

## New Zealand Society of Animal Production online archive

This paper is from the New Zealand Society for Animal Production online archive. NZSAP holds a regular annual conference in June or July each year for the presentation of technical and applied topics in animal production. NZSAP plays an important role as a forum fostering research in all areas of animal production including production systems, nutrition, meat science, animal welfare, wool science, animal breeding and genetics.

An invitation is extended to all those involved in the field of animal production to apply for membership of the New Zealand Society of Animal Production at our website [www.nzsap.org.nz](http://www.nzsap.org.nz)

[View All Proceedings](#)

[Next Conference](#)

[Join NZSAP](#)

The New Zealand Society of Animal Production in publishing the conference proceedings is engaged in disseminating information, not rendering professional advice or services. The views expressed herein do not necessarily represent the views of the New Zealand Society of Animal Production and the New Zealand Society of Animal Production expressly disclaims any form of liability with respect to anything done or omitted to be done in reliance upon the contents of these proceedings.

This work is licensed under a [Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License](https://creativecommons.org/licenses/by-nc-nd/4.0/).



You are free to:

**Share**— copy and redistribute the material in any medium or format

Under the following terms:

**Attribution** — You must give [appropriate credit](#), provide a link to the license, and [indicate if changes were made](#). You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

**NonCommercial** — You may not use the material for [commercial purposes](#).

**NoDerivatives** — If you [remix, transform, or build upon](#) the material, you may not distribute the modified material.

<http://creativecommons.org.nz/licences/licences-explained/>

## Relationships between objective and subjective measurements of carcass muscularity

A.Y.ABDULLAH, R.W.PURCHAS, A.S.DAVIES<sup>1</sup> AND A.H.KIRTON<sup>2</sup>

Department of Animal Science, Massey University, Palmerston North, New Zealand.

### ABSTRACT

Data from 95 lamb carcasses (2 data sets) and 90 bull carcasses were used to examine relationships between objective measures of carcass muscling and subjective scores of muscularity or conformation. Objective indexes calculated for lamb carcasses included muscle to bone ratios (M:B), muscularity indexes (MUSC) for both the leg and the whole side, the ratio of eye muscle depth to width (B:A), weight-adjusted eye muscle area and carcass weight per unit length. Similar variables were calculated for beef carcasses except that the weights of three commercial leg cuts were used in place of dissected muscle weights.

Leg MUSC had the closest relationships with subjective scores of muscularity or conformation ( $R^2\%$  = 69 to 80% for lambs and 56% for bulls), with leg M:B being only slightly inferior ( $R^2\%$  = 62% for lambs and 52% for bulls). Side MUSC or M:B were the next best as predictors, but variables based on the eye muscle were poor. Carcass weight per unit length showed close relationships with subjective scores in some cases but its usefulness is limited by the fact that it can be influenced by fatness and is breed related.

These results support the contention that measures of M:B may not always reflect muscularity scores because they are based on weights rather than depths and lengths. It is concluded that the objective measures of MUSC used here reflect subjective scores satisfactorily, given that subjective scores have limitations with respect to repeatability. MUSC based on the femur and the muscles or cuts surrounding it, in particular, may constitute a useful objective standard for use in the industry.

**Keywords:** lamb carcass, bull carcass, muscularity, conformation.

### INTRODUCTION

Carcass muscularity was defined by DeBoer *et al.*, (1974) as the thickness of muscle relative to skeletal dimensions, and conformation as the thickness of muscle and fat relative to skeletal dimensions. However, despite the existence of such clear definitions, objective measurements of muscularity have not been widely reported because of difficulties in measuring average muscle depth. Most information in this area is in terms of subjective scores (Kempster *et al.*, 1981; Colomer-Rocher *et al.*, 1980; Kirton *et al.*, 1983).

In previous studies, subjective muscularity and conformation scores have been evaluated on the basis of their relationships with various objective carcass measurements. Some workers have reported that cattle carcasses with better conformation have higher meat yields and greater muscle content (Martin *et al.*, 1966; Kempster & Harrington, 1980; Colomer-Rocher *et al.*, 1980) particularly when differences in fatness have been small or have been adjusted for statistically. Also, at the same carcass weight and fatness, carcasses with better conformation have been reported to have higher muscle to bone ratios (Cuthbertson *et al.*, 1972; Kempster, 1978), shorter hindquarters (Colomer-Rocher *et al.*, 1980) and greater *M.longissimus* depths (Kempster *et al.*, 1981, Kirton *et al.*, 1983).

