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BREEDING TO IMPROVE MEAT EATING QUALITY IN TERMINAL SIRE SHEEP BREEDS

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SUMMARY

An economic value for sheep meat eating quality was derived using consumer taste panel sensory trait scores and willingness to pay data. Improving eating quality by one score generated a price premium to commercial producers of \$0.15/kg relative to a carcass price of \$4.50/kg. Eating quality was included in a breeding objective with growth and lean meat yield. Under selection index scenarios modelled, simultaneous improvement of all traits was only possible with genomic testing of male selection candidates due to antagonistic correlations involving yield, eating quality, intramuscular fat, and shear force. Economic gain could be increased by up to 20% compared to current industry selection indexes.

INTRODUCTION

Terminal sire breeders in Australia have made sustained genetic gains over a long period of time (e.g. Swan *et al.*, 2009). One of the ingredients for this success has been a simple breeding objective targeting increased growth and lean meat yield, which can be accurately evaluated from a young age using selection indexes based on body weight, and eye muscle and fat depth scanned on live animals. While the genetic gain in lean meat yield has contributed to lamb becoming a highly desirable product with increased consumer demand, care is needed to avoid making carcasses too lean and creating problems with eating quality.

The Sheep CRC has undertaken an extensive measurement program of carcass and eating quality traits on individual animals in the Information Nucleus (IN) flocks (Van der Werf *et al.*, 2010). In this study this data is used to develop an economic value for sheep meat eating quality which can be included in a breeding objective with economic traits including lean meat yield, and compare selection responses for indexes with and without eating quality and genomic selection.

MATERIALS AND METHODS

Eating quality traits. An eating quality trial based on consumer taste panels was conducted by the Sheep CRC on samples taken from IN animals born in 2009 and 2010. The design of the trial has been described in detail by Pannier *et al.* (2014), but briefly, ten samples were taken from both the loin and topside portions of carcasses of IN slaughter animals (n=1400+). These were prepared using a standard cooking method, and then consumed by the taste panels. The taste panel members scored each sample for five sensory eating quality traits on a 0 – 100 scale: odour, flavour, juiciness, tenderness, and overall liking.

The sheep meat industry uses the Meat Standards Australia (MSA) retail grading system with four effective grades (ungraded, and grades 3, 4, and 5). These are determined by an MSA score often derived as a linear function of the consumer eating quality traits (e.g. Johnston *et al.*, 2003) and expressed on the 0 – 100 scale. Genetic parameters estimated from the IN data (Mortimer *et al.*, 2015) show that within the loin and topside cuts genetic correlations between eating quality

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traits were always greater than 0.9, and the genetic correlation between loin and topside overall liking was 0.93. Therefore for the purposes of this study, topside overall liking is defined as the eating quality breeding objective trait (denoted as tmsa). After correcting for fixed effects including breed, the mean and standard deviation of tmsa in the IN data were 52.1 and 9.1 respectively. These values were used in the derivation of the economic value, defining the base distribution of eating quality in a commercial flock as $N(\mu = 52.1, \sigma = 9.1)$.

Two measured carcass traits, intramuscular fat (imf, %) and shear force (sf5, Newtons) are strongly related to eating quality, and these were also considered as selection criteria.

Economic value for eating quality. There were thresholds assumed on the tmsa trait scale which determine MSA retail grade, as shown in Table 1. Further, consumer willingness to pay surveys establish price relativities between retail grades, and the values assumed are also shown in Table 1. These two pieces of information can be used to derive an economic value for eating quality. Firstly, carcass value (CV) to the commