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Expected responses in carcass composition to selection for muscularity in sheep

D.F. WALDRON, J.N. CLARKE, A.L. RAE[1] AND E.G. WOODS

AgResearch, Ruakura Agricultural Centre, Private Bag 3123, Hamilton, New Zealand.

ABSTRACT

Objective measures of muscularity were calculated for 1602 Romney and Romney-cross carcasses which were the progeny of 102 sires. Muscularity was defined as a measure of muscle thickness relative to carcass length. Phenotypic and genetic parameters were calculated from REML estimates of variance and covariance components. Different measures of muscularity had genetic correlations with one another between .48 and .84 and phenotypic correlations between .30 and .62. Measures of muscularity had high heritability (.40 to .68), positive genetic correlations with weight of carcass lean (.32 to .53) and carcass weight (.08 to .32), and negative genetic correlations with carcass fat (-.06 to -.33), and carcass length (-.11 to -.30). Single trait selection on muscularity was expected to result in increased lean and decreased fat. Selection on some of the muscularity measures was expected to result in increased subcutaneous fat. When the breeding objective gave positive emphasis to lean weight and negative emphasis to fat weight and the selection criteria were carcass weight and a muscularity measure, the muscularity measure that gave the greatest economic response to selection was that which used the longissimus muscle width (A) as a measure of muscle thickness.

Keywords Carcass, sheep, genetic parameters.

INTRODUCTION

The need for a useful definition of muscling for lamb carcasses was suggested by Kirton *et al.*, (1983). They showed that well muscled carcasses, according to subjective visual assessment, were associated with a higher muscle to bone ratio and a higher fat to muscle ratio. Conformation was also assessed on the carcasses and the MLC conformation scale clearly separated the carcasses into groups matching the muscling classification. This suggests that the visual assessment of muscling is, in effect, closely related to visual assessment of conformation. Kempster *et al.*, (1981) concluded that a visual assessment of better conformation of carcasses that varied in fatness, as would be the case in commercial practice, was associated with increased fatness. From these results it seems probable, as suggested by Kirton *et al.*, (1983), that if the market rewards good conformation carcasses or well muscled carcasses, based on visual assessment, there will be an undesirable associated increase in fatness.

One purpose of using the concept of muscularity is to describe carcass muscle content relative to the size of carcass. Size, as used here, is a function of skeletal dimension. A working definition of muscularity for cattle was given as 'thickness of muscle relative to dimensions of skeleton' by De Boer *et al.*, (1974). An objective measure of muscularity in sheep based on this definition has been proposed by Purchas *et al.*, (1991). They concluded that differences in muscularity, by this definition, were not always accompanied by differences in muscle to bone ratio. They also used data from a sample of Southdown rams from divergent backfat selection lines to show that muscularity was higher in the high-backfat line rams. Thus, there is evidence that animals that have desirable muscling or muscularity also have an undesirable greater amount of fat.

The New Zealand Meat Producers Board plans to introduce a muscling class or conformation grade for lamb carcasses from 1 October 1992 to recognize heavier muscled lambs. This class will be introduced for carcasses that are 13.3 kg or greater with 12 mm or less GR. It is important to the meat industry to have knowledge of both genetic and phenotypic relationships among muscularity and other important carcass traits. Selection for an objective measure of muscularity may also produce correlated responses in other traits. The purpose of this study was to 1) quantify relationships among carcass traits and muscularity, 2) estimate the genetic and phenotypic parameters needed to utilize an objective measure of muscularity in a selection index and 3) predict direct and correlated responses to selection for greater muscularity.

MATERIALS AND METHODS

Carcass data were obtained from 1602 Romney and Romney-cross carcasses which were dissected as part of the Wiremu Lean Lamb selection project between 1982 and 1984. Age at slaughter averaged 205 days (range 141 to 253). The carcasses represented 102 sires of the Romney (60 sires), Border Leicester (18 sires), Poll Dorset (14 sires) and Coopworth (10 sires) breeds. All dams were commercial New Zealand Romney ewes. Animal rearing and slaughtering procedures and details of carcass measurements were given by Waldron *et al.*, (1992).