Anous (1989) stated that muscle to bone ratio (M:B) offered an index of carcass muscling, but it may be unreliable

because, although a high M:B is often associated with superior muscularity (Dumont & Pouliquen, 1988; Young & Sykes, 1987), this will not necessarily be the case. Theoretically, a higher M:B ratio can be due to a lower bone weight per unit length rather than heavier muscles so that measures of muscularity as defined above may not differ even when quite large differences in M:B exist. Fisher & Bayntun (1981), for example, found that the ranking of four sheep breeds was different for conformation score (weight of lean per unit bone length) than M:B. They concluded that differences in bone shape rather than bone density were responsible, with some breeds having thinner bones than others. Young (1989) also showed in sheep that differences in bone weight per unit length were due to differences in bone shape rather than density.

In order to facilitate the study of muscularity, Purchas *et al.*, (1991) proposed an objective muscularity index based on a measure of muscle depth relative to a skeletal dimension. In this paper relationships between subjective scores of conformation or muscularity and objective indexes are reported.

### MATERIAL AND METHODS

#### Animals and carcass measurements

Data for this study came from two AgResearch-Ruakura experiments with lambs (data sets 1 and 2), and an experiment with bulls from Massey University (data set 3).

<sup>1</sup>Department of Physiology and Anatomy, Massey University, Palmerston North, New Zealand.

<sup>2</sup>AgResearch, Ruakura Agriculture Centre, Hamilton, New Zealand.

Data set 1 included information on the 26 carcasses described by Kirton *et al.*, (1983). Carcasses of unknown origin were selected by supervising graders of the New Zealand Meat Producers Board to represent three levels of muscling (well muscled, average muscled, and poorly muscled). Later, the authors assessed the carcasses for conformation on a 6-point British Meat and Livestock Commission (MLC) conformation scale (E, Av+, Av, Av-, C, and Z, where E is blockiest and Z is leggiest; Cuthbertson & Harrington, 1976). Carcass evaluation procedures in terms of linear measurements and physical dissection were described by Kirton *et al.*, (1983) except that additional muscle and bone weights and lengths are reported here.

Data set 2 included information on carcasses of 69 1981-born lambs that were processed at the Ruakura abattoir in January and April 1982 according to standard Ruakura procedures (Kirton & Pickering, 1967). The four breed and breed crosses involved were Perendale, Romney, Coopworth and Southdown x Romney. Assessments of MLC conformation on a 6-point scale were conducted as for data set 1. Linear measurements and all other carcass evaluation procedures including physical dissection were carried out according to standard Ruakura procedures (Kirton & Pickering, 1967; Kirton *et al.*, 1983) with some additional bone and muscle measurements being taken.

Data set 3 contained information from 90 bull carcasses including the weight and length of one femur bone and the weights of the three main commercial cuts from around the femur (knuckle, inside, and outside)(NZMPB, 1991) from both sides (Purchas *et al.*, 1992). The bulls included 30 each of Friesian, Piedmontese X Friesian, and Belgian Blue X Friesian. Carcass conformation was assessed using the 5-point MLC scale (Kempster *et al.*, 1982) by a supervising grader of the New Zealand Meat Producers Board.

### Calculation of derived variables

Variables chosen as potential objective measures of muscularity were those that measured differential growth and that would not change if growth involved no changes in the proportions of body parts (i.e., isometric growth).

Muscularity (as described by Purchas *et al.*, 1991) and muscle to bone ratio, respectively, were calculated from either (1) the weight of four leg muscles (*M.semimembranosus*, *M.semitendinosus*, *M.biceps femoris*, and *M.quadriceps femoris*) to femur length or weight (MUSC(FL); M:B(FW)), (2) the total muscle weight in the side to carcass length or total bone weight (MUSC(LB); M:B(TBWT)) or (3) the weight of three leg cuts (inside, knuckle, and outside) to femur length or weight (MUSC(CFL); M:B(CFW)).

Other indexes of shape included the ratio of eye muscle depth (B) to width (A) (B:A ratio) as an index of muscle depth, the ratio of eye-muscle area (EMA, cm<sup>2</sup>) raised to the power of 1.5 and carcass weight (EMA ratio), and the ratio of carcass weight (kg) to carcass length cubed (m) (CWT/L<sup>3</sup>).

### Statistical methods

The three data sets were analysed by general-least-squares procedures within the SAS computer programme (SAS Institute Inc. 1987). General-least-squares

models were used with conformation class as a discrete design variable and objective measures as dependent variables. Covariates were not included for the indexes described above but side weight was included as a covariate for some other variables as indicated below. Multiple comparisons between means were made using the "PDIFF" option within the "LSmean" statement in the "GLM" procedure of the SAS programme (SAS Institute Inc. 1987).

## RESULTS

Results for data sets 1 and 2 (Tables 1 and 2 respectively) are presented as two parts within each table. The first part of each table includes mainly ratios that are measures of differential growth, while the second part of each table includes characteristics that will change with both absolute and differential growth. The measures of absolute growth have been adjusted to a constant weight, but the measures of differential growth have not been because this may have removed some of the variation associated with differences in the subjective conformation or muscularity scores.

**TABLE 1:** Means for measures of muscularity, M:B and associated characteristics of lamb carcasses, which were subjectively placed into three muscling classes (data set 1).

Item	Muscling Class <sup>d</sup>			R <sup>2</sup> %	Side weight effect <sup>f</sup>
	1	2	3		
n <sup>c</sup>	7	7	12		
Variables not adjusted for weight:					
Side weight (kg)	6.8	6.6	5.9	11	
MUSC(LB)	0.072 <sup>a</sup>	0.069 <sup>b</sup>	0.064 <sup>c</sup>	64	
M:B(TBWT)	3.57 <sup>a</sup>	3.19 <sup>b</sup>	2.93 <sup>b</sup>	52	
EMA ratio	2.437 <sup>a</sup>	2.182 <sup>a</sup>	1.846 <sup>b</sup>	40	
B:A ratio	0.508 <sup>a</sup>	0.529 <sup>a</sup>	0.450 <sup>b</sup>	42	
CWT:L <sup>3</sup>	19.8 <sup>a</sup>	17.9 <sup>b</sup>	14.8 <sup>c</sup>	70	
MUSC(FL)	0.475 <sup>a</sup>	0.418 <sup>b</sup>	0.391 <sup>b</sup>	75	
Variables adjusted for weight:					
Femur length(mm)	142.5 <sup>a</sup>	150.3 <sup>b</sup>	159.1 <sup>c</sup>	66	NS
Eye muscle area(cm <sup>2</sup> )	9.8 <sup>a</sup>	9.0 <sup>ab</sup>	8.2 <sup>b</sup>	76	***
Muscle width A(mm)	51.6	49.8	51.1	44	***
Muscle depth B(mm)	25.9 <sup>a</sup>	26.1 <sup>a</sup>	23.4 <sup>b</sup>	76	***
Carcass length(mm)	860.0 <sup>a</sup>	888.0 <sup>b</sup>	942.0 <sup>c</sup>	85	***
Side muscle %	54.9	55.0	58.0	18	NS
Side fat %	29.6 <sup>a</sup>	27.6 <sup>a</sup>	22.1 <sup>b</sup>	36	NS

<sup>a,b,c</sup> Mean values in the same row with superscripts that do not contain a common letter differ significantly (P<.05).

<sup>d</sup> 1= good, 2=average and 3=poor.

<sup>e</sup> n= The number of animals for the different muscling classes for all variables except MUSC(FL) and femur length, were the number will be equal to 4, 5 and 9 for the muscling class 1, 2 and 3 respectively.

<sup>f</sup> NS= P>0.10; \*\*\*= P<0.001.

### Characteristics indicating differential growth.

Results in Tables 1 to 3 and Figures 1 and 2 show that for data sets 1,2, and 3 the better muscling and conformation classes had significantly higher mean muscularity indexes, M:B ratios, EMA ratios, B:A ratios, and CWT:L<sup>3</sup> ratios.

For data set 1 (Table 1) muscling class accounted for variation ranging from a high of 75% for MUSC(FL) to 40%

**TABLE 2:** Means for measures of muscularity, M:B and associated characteristics of lamb carcasses, which were subjectively placed into five conformation classes (data set 2).

