deviations for selected characteristics are presented in Table 2. Carcass weights increased with the slaughter age of the animals. Fat depth C, tissue depth GR, eye muscle dimensions, leg muscle:bone ratio, and the index of leg muscularity all increased with carcass weight, with the exception of fat depth C and tissue depth GR in the purebred Romney line.

Least-squares means for the live and carcass characteristics measured after adjustment to a constant carcass weight for each breed group are presented in Table 3. Carcass weight had a significant effect (P<0.001) for all measurements. Significant

TABLE 2 Means and pooled within-group standard deviations (S) for selected characteristics of the rams within source and slaughter groups

	Sire Breed						
	Romney			Texel		Oxford	S[a]
Number	20	20	11	16	11	11	
Carcass weight	17.4	20.4	29.0	14.7	32.5	33.4	2.9
Ultrasonic Measurements							
Rib-eye area (cm^2)	-	11.20	15.04	10.70	15.23	14.30	1.84
Muscle Depth B (mm)	20.9	22.8	28.3	23.1	28.1	26.8	2.67
Fat depth C (mm)	1.95	2.68	3.95	1.84	3.50	3.59	0.81
Carcass Measurements							
Rib-eye area (cm^2)	10.12	11.55	16.26	11.03	20.40	18.67	1.46
Muscle Depth B (mm)	23.1	25.3	33.4	23.8	37.3	36.0	2.5
Fat Depth C (mm)	1.51	1.45	4.18	2.00	3.09	3.32	1.37
Tissue Depth GR (mm)	4.74	4.32	13.54	5.56	12.14	12.50	3.45
Leg M:B[b]	6.19	6.47	8.04	7.25	9.01	7.31	0.63
Leg muscularity[c]	0.412	0.427	0.463	0.453	0.504	0.449	0.024

[a] Pooled within-group standard deviation

[b] Ratio of weight of four muscles (semimembranosus, semitendinosus, biceps femoris and quadriceps femoris) to femur weight

[c] Muscularity calculated from the weight of the same four muscles and femur length

TABLE 3 Least-squares means showing differences between the breed groups in several characteristics after adjustment to a constant carcass weight.

Item	Sire Breed			Carcass Weight	R^2 (%)	RSD
	Romney	Texel	Oxford	Effect		
Ultrasonic Measurements:						
Rib-eye area (cm^2)	12.86[a] (31)[d]	13.30[a] (27)	11.56[b] (11)	***	68	1.55
Muscle depth B (mm)	24.0[b] (51)	25.5[a] (26)	22.6[b] (11)	***	59	2.5
Fat depth C (mm)	5.51[a] (51)	5.52[a] (27)	4.11[b] (11)	***	56	1.55
Carcass Measurements:						
Rib-eye area (cm^2)	13.23[b] (51)	15.83[a] (19)	14.07[b] (11)	***	89	1.40
Muscle depth B (mm)	28.0[b] (51)	30.7[a] (19)	29.1[ab] (11)	***	84	2.60
Fat depth C (mm)	2.49 (51)	2.41 (19)	1.72 (11)	***	44	1.28
Tissue depth GR (mm)	7.96 (51)	8.61 (19)	6.95 (11)	***	63	3.22
Leg M:B	6.91[b] (51)	8.07[a] (27)	6.09[c] (11)	***	73	0.59
Leg muscularity	0.435[b] (51)	0.477[a] (27)	0.413[c] (11)	***	66	0.022

[a,b,c] Means in the same row with superscripts that do not contain a common letter differ significantly (P<0.05).

[d] Numbers of animals per group are shown in brackets. Comparisons should not be made between characteristics measured on different numbers of animals within a breed.

differences (P<0.05) between breeds occurred for each measurement except carcass fat depth C and tissue depth GR. For live animal and carcass rib-eye dimensions, the Texel tended to have the highest values, with the Romney and Oxford Down being at comparable lower values. For muscle:bone and the index of muscularity, the Texel ranked highest, followed by the Romney, then Oxford Down.

Prediction of Carcass Measures from Ultrasonic Measures

The prediction of carcass rib eye area (REA) or longissimus muscle depth (B), was achieved with higher accuracy using carcass weight alone than either ultrasonic REA or ultrasonic B (Table 4). The highest coefficients of determination for the prediction of either carcass REA or carcass B were achieved with carcass weight plus ultrasonic B. Partial correlations between live and carcass measures, when carcass weight was held constant, were highest for muscle depth B, but in both cases were low. The relationship between ultrasonic B and carcass B (Figure 1) indicated that the live animal ultrasonic measurement underestimated carcass values over the whole range, but that this effect was more marked at B values above about 34 mm. This gave rise to a curvilinear relationship as shown by the regression line in Figure 1.

TABLE 4 The accuracy with which carcass rib-eye area (REA) and longissimus muscle depth (B) were predicted from comparable measurements made ultrasonically on the live animal and from carcass weight, as shown by coefficients of determination (R^2) and residual standard deviations (RSD).

Independent Variables (s)	R^2 %	RSD	Partial Correlation[a]
Dependent variable = Carcass REA (N=61):			
Carcass weight (***)	79.7	1.86	
Ultrasonic REA (***)	58.3	2.66	
Carcass Weight (***) + ultrasonic REA (NS)	80.3	1.84	0.18
Carcass Weight (***) + ultrasonic B (P=0.05)	81.0	1.81	0.24
Dependent variable = Carcass muscle depth B (N=81):			
Carcass weight (***)	80.1	3.00	
Ultrasonic B (***)	62.6	3.87	
Carcass weight (***) + ultrasonic B (***)	83.3	2.61	0.40

[a] Correlation between ultrasonic and carcass measurement with carcass weight held constant.

Prediction of Muscling from Carcass or Ultrasonic Measures

Table 5 shows the accuracy with which leg muscularity and muscle:bone ratio were predicted from various combinations of variables. Carcass weight alone accounted for a highly significant amount of variation in each of these traits, but a significant improvement in prediction was achieved when either ultrasonic or carcass measures of B or REA were combined with carcass weight in prediction equations. However, these equations did not appear to satisfactorily account for breed differences in muscularity or M:B, as the inclusion of a breed classification in the prediction equations led to further appreciable increases in accuracy. When the breed factor was fitted before B or REA in the prediction equations rather than after these factors (as shown in Table 5), the significance of B or REA was reduced.

FIGURE 1 The relationship between longissimus muscle depth B measured directly on the carcass and ultrasonically on the live animal, shown as the cubic-fit regression line (with 99% confidence intervals) and as individual points for the 80 ram lambs.

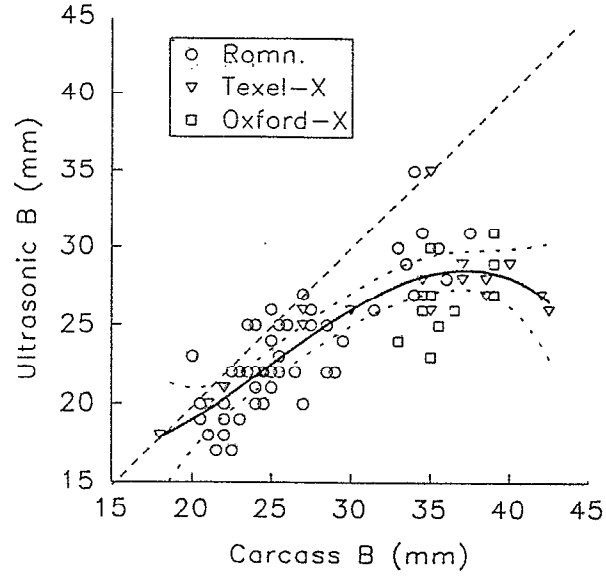

TABLE 5 The effectiveness with which variation in leg muscularity or leg muscle to bone ratio was accounted for by variation in carcass weight, breed differences, or cross-sectional dimensions of the longissimus muscle measured either ultrasonically on the live animal (US) or directly on the carcass (CC), as shown by coefficients of determination (R^2) or residual standard deviations (RSD). (N = 61).

Independent Variable(s)[a]	Dependent Variable: Leg M:B[b]		Leg Muscularity[b]	
	R^2 %	RSD	R^2 %	RSD
CW[c]	42.2	.86	26.9	.031
CW + BRD (***)	72.3	.61	61.9	.023
CW + Bcc (**)	51.8	.78	38.1	.029
CW + REAcc (***)	53.4	.78	41.6	.028
CW + Bcc (***) + BRD (***)	76.0	.57	65.2	.022
CW + REAcc (***) + BRD (***)	73.6	.60	63.0	.023
CW + Bus (**)	51.5	.80	35.7	.030
CW + REAus (*,**)[d]	48.4	.82	35.0	.030
CW + Bus (***) + BRD (***)	75.6	.58	65.2	.020
CW + REAus (***) + BRD (***)	74.1	.59	65.5	.022

[a] CW = Carcass weight
BRD = sire breed (Romney, Texel, Oxford)
Bcc, REAcc = Carcass longissimus muscle depth and area, respectively
Bus, REAus = Ultrasonic muscle depth and area
[b] Defined in footnotes with Table 1
[c] The carcass weight was highly significant in each case (***)
[d] "*" for M:B and "**" for muscularity

DISCUSSION

Prediction of Carcass Measures from Ultrasonic Measures

The ability of ultrasonic measures in this trial to explain an additional proportion of the variation in the corresponding carcass measures over and above the effect of carcass weight is at the low end of the ranges reported for other work. McEwan *et al.*, (1989) reported partial correlations between ultrasonic and carcass rib eye muscle depth B (after adjusting for liveweight) of 0.72 and 0.41 for two trials evaluating two different B-mode

scanners. In this trial a partial correlation of 0.40 was found between ultrasonic and carcass B. Areas of difference between this trial and the 1989 trial may have decreased the effectiveness of ultrasound in this trial. Water-filled offsets were not used, as a suitable type was not available for the Dynamic Imaging transducer. This may have led to compression of muscle depths/areas in the live animal due to higher pressures needed to keep the face of the transducer in contact with the skin. As depicted in Figure 1, this compression effect appeared to increase as the depth of the eye muscle increased. The carcasses in this trial had lower weight-adjusted C fat depths than the 5 mm reported by McEwan *et al.,* (1989). This thinner fat covering may have allowed more slack in the eye muscle in the chilled carcasses, causing greater variation when being measured. Finally, carcass weights were used to adjust for the effect of animal weight on the various measures in this trial, rather than liveweights as would be expected in a sheep selection trial. It might be expected that liveweight would not be as closely related to carcass measures as carcass weight because of the variability inherent in the relationship of liveweight to carcass weight. Thus when B or REA was adjusted to a constant liveweight rather than carcass weight there may tend to be an increase in the proportion of variation in carcass measures that was explained by ultrasonic measures.

Prediction of Leg Muscle:Bone Ratio and Muscularity from Ultrasonic Measures

In this trial, although the addition of either ultrasonic or carcass measures of rib eye area or depth did lead to a significant improvement in the prediction of carcass leg muscle:bone or index of muscularity over carcass weight alone, a significant breed effect still existed. This suggests that rib eye muscle dimensions are not strongly related to hindquarter muscularity, a finding which is in agreement with other work (Kadim *et al.,* 1989, Wolf *et al.,* 1981).

Rib eye area is an important carcass trait in itself, as it is known to have an influence on consumer purchasing decisions (Carpenter 1966). Therefore selection for rib-eye area using ultrasonic muscle depth B would improve carcass quality through improvements to carcass loin muscle depth; and would also have a small positive effect on hindquarter muscularity.

CONCLUSIONS

1. Leg muscling in terms of muscle to bone ratio as well as a muscularity index was clearly superior for Texel cross lambs, and was better in Romney than Oxford cross lambs. Differences in rib-eye area and depth(B) were less pronounced.
2. Ultrasonic measures of REA and B provided useful information on leg muscularity, but did not fully account for breed differences in this characteristic.
3. Ultrasonic muscle depth B was at least as useful as ultrasonic REA in predicting carcass REA or leg muscularity.

ACKNOWLEDGEMENTS

The authors thank Mr F Cameron and Lamb XL for the provision of sheep and help in taking live animal measurements.

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