ECONOMIC BENEFITS OF INCLUDING COMPUTED TOMOGRAPHY MEASUREMENTS IN SHEEP BREEDING PROGRAMMES

N.B. JOPSON[1†], J.C. MCEWAN[1], K.G. DODDS[1] AND M.J. YOUNG[2]

[1] AgResearch, Invermay Agricultural Centre, Private Bag 50034, Mosgiel, New Zealand
[2] Animal and Veterinary Sciences Group, Lincoln University, New Zealand
[†] Recipient of a New Zealand Science and Technology Post-doctoral Fellowship

SUMMARY

Selection indices for dual-purpose sheep were used to examine the benefits of incorporating Computed Tomography (CT) to increase carcass lean and decrease carcass fat content. Index measurements included live weight (LW), back fat thickness over the eye muscle (C), eye muscle depth (B) and width (A), and carcass lean and fat weight. Literature estimates of phenotypic and genetic parameters for Romney and Romney-cross sheep were used to create two initial correlation matrices, one based upon carcass measurements and one on ultrasonic measurements. The relative economic values (REV) used for lean and fat were +240 and -190 cents per kg, respectively (i.e. those currently used by NZABT). Parametric bootstrapping was applied to generate 10,000 new correlation matrices based upon the original heritabilities, phenotypic and genetic correlations and their estimated standard errors. CT gave an additional 30 (P=0.057) and 70 (P<0.001) percent gain in economic index over the best selection result using linear carcass (taken as potential of future ultrasonic technology) or present ultrasonic measures, respectively. The technique used has general applicability and would be useful in any situation requiring estimates of the variability in genetic response using different combinations of predictor traits.

INTRODUCTION

Selection to improve carcass growth and composition in sheep is a well established technology in New Zealand. At present, index selection is based on live weight and ultrasonic fat and muscle measurements. Genetic and phenotypic parameters were derived from the Waldron et al. (1992) experiment of 102 sires and 1602 progeny, subsequent to initial estimates of the benefits by Simm et al. (1987). Computed Tomography (CT) can directly measure the traits under improvement, resulting in faster rates of progress. Simm and Dingwall (1989) estimated the annual response in carcass lean and fat content for terminal sire sheep breeds could be improved from +194 to +262 g/year and +67 to -16 g/year, respectively. They used an index of live weight and perfect *in vivo* measurement of lean and fat content compared to an index of live weight and ultrasonic fat and lean depth measurements using relative economic values (REV) and genetic parameters applicable to the British industry. However, no attempt has been made to quantify the variability of these estimates.

This paper describes the potential of incorporating CT measurements into selection indices and quantifies the variation associated with the estimated benefits using New Zealand REVs and genetic parameters. The breeding structures required to obtain cost effective benefits from the measurements for the New Zealand farmer are also briefly examined.

MATERIALS AND METHODS

Genetic and phenotypic parameter estimates for carcass traits from Waldron et al. (1992) were used to estimate the increase in genetic gain by selecting directly for carcass lean and fat weight compared with selection based on carcass linear measurements. CT measures were assumed to be equivalent to direct measurement of the carcass as has been shown by Afonso (1992). Carcass linear traits were used as an estimate of the limit of future developments in ultrasonic technology. For an estimate of ultrasonic traits using existing technology, phenotypic and genetic correlations were left unchanged, but heritabilities for C, GR, A and B were reduced from their original values to 0.25. These are similar to the mean of literature results (Atkins et al. 1991; Clarke et al. 1991; McEwan et al. 1991, 1993). Selection index gains (Falconer 1983) were determined for a flock with all retained lambs measured and selection based on the animal's own information. Lean and fat REVs of +240 and -190 cents per kilogram, respectively, were used to calculate the index. These values are those presently used by the New Zealand Animal Breeding Trust (NZABT) and their ratio is similar to that described by Waldron et al. (1991).

Parametric bootstrapping (Efron 1982) was applied to generate 10,000 sets of heritabilities, phenotypic and genetic correlations based upon the original estimates from Waldron *et al.* (1992). Phenotypic standard deviations remained fixed. Each set of new estimates was used to reconstruct the selection index. The simulations were run for both carcass and ultrasonic parameter sets. The standard errors from the original experiment were not published, but it was assumed that they were estimated from a paternal •-sib experiment with n_s=100 sires and n_p=15 progeny per sire (1-way random model). Phenotypic correlations were sampled from the normal distribution with variance $1/(n_s(n_p-1)-3)$ after Z-transformation. A new heritability estimate (h^{*2}) was sampled using $F/(n_s h^{*2}/(4-h^{*2})+1) \sim F(n_s-1, n_s(n_p-1))$ (Searle 1971, p415), where $F=n_s h^2/(4-h^2)+1$. The standard error of a genetic correlation was estimated using equation 19.4 of Falconer (1983) with variances of heritability estimates calculated using the above F distribution and the delta method for transformations (Efron, 1982). These were subsequently Z-transformed and new estimates sampled from the normal distribution.

RESULTS AND DISCUSSION

The genetic gains resulting from selection on the economic index and correlated responses in other traits are presented in Tables 1 and 2. Genetic gains in Table 1 were calculated based upon carcass linear measurements for C, A and B, while in Table 2 they were measured ultrasonically. In both cases, lean and fat weights were assumed to be equivalent to values obtained by CT. Selection based on LW alone produced gains in all traits including fat weight, and resulted in a low value for the economic index (EI) of 34 cents per unit selection intensity (¢/*i*). Including linear measurements produced negative values for the fatness traits while maintaining reasonable gains in LW and improving weight of lean. This increased the value of the EI, with a maximum of 93 ¢/*i* for selection based on LW+C+B+A. Greatest gains for lean and reductions in fat were achieved when selection was based upon LW+lean+fat resulting in a EI value of 121 ¢/*i*, indicating that CT has the potential to increase rates of genetic gain by at least 30 percent over future methods based on linear measurements.

Fat and muscle depths are measured 'on farm' by techniques such as B-mode ultrasonic scanning (McEwan et al. 1989, Young and Deaker 1994). The economic gains presented in Table 1 may not be achievable because measurement errors associated with ultrasound need to be included in the index. When these were included (Table 2), gains in lean and fat were reduced for all parameters in which selection included ultrasonic measurements. Selection based on LW+lean+fat was 70 percent better than selection based on LW+C+A+B. Tables 1 and 2 demonstrate that economic response improves with each additional linear

Table 1. Estimated genetic gains in lamb carcass traits based on selection for live weight at eight months and combinations of traits for direct linear measurements made on the carcass or carcass lean and fat weight (taken as the potential of future ultrasonic technology).

	Gain in trait per unit intensity									
Selection based on:	LW8 (kg)	C (mm)	GR (mm)	A (mm)	B (mm)	EMA (mm²)	Lean (kg)	Fat (kg)	HCW (kg)	EI/*i** (¢)
LW	0.88	0.13	0.38	0.50	0.26	0.20	0.26	0.14	0.48	34
LW + C	0.56	-0.18	-0.09	0.69	0.04	0.09	0.24	-0.03	0.29	62
LW + C + B	0.42	-0.13	-0.02	0.91	0.50	0.28	0.29	-0.05	0.27	71
LW + C + A + B	0.40	-0.16	-0.20	1.90	0.65	0.48	0.31	-0.09	0.28	93
LW + lean + fat	0.41	-0.23	-0.32	1.43	0.63	0.46	0.37	-0.17	0.27	121

*Gain in the economic index per unit of selection intensity

Table 2. Estimated genetic gains in lamb carcass traits based upon selection on live weight at eight months and combinations of traits for linear measurements made using ultrasound or carcass lean and fat weight.

Selection based on:	Gain in trait per unit intensity									
	LW8 (kg)	C (mm)	GR (mm)	A (mm)	B (mm)	EMA (mm^2)	Lean (kg)	Fat (kg)	HCW (kg)	EI/*i** (¢)
LW	0.88	0.12	0.37	0.32	0.21	0.20	0.26	0.14	0.48	34
LW + C	0.59	-0.15	-0.05	0.43	0.04	0.10	0.24	-0.01	0.31	61
LW + C + B	0.47	-0.13	-0.03	0.50	0.26	0.21	0.25	-0.03	0.28	65
LW + C + A + B	0.40	-0.14	-0.11	0.71	0.30	0.27	0.25	-0.06	0.25	71
LW + lean + fat	0.41	-0.22	-0.31	0.90	0.51	0.45	0.37	-0.17	0.27	121

*Gain in the economic index per unit of selection intensity

measurement used, albeit at the cost of additional measurements. Secondly, the results of Simm and Dingwall (1989) are supported in that measurement of the trait under selection resulted in greater economic responses than any combination of linear measurements using REVs applicable to New Zealand conditions. The differences between EI estimates in the two tables give an indication of the variation for the genetic and phenotypic parameters found in the literature. In particular, the linear measurement estimates show considerable variation between studies. For example, the heritability of A was reported to be 0.63 for carcass measurements and 0.07 for ultrasonic measurements by Waldron et al. (1992) and McEwan et al. (1993), respectively. Techniques for prediction of carcass composition also appear to be important. Young and Deaker (1994) reported that prediction of carcass composition based upon ultrasonic measurements was better than using linear carcass measurements directly, which contrasts with the results of McEwan et al. (1989). While the variation in the economic index (due to imprecision in estimation of genetic parameters) can be estimated algebraically, all methods suffer from their lack of general application and often rely on *ad hoc* assumptions using different predictor sets. Our approach was to circumvent these problems by using parametric bootstrapping (Table 3).

Mean EI values for the two simulation runs (Table 3) were similar to the values in Tables 1 and 2. Simulation means were slightly higher than index means due to non-symmetry of the distribution used. EI values from each simulation iteration were treated as pairwise observations for selection comparisons. The improvement in EI associated with each additional carcass linear measurement was significant ($P<0.001$), with the magnitude of the improvement depending on whether carcass or ultrasonic measurements were used. Additional measurements always improved EI as heritabilities could not be negative. These improvements are different from, and should not be compared with, estimation of carcass components by regression. For example, McEwan et al. (1989) reported that prediction of carcass fat content using LW and ultrasonic C accounted for 67% of the variation in carcass fat, and further ultrasonic traits gave no

Table 3. Mean economic index response (EI; ¢/*i*) and variation based upon selection for live weight at eight months and combinations of traits for carcass lean and fat content, with linear measurements taken on carcasses post-slaughter or by using ultrasonics on live animals.

Selection based on:	Carcass measurement			Ultrasonic measurement		
	Mean EI	SD	Ratio*	Mean EI	SD	Ratio*
LW	34	7.0	0.28	34	7.0	0.28
LW + C	63	10.7	0.51	62	10.4	0.50
LW + C + B	73	10.5	0.60	67	9.9	0.55
LW + C + B + A	95	11.3	0.78	73	9.1	0.59
LW + lean + fat	125	21.8	1.00	125	21.8	1.00

*Ratio is the mean percentage progress relative to selection based on LW + lean + fat significant improvement in fat content prediction.

Bootstrapping demonstrated that index gains in lean and fat for selection based upon CT over ultrasound were quite robust. The relative ranking of the selection approaches did not vary significantly after allowing variation in the genetic and phenotypic parameters, regardless of which correlation matrix was used. CT was better than any of the ultrasonic measurements 99.9% ($P<0.001$) of the time using ultrasonic measurements, with a mean EI improvement of 52 *¢/i*. Selection based on CT had an additional EI gain of 30 *¢/i* and was better than any of the ultrasonic estimates 94.3% ($P=0.057$) of the time for carcass measurements. Thus, CT will continue to offer advantages over ultrasonics even given improvements in technology. These results are dependent on the REV's for lean and fat, as has been demonstrated by simulations using a range of REV's (Simm and Dingwall 1989, Clarke and Rae 1991, Waldron et al. 1991).

This study has extended previous work by examining the effect of genetic parameter estimation error. It has shown that incorporation of CT measures into selection indices will result in a significant increase in carcass value. In the present study, a simplified model for genetic selection was used. In the future, we intend to examine optimal genetic breeding structures using ZPlan (Nitter et al. 1994), incorporating the parametric bootstrapping technique described above. Other factors such as the cost and portability of ultrasound compared with CT mean that the two techniques are complementary. CT scanning will only be economically viable on animals with a high probability of genetic superiority and if appropriate breeding structures for disseminating the benefits are in place. We currently recommend a two-stage selection procedure for carcass quality traits with an initial screening based on live weight and ultrasonic measurements and inclusion of relatives' information. Final selection would be based on CT measurement of the highest ranking animals.

REFERENCES

ATKINS, K.D., MURRAY, J.I., GILMOUR, A.R. and LUFF, A.L. (1991) *Aust. J. Agr. Res.* **42**:629.
AFONSO, J.J.M. (1992). PhD Thesis, University of New England.
CLARKE, J.N. AND RAE, A.L. (1991) *Proc. N.Z. Soc. Anim. Prod.* **51**:401.
CLARKE, J.N., WALDRON, D.F. AND RAE, A.L. (1991) *Proc. A.A.A.B.G.* **9**:265.
EFRON, B. (1982) "The Jackknife, the Bootstrap, and Other Resampling Plans", SIAM, Philadelphia
FALCONER, D.S. (1983) "Introduction to Quantitative Genetics", 2nd ed. Longman, New York.
MCEWAN, J.C., CLARKE, J.N., HICKEY, S.M. AND KNOWLER, K.J. (1993) *Proc. N.Z. Soc. Anim. Prod.* **53**:347
MCEWAN, J.C., CLARKE, J.N., KNOWLER, M.A. AND WHEELER, M. (1989) *Proc. N.Z. Soc. Anim. Prod.* **49**:113.
MCEWAN, J.C., DODDS, K.G., DAVIS, G.H., FENNESSY, P.F. AND HISHON, M. (1991) *Proc. A.A.A.B.G.* **9**:276.
NITTER, G., GRASER, H.-U. and BARWICK, S.A. (1994) *Aust. J. Agric. Res.* **45**:1641.
SEARLE, S.R. (1971) "Linear Models", Wiley, New York.
SIMM, G., YOUNG, M.J. and BEATSON, P. (1987) *Anim. Prod.* **45**:465.
SIMM, G. AND DINGWALL, W.S. (1989) *Livest. Prod. Sci.* **21**:223.
WALDRON, D.F., CLARKE, J.N. AND RAE, A.L. (1991) *Proc. N.Z. Soc. Anim. Prod.* **51**:405.
WALDRON, D.F., CLARKE, J.N., RAE, A.L., KIRTON, A.H. AND BENNETT, G.L. (1992a) *N.Z.J. Agr. Res.* **35**:287.
YOUNG, M.J. AND DEAKER, J.M. (1994) *Proc. N.Z. Soc. Anim. Prod.* **54**:215.