Item	MLC Conformation Class <sup>e</sup>					R <sup>2</sup> %	Carcass weight effect <sup>f</sup>
	5	4	3	2	1		
Variables not adjusted for weight:							
n	13	18	26	6	6		
MUSC(LB)	0.074 <sup>a</sup>	0.070 <sup>b</sup>	0.066 <sup>c</sup>	0.064 <sup>c</sup>	0.061 <sup>d</sup>	58	
M:B(TBWT)	3.84 <sup>a</sup>	3.43 <sup>b</sup>	3.12 <sup>c</sup>	3.04 <sup>c</sup>	2.65 <sup>d</sup>	53	
EMA ratio	2.478 <sup>a</sup>	1.977 <sup>b</sup>	1.702 <sup>bc</sup>	1.681 <sup>bc</sup>	1.474 <sup>c</sup>	52	
B:A ratio	0.589 <sup>a</sup>	0.521 <sup>b</sup>	0.514 <sup>b</sup>	0.497 <sup>b</sup>	0.473 <sup>b</sup>	31	
CWT:L <sup>3</sup>	21.6 <sup>a</sup>	19.3 <sup>b</sup>	17.1 <sup>c</sup>	17.1 <sup>cd</sup>	15.0 <sup>d</sup>	55	
Variables adjusted for weight:							
Eye muscle area(cm <sup>2</sup> )	10.9 <sup>a</sup>	9.3 <sup>b</sup>	8.3 <sup>c</sup>	8.3 <sup>c</sup>	7.6 <sup>c</sup>	79	***
Muscle width A(mm)	52.6 <sup>a</sup>	51.6 <sup>a</sup>	49.3 <sup>b</sup>	49.9 <sup>ab</sup>	48.2 <sup>b</sup>	29	***
Muscle depth B(mm)	29.1 <sup>a</sup>	26.8 <sup>b</sup>	25.2 <sup>c</sup>	25.2 <sup>c</sup>	23.9 <sup>c</sup>	82	***
Femur weight(g)	95.9 <sup>a</sup>	104.9 <sup>b</sup>	114.8 <sup>c</sup>	118.4 <sup>c</sup>	124.1 <sup>c</sup>	46	***
Femur length(mm)	144.5 <sup>a</sup>	152.0 <sup>b</sup>	157.9 <sup>c</sup>	159.8 <sup>cd</sup>	164.4 <sup>d</sup>	56	***
Carcass length(mm)	886.5 <sup>a</sup>	903.2 <sup>b</sup>	927.7 <sup>c</sup>	945.3 <sup>cd</sup>	959.5 <sup>d</sup>	72	***

<sup>a,b,c,d</sup> See footnotes to Table 1.

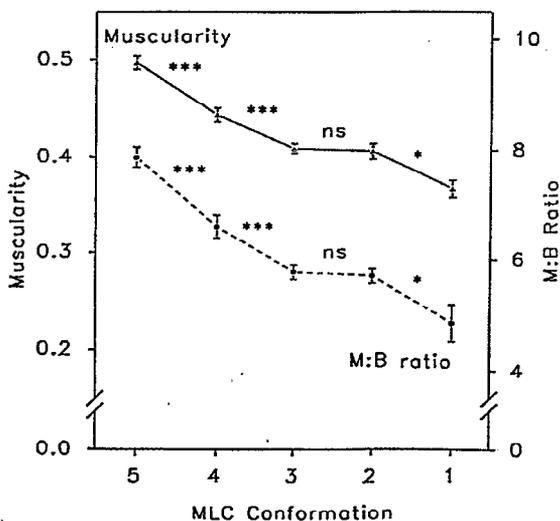
<sup>e</sup> 5 represents the best conformation.

<sup>f</sup> \*\*\*=P<0.001.

for EMA ratio. Thus, the ranking of the variables as predictors of muscling class based on R<sup>2</sup> values was: MUSC(FL)>CWT:L<sup>3</sup> ratio>MUSC(LB)>M:B(TBWT)>B:A ratio>EMA ratio. Similar patterns were found when the carcasses were assessed according to the five MLC conformation classes (data not shown).

Relationships between subjective scores and objective muscling indexes for data set 2 (Table 2 and Figure 1) showed that MLC conformation class generally explained less variation than for data set 1 (Table 1). R<sup>2</sup>(%) values for MUSC(FL) and M:B(FW) were 69% and 62% respectively, so that the ranking of predictors in terms of R<sup>2</sup> was similar with MUSC(FL)> M:B(FW)> MUSC(LB)> CWT:L<sup>3</sup> ratio>M:B(TBWT)> EMA ratio> B:A ratio.

**FIGURE 1:** Mean (± SE) leg muscularity indexes (MUSC(FL)) and muscle to bone ratios (M:B(FW)) for 5 MLC lamb conformation classes (data set 2). The significance of differences between adjacent means are shown (NS=P>0.10; \*P<0.05; \*\*\*P<0.001).



Results for bull carcasses (Table 3) showed that a move from the best conformation [E] class to the poorest conformation [O] class was accompanied by decreases in means for carcass weight, six-cut yield, dressing-out percentage and in CWT:L<sup>3</sup> ratio. Relationships of subjective scores with indexes of muscling were generally lower than those for lamb carcasses. R<sup>2</sup>(%) values for MUSC(CFL) and M:B(CFW) were 56% and 52% respectively, so that the ranking of indexes was similar in terms of R<sup>2</sup>% values with MUSC(CFL)> M:B(CFW)> CWT:L<sup>3</sup> ratio.

**TABLE 3:** Means for measures of muscularity, M:B and associated carcass characteristics of bull carcasses, which were subjectively placed into four conformation classes (data set 3).

Item	MLC Conformation Class <sup>e</sup>					R <sup>2</sup> %
	E	U	R	O	P	
Variables not adjusted for weight:						
n	2	28	50	10	0	
Carcass weight(kg)	297.8 <sup>ab</sup>	315.0 <sup>b</sup>	291.1 <sup>ab</sup>	264.5 <sup>a</sup>	-	17
CWT/L <sup>3</sup>	35.69 <sup>a</sup>	34.04 <sup>a</sup>	30.44 <sup>b</sup>	26.88 <sup>c</sup>	-	49
Yield of 6 cuts(%) <sup>f</sup>	26.2 <sup>a</sup>	24.0 <sup>b</sup>	23.3 <sup>bc</sup>	22.5 <sup>c</sup>	-	31
Dressing-out %	61.1 <sup>a</sup>	57.8 <sup>b</sup>	55.2 <sup>c</sup>	52.0 <sup>d</sup>	-	45

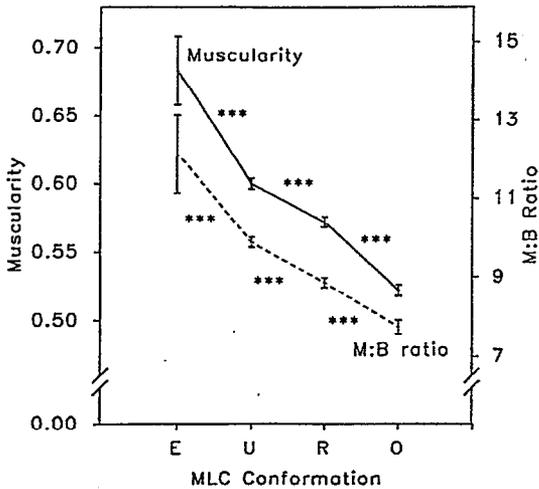
<sup>a,b,c,d</sup> See footnotes to Table 1.

<sup>e</sup> E represents the best conformation.

<sup>f</sup> knuckle+inside+outside+tenderloin+striploin+D-rump.

Relationships amongst measures of muscularity, M:B ratios, B:A ratios, EMA ratios and CWT:L<sup>3</sup> ratios for data sets 1,2, and 3 are shown in terms of R<sup>2</sup>% values in Table 4. Relationships were closest between the M:B ratios and muscularity indexes and the poorest relationships were with B:A ratio. Relationships between MUSC and M:B were not significantly different between conformation classes.

**FIGURE 2:** Mean ( $\pm$  SE) leg muscularity indexes (MUSC(CFL)) and muscle to bone ratios (M:B(CFW)) for 4 MLC beef conformation classes (data set 3). The significance of differences between adjacent means are shown (\*\*\*) $P < 0.001$ .

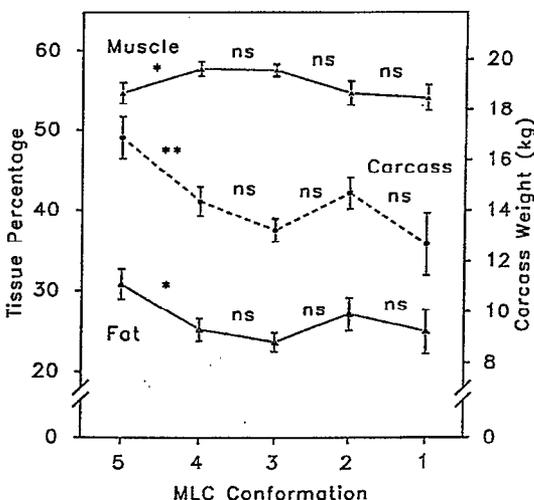


### Characteristics indicating absolute growth.

For data set 1 (Table 1), better-muscling classes had significantly larger eye muscle areas, deeper muscle depths (B), and lower length measurements (femur and carcass length). Side muscle percentage did not differ between the muscling classes, but side fat percent increased from worst to best muscling class.

Results for data sets 1 and 2 were similar except that better conformation was associated with wider eye muscles (A), and higher weight-adjusted side muscle percent in data set 2 only, apparently because better conformation was accompanied by higher side fat percent in data set 1 to a greater extent than for data set 2 (Table 1 and Figure 3).

**FIGURE 3:** Mean ( $\pm$  SE) carcass weights and carcass muscle and fat percentage 5 for 5 MLC lamb conformation classes (5=best conformation) (data set 2). Percentage values have not been adjusted for carcass weight. The significance of differences between adjacent means are shown (NS= $P > 0.10$ ; \*= $P < 0.05$ ; \*\*= $P < 0.01$ ).



For the two lamb data sets most of the variation in carcass muscle percent was accounted for by variation in

carcass fat percent ( $R^2\% = 86$  and  $85$  for data sets 1 and 2, respectively), but when MUSC(FL) was fitted after fat percent in multiple regression equations significant positive relationships were found ( $P < 0.001$ ,  $R^2\% = 96$  and  $95$  for data sets 1 and 2, respectively). For data set 3 all carcasses were very lean and a moderately close positive relationship between MUSC(CFL) and 6-cut yield percent was found ( $R^2\% = 38$ ). For all three data sets, measures of M:B accounted for a similar proportion of variation in muscle percent as measures of muscularity.