Muscularity was defined as a measure of muscle thickness relative to skeletal size. Carcass length (CL, Moxham and Brownlie, 1976) provided a measure of overall skeletal size and was used as an indicator of muscle length because no direct measure of muscle length was available. Muscle thickness measurements that were used were the width (A) and depth (B) of the longissimus muscle measured at the cut surface at the last thoracic vertebra (Palsson, 1939). Muscularity values, MA and MB were calculated by dividing A and B by CL. In addition, an approximation of muscle thickness was obtained by taking the square root of (muscle weight/carcass length) for the longissimus muscle (LM) and the psoas major muscle (PM) as suggested by Purchas *et al.*, (1991). Muscularity values ML and MP were calculated as approximated thickness of LM and PM divided by CL.

[1] Professor Emeritus, Massey University, Palmerston North, New Zealand.

Variances and covariances were estimated using multivariate REML via an EM-type algorithm of Henderson (1984). The model included fixed effects for breed of sire, sex, birth rank, pre-weaning grazing mob and slaughter group, a covariate for day of birth and random effects for sire and residual. Heritability was estimated as four times the estimated sire variance divided by the estimated phenotypic variance.

The traits analyzed were the four measures of muscularity, (MA, MB, ML and MP) weight of dissectible carcass lean (LEAN), weight of dissectible carcass fat (FAT), carcass length (CL), hot carcass weight (HCW), GR and muscle to bone ratio (M:B).

Direct and correlated responses to selection for muscularity were predicted. Selection responses to two trait index selection, where HCW and a measure of muscularity were the selection criteria with increased LEAN plus decreased FAT as the selection objective, were calculated using relative economic values of 1.25 for LEAN and -1 for FAT (Waldron *et al.,* 1991).

RESULTS

Means and phenotypic variation are shown in Table 1. Muscle weights and measurements have been included for reference. The range of coefficients of variation goes from 3.6% for CL to 35.4% for GR. The four muscularity measures had a narrow range of coefficients of variation, 5.7% (MA) to 8.8% (MB). Longissimus width is an earlier maturing dimension than depth (Young 1990), which may be a factor causing CV of MA to be smaller than that of MB.

Estimated genetic and phenotypic parameters are shown in Table 2. The four measures of muscularity had genetic correlations with one another between .48 and .84 and phenotypic correlations between .30 and .62.

For each pair of muscularity measures the genetic correlation was greater than the phenotypic correlation. The pair with the smallest correlations was MA and MB. The pair with the highest correlations was ML and MB. Measures of muscularity had high heritability, .40 to .68. The heritability values for muscularity were each greater than the heritability estimate of their corresponding weight or measurement (Waldron *et al.,* 1992), i.e. MA had a greater heritability than A and ML had a greater heritability than weight of longissimus muscle. Muscularity measures had positive genetic correlations with weight of carcass lean (.32 to .53), and carcass weight (.08 to .32) and negative genetic correlations with carcass fat (-.06 to -.33), and carcass length (-.11 to -.30). Each of the four measures of muscularity was positively correlated with M:B (.48 to .67 genetic and .18 to .49 phenotypic). The muscularity measure that was the least correlated with M:B was MA. MA was also the only trait that had a negative phenotypic correlation with FAT.

Expected responses to a standard deviation of selection are presented in Table 3 for HCW and each of the four measures of muscularity. Calculations were based on parameter estimates from Table 2. Substantial progress is obtainable because of the

TABLE 1 Means[a] and variances[b] of carcass weights and measures.

Trait	Mean	σ^2_p	σ_p	CV%[c]
LEAN,kg	7.83	.99	.99	12.7
FAT,kg	3.05	.60	.77	25.4
A,mm	51.2	10.3	3.21	6.3
B,mm	26.7	6.20	2.50	9.3
LM,kg	.73	.013	.11	15.6
PM,kg	.13	.00037	.019	14.8
MA[d]	53.8	9.48	3.08	5.7
MB[e]	28.0	6.03	2.45	8.8
ML[f]	9.2	.31	.56	6.1
MP[g]	38.5	5.90	2.43	6.3
HCW,kg	14.6	3.57	1.89	12.9
CL,cm	95.1	12.04	3.5	3.6
GR,mm	6.8	5.80	2.41	35.4
M:B	3.27	.093	.306	9.3

[a] Raw unadjusted mean
[b] the sum of the estimated sire and residual variances
[c] CV = coefficient of variation
[d] $MA = 10^2 \times (A / CL)$
[e] $MB = 10^2 \times (B / CL)$
[f] $ML = 10^4 \times \mathrm{sqrt}(LM / CL) / CL$
[g] $MP = 10^5 \times \mathrm{sqrt}(PM / CL) / CL$

TABLE 3 Expected response to one standard deviation of selection on each of four objective measures of muscularity.

Criteria	Direct response, (% of mean)		Correlated response LEAN,kg	FAT,kg	HCW,kg	GR,mm	M:B
ML	.22	(2.4)	.20	-.04	.19	.06	.80
MP	1.31	(3.4)	.16	-.11	.06	-.04	.78
MA	2.10	(3.9)	.18	-.11	.08	-.26	.75
MB	1.05	(3.7)	.13	-.02	.12	.14	.78
HCW	.50	(3.4)	.28	.15	.50	.38	.42

TABLE 2 Genetic and phenotypic parameters[a] of carcass traits.

Trait[b]	LEAN	FAT	ML	MP	MA	MB	CL	HCW	GR	M:B
LEAN	<u>.38</u>	.62	.53	.35	.16	.36	.74	.91	.50	.43
FAT	.24	<u>.32</u>	.30	.05	-.09	.25	.57	.84	.81	.31
ML	.53	-.13	<u>.40</u>	.59	.44	.62	.02	.42	.35	.49
MP	.36	-.33	.81	<u>.54</u>	.32	.36	-.12	.20	.16	.34
MA	.35	-.31	.72	.56	<u>.68</u>	.30	-.15	.05	-.02	.18
MB	.32	-.06	.84	.53	.48	<u>.43</u>	-.01	.32	.31	.35
CL	.70	.40	-.11	-.30	-.14	-.18	<u>.43</u>	.79	.34	.13
HCW	.88	.65	.32	.08	.09	.18	.77	<u>.26</u>	.67	.38
GR	.29	.83	.08	-.04	-.25	.17	.21	.60	<u>.27</u>	.37
M:B	.60	.09	.67	.56	.48	.62	.03	.43	.33	<u>.39</u>

[a] Phenotypic correlations above the diagonal, genetic correlations below the diagonal, heritabilities on diagonal
[b] See text for trait definitions

high heritability of muscularity even though the coefficients of variation were relatively low. Single trait selection on these measures of muscularity was expected to result in correlated responses of increased HCW, M:B, LEAN and decreased FAT. Muscularity measures MP and MA also gave a decrease in GR whereas ML and MB gave increases in GR. The correlated increase in HCW was 12 to 38% of that expected from selection on HCW alone.

When the breeding objective was (1.25 x LEAN) minus FAT and the selection criteria were HCW and one of the four muscularity measures, the muscularity measure that gave the greatest economic response to selection was that which used the longissimus muscle width, A, as a measure of muscle thickness (Table 4). The response from this index compared to selection on HCW alone gave a greater response in LEAN along with a decrease in FAT, in contrast to the increase in FAT expected from selection on HCW. This suggests that the measure of muscularity was discriminating between lean, heavy animals and merely heavy animals.

TABLE 4 Expected responses to one standard deviation of selection on two trait indices that include hot carcass weight when the selection objective is lean weight minus fat weight.

Criteria	Response		
	LEAN,kg	FAT,kg	Economic[a]
HCW + ML	.25	.01	.30
HCW + MP	.25	-.02	.34
HCW + MA	.28	-.02	.38
HCW + MB	.26	.09	.23

[a] = (1.25 x LEAN) - FAT

DISCUSSION

The most striking difference between selection on muscularity and selection on HCW is the different correlated responses in FAT. Selection for muscularity is expected to produce a desirable increase in LEAN and a desirable decrease in FAT. However, the muscularity measures, ML and MB are expected to produce a correlated increase in GR, which is largely a measure of subcutaneous fat. The New Zealand lamb carcass schedule has provided a financial incentive to avoid high GR values (Waldron *et al.*, 1991). The penalty for marketing lambs that fall in the T or F grades has been substantial. If ML or MB were used as selection criterion there would have to be a financial incentive to offset the expected loss from the penalties associated with increased GR.

These expected responses to selection were calculated with parameters estimated from data on Romney cross carcasses with an average age of seven months and should be validated in other populations. There may be important differences associated with rate of maturity of muscle dimensions A and B (Young 1990). Responses to selection (Tables 3 and 4) showed that MB did not provide the discrimination between LEAN and FAT that MA did. An increase in the muscle weights and dimensions presented here may not imply greater thickness of leg muscles used by Purchas *et al.*, (1991). However, Waldron *et al.*, (1992) reported positive genetic and phenotypic correlations among A, B and the weight of lean tissue in the leg joint.

The expected responses presented were calculated as if the muscle weights or dimensions and carcass length could be measured in the live animal. Technological advances may soon make this feasible for commercial situations. Presently the alternatives are progeny tests of sires and ultrasound measurements of muscle dimensions in live animals. Repeatability of live animal ultrasound measurements of longissimus muscle width, A, has been reported as less than that for muscle depth (McEwan *et al.*, 1989). Further research is required in this area in order to have reliable genetic parameters for the ultrasound measurements of muscle dimensions. It is expected that there will be more error in ultrasound measurements than in carcass measurements.

CONCLUSIONS

Results presented here suggest that muscularity does need a specific definition. The differences in predicted response reveal that the response to selection depends on which measure of muscularity is used. While selection on each of the four muscularity measures presented here was expected to result in a correlated decrease in FAT, selection on ML or MB was expected to result in a correlated increase in GR. A better understanding of correlated responses to selection for muscularity is required before it can be recommended that sheep breeders select replacements based on measures of muscularity. Unless rewards are paid for superior muscling there is no incentive for breeders to include muscularity in a selection objective. However, an objective measure of muscularity may be a useful selection criterion to select for increased LEAN and decreased FAT. Further research is required to determine if there is a better way to combine information from the skeletal and muscle measurements and carcass weight in order to maximize progress in this selection objective.

REFERENCES

De Boer, H.; Dumont, B.L.; Pomeroy, R.W.; Weniger, J.H. 1974. Manual on E.A.A.P. reference methods for the assessment of carcass characteristics in cattle. *Livestock Production Science* **1:** 151-164.

Henderson, C.R. 1984. Applications of Linear Models in Animal Breeding. Guelph, University of Guelph.

Kempster, A.J.; Croston, D.; Jones, D.W. 1981. Value of conformation as an indicator of sheep carcass composition within and between breeds. *Animal Production.* **33:** 39-49.

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.

McEwan, J.C.; Clarke, J.N.; Knowler, M.A.; Wheeler, M. 1989. Ultrasonic fat depths in Romney lambs and hoggets from lines selected for different production traits. *Proceedings of the New Zealand Society of Animal Production* **49:** 113-119.

Moxham, R.W.; Brownlie, L.E. 1976. Sheep carcase grading and classification in Australia. *Wool Technology and Sheep Breeding* **23(2):** 17-25.

Palsson, H. 1939. Meat quality in sheep with special reference to Scottish breeds and crosses. *Journal of Agricultural Science, Cambridge* **29:** 544-626.

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.

Waldron, D.F.; Clarke, J.N.; Rae, A.L. 1991. Analysis of lamb schedules and relative economic values of lean and fat. *Proceedings of the New Zealand Society of Animal Production* **51:** 405-409.

Waldron, D.F.; Clarke, J.N.; Rae, A.L.; Kirton, A.H.; Bennett, G.L. 1992. Genetic and phenotypic parameter estimates for selection to improve lamb carcass traits. *New Zealand Journal of Agricultural Research* **35:** In Press.

Young, M.J. 1990. Developmental changes in muscularity and selection to alter body composition. *Australian Association of Animal Breeding and Genetics* **8:** 553-554.