Interactions between the appropriate covariates and subjective scores were not significant for any of the characteristics analysed.

## DISCUSSION

### Carcass shape and muscularity or muscle to bone ratio

Subjective scores of muscling or conformation were more closely related to indexes based on ratios of the thickness of muscle relative to skeletal dimensions than any other objective index. The muscularity index calculated from the weight of four leg muscles and femur length MUSC(FL4) had the closest relationships with subjective scores, possibly because these four leg muscles are closely associated with the femur bone and because the measurement of the femur bone length can be made more accurately than the measurement of carcass length. Also the individual muscles were probably more accurately weighed than the total side muscle or the 6 commercial cuts because the four muscles chosen were relatively large and were easily dissectible anatomical entities. Finally, the relationships may have been closer because the femur region is one of the main regions assessed when conformation scores are given.

Relationships between muscle to bone ratios (M:B) and subjective scores were not as close as for MUSC indexes indicating that the two variables were not measuring the same characteristic. Studies of Kempster *et al.*, (1981) for sheep, and Kempster (1978) for cattle, showed that measures of conformation were not always closely related to M:B ratio, especially when animals from different breeds were being compared. Kempster (1978) suggested that the poor relationships between the breeds of cattle resulted from differences in bone structure and density. However, Purchas *et al.*, (1991) noted that the breed differences discussed by Kempster (1978) could have arisen from bones with different diameters. Kempster & Cuthbertson (1977) reported that 7-point carcass conformation scores for lambs were poorly related ( $R^2\% = 13$ ) to lean to bone ratio. Similar results were given by Harries *et al.*, (1974), Dolezal *et al.*, (1982), and Muller *et al.*, (1989). Relationships between objective indexes of muscularity and M:B reported here (Table 4) were moderately close, however.

### Carcass shape and eye muscle dimensions

Poor relationships between B:A ratios or EMA ratios and subjective scores may be partially explained by the inaccuracies associated with linear and area measurements taken on the cut surface of *M. longissimus*, compared with

**TABLE 4:** Relationships between selected measurements made on carcasses (data sets 1,2, and 3) in terms of coefficients of determination ( $R^2\%$ ).

Item	DS1		DS2		DS3	
	M:B(TBWT)	MUSC(FL)	M:B(FW)	MUSC(FL)	M:B(CFW)	MUSC(CFL)
MUSC(FL)	53	-	85	-		
MUSC(LB)	53	79	79	76		
M:B(TBWT)	-	53	88	76		
EMA ratio	66	45	52	55		
B:A ratio	15	3	49	37		
CWT:L <sup>3</sup>	50	67	74	71	52	46
MUSC(CFL)					64	

measurements of muscle weights and bone lengths. Kempster & Cuthbertson (1977) found that a 7-point lamb carcass conformation score was poorly related to eye muscle area ( $R^2\% = 18$ ). Similar results for cattle were reported by Apple *et al.*, (1991) and Kempster & Harrington (1980).

In this study, lamb carcasses with better conformation or muscling at a set weight had larger eye muscle areas, deeper muscle depths (B), and similar or wider muscle widths (A), which is in general agreement with the results of Martin *et al.*, (1966), Kirton & Pickering (1967), Kirton *et al.*, (1983), and Williams *et al.*, (1989). Also, the association of higher eye muscle areas with shorter carcass lengths agrees with the suggestion of Butterfield (1965) that, at the same weight, shorter carcasses have bigger eye muscle areas.

### Carcass shape and carcass length

Carcass weight per unit length was quite closely related to subjective scores in some cases, but this ratio can be affected by fat weight in the carcass, which may be why  $R^2$  values were higher for data set 1 than for the other two data sets. Lindsay *et al.*, (1978) studied the relationships between beef side length and a 7-point subjective score, and showed that longer sides within weight groups had a thinner shape. In that study correlations between objective and subjective scores were not reported, but it was concluded that side length may be used as an objective indicator of carcass shape. Kadim *et al.*, (1989) also indicated that carcasses from a high-fat selection line, that had higher muscularity values than a low-fat line at a set weight, also had shorter carcasses and femurs.

For all three data sets, the indications that better carcass conformation or muscling at a set weight were associated with shorter carcasses and femurs at the same weight are consistent with results of other studies with sheep (Kirton & Pickering, 1967; Jackson & Mansour, 1974) and cattle (Colomer-Rocher *et al.*, 1980).

### Carcass shape and percent meat yield

Carcass meat yield is determined by trimmed fat percent and meat to bone ratio. In order for muscularity to be closely related to meat yield it must be closely related to muscle to bone ratio and variation in trimmed fat percent must account for only a small proportion of the variation in meat yield.

Significant group differences were found in side muscle percentage or yield of 6 cuts in data sets 2 and 3 but not in data set 1. For all three data sets in this study higher values of

MUSC indexes were significantly associated with higher yields of muscle or meat cuts, although for the lamb data this relationship was only apparent after adjusting for differences in fat percent. Differences between conformation classes for muscle percentage have also been reported by Colomer-Rocher *et al.*, (1980) in cattle. They found that the concave carcasses had the lowest percentage of meat and the highest percentage of fat at the same carcass weight when the carcasses were classified according to MLC conformation classes.

Garrett *et al.*, (1992), in contrast, reported a correlation of only -0.12 between measures of lamb leg conformation and the yield of cuts trimmed to 0.25cm. Kempster *et al.*, (1982) in a review of the relationships between conformation and meat yield concluded that 'fat-corrected' conformation is not a valuable predictor of carcass composition in sheep. Apple *et al.*, (1991) found that hindquarter muscling score in beef carcasses was significantly but poorly related to percentage of retail product trimmed to 0.76cm of fat ( $R^2\% = 2$ ). In an experiment with dissected carcasses from beef, Kempster & Harrington (1980) reported that the relationship between a 5-point conformation scale and carcass lean percentage was low ( $R^2\% = 8$ ), both at equal carcass subcutaneous fat percentage (SF%) and when both SF% and carcass weight were held constant. Similar results were reported in cow carcasses by Harries *et al.*, (1974) and Muller *et al.*, (1989).

### Repeatability of subjective scores

The closeness of relationships between objective and subjective measurements will be limited by the repeatability with which visual appraisals can be made. Repeatability can be improved with training and experience (Harries *et al.*, 1974), and the use of well-designed score cards (Williams, 1972) or photographic standards (DeBoer & Nijeboer, 1973) can help, but the subjective element will mean that objective/subjective relationships will never be perfect.

### CONCLUSION

From a selection of objective measures of carcass shape, the muscularity index based on the depth of muscles surrounding the femur relative to femur length appeared to be most closely related to subjective scores of muscling or conformation of lamb and beef carcasses.

Other objective measures, including M:B, weight adjusted eye-muscle area, and carcass weight per unit length, appear to be less useful.

It is suggested that the MUSC index, based on the femur and the muscles or cuts surrounding it, may constitute a useful objective standard for use in training and calibrating carcass graders in the industry.

## REFERENCES

- Anous, M.R. 1989. Relationship between muscle and bone development of the hind limbs of different breeds. *Animal production* **48**: 121-129.
- Apple, J.K.; Dikeman, M.E.; Cundiff, L.V.; Wise, J.W. 1991. Determining beef carcass retail product and fat yields within 1 hour postmortem. *Journal of animal science* **69**: 4845-4857.
- Butterfield, R.M. 1965. Practical implications of anatomical research in beef cattle. *Proceedings of the New Zealand Society of Animal Production* **25**: 152-263.
- Colomer-Rocher, F.; Bass, J.J.; Johnson, D.L. 1980. Beef carcass conformation and some relationships with carcass composition and muscle dimensions. *Journal of agricultural science, Cambridge* **94**: 697-708.
- Cuthbertson, A.; Harrington, G.; Smith, R.J. 1972. Tissue separation - to assess beef and lamb variation. *Proceedings of the British Society for Animal Production (New Series)* **1**: 113-122.
- Cuthbertson, A.; Harrington, G. 1976. The MLC sheep carcass classification scheme. Proceedings of the Carcass Classification Symposium, Adelaide, May 1976, Australian Meat Board, Sydney, Paper S2, 22pp.
- DeBoer, H.; Dumont, B.L.; Pomeroy, R.W.; Weniger, T.H. 1974. Manual on E.A.A.P. reference methods for the assessment of carcass characteristics in cattle. *Livestock production science* **1**: 151-164.
- DeBoer, H.; Nijeboer, H.; 1973. Stereo diapositives as an aid in carcass assessment. *World review of animal production* **9**(3): 51-57.
- Dolezal, H.G.; Murphey, C.E.; Smith, G.C.; Carpenter, Z.L. 1982. Muscle:Bone ratios in beef rib sections. *Meat science* **6**: 55-64.
- Dumont, B.L.; Pouliquen, O. 1988. Morphological traits of femur and tibia in relation to fleshiness (muscle/bone ratio) in lambs. In: *Proceeding 3rd World Congress on Sheep and Cattle Breeding*, (INRA Publ., Paris) Volume (1) pp.477-479.
- Fisher, A.V.; Bayntun, J.A. 1981. Differences between sheep breeds in the growth of the limb bones and the development of conformation. *Animal production* **32**: 376(abst.).
- Garrett, R.P.; Edwards, J.W.; Savell, J.W.; Tatum, J.D. 1992. Evaluation of the Hennessy grading probe to predict yields of lamb carcasses fabricated to multiple end points. *Journal of animal science* **70**: 1146-1152.
- Harries, J.M.; Pomeroy, R.W.; Williams, D.R. 1974. Composition of beef carcasses, III. The reliability and use of visual assessment. *Journal of agricultural science, Cambridge* **83**: 203-211.
- Jackson, T.H.; Mansour, Y.A. 1974. Differences between groups of lamb carcasses chosen for good and poor conformation. *Animal production* **19**: 93-105.
- Kadim, I.T.; Purchas, R.W.; Rae, A.L.; Barton, R.A. 1989. Carcass characteristics of Southdown rams from high and low backfat selection lines. *New Zealand journal of agricultural research* **32**: 181-191.
- Kempster, A.J. 1978. Bone growth and development with particular reference to breed differences in carcass shape and lean to bone ratio. Pp.149-166 In: Patterns of growth and development in cattle. H. DeBoer and J. Martin (Ed.). *Current Topics in Veterinary Medicine* **2**, Martinus Nijhoff, The Hague.
- Kempster, A.J.; Croston, D.; Jones, D.W. 1981. Value of conformation as an indicator of sheep carcass composition within breeds. *Animal production* **33**: 39-49.
- Kempster, A.J.; Cuthbertson, A. 1977. A survey of the carcass characteristics of the main types of British lamb. *Animal production* **25**: 165-179.
- Kempster, A.J.; Cuthbertson, A.; Harrington, G. 1982. The relationship between conformation and yield and distribution of lean meat in the carcasses of British pigs, cattle and sheep: A review. *Meat science* **6**: 37-53.
- Kempster, A.J.; Harrington, G. 1980. The value of conformation as an indicator of beef carcass composition within and between breeds. *Livestock production science* **7**: 361-372.
- Kirton, A.H.; Pickering, F.S. 1967. Factors associated with differences in carcass conformation in lamb. *New Zealand journal of agricultural research* **10**: 183-200.
- Kirton, A.H.; Woods, E.G.; Duganzich, D.M. 1983. Comparison of well and poorly muscled lamb carcasses as selected by experienced meat industry personnel. Proceedings of the New Zealand Society of Animal production **43**: 111-113.
- Lindsay, J.A.; English, P.R.; Dempster, D.G.; Broadbent, P.J. 1978. The effect of variation in length on carcass components in Friesian steers. *Proceedings of the Australian Society of Animal Production* **12**: 241.
- Martin, E.L.; Walters, L.E.; Whiteman, J.V. 1966. Association of beef carcass conformation with thick and thin muscle yields. *Journal of animal science* **25**: 682-687.
- Muller, L.; Palmer, A.Z.; West, R. 1989. The effect of carcass muscling on yield of edible portion of cull cow carcasses. *Proceedings of European Meeting of Meat Research Workers* **35**: 226-232.
- NZMPB, 1991. New Zealand meat trade guide. New Zealand Meat Producers Board, Wellington.
- Purchas, R.W.; Davies, A.S.; Abdullah, A.Y. 1991. An objective measure of muscularity: changes with animal growth and differences between genetic lines of Southdown sheep. *Meat science* **30**: 81-94.
- Purchas, R.W.; Morris, S.T.; Grant, D.A. 1992. A comparison of characteristics of the carcasses from Friesian, Piedmontese x Friesian, and Belgian Blue x Friesian bulls. *New Zealand journal of agricultural research* **35**: 401-409.
- SAS Institute Inc. 1987: SAS User's Guide. Statistics, Version 6 Edition. SAS Institute Inc., Cary, NC. U.S.A.
- Williams, D.R. 1972. Visual assessment of beef and lamb. *World review of animal production* **8**(2): 87-97.
- Williams, S.E.; Tatum, J.D.; Stanton, T.L. 1989. The effects of muscle thickness and time on feed on hot fat trim yields, carcass characteristics and boneless subprimal yields. *Journal of animal science* **67**: 2669-2676.
- Young, M.J.; Sykes, A.R. 1987. Bone growth and muscularity. *Proceedings of the New Zealand Society of Animal Production* **47**: 73-75.
- Young, M.J. 1989. The influence of changes in tissue shape on muscle:bone ratio in growing sheep. *Animal production* **48**: 635(abst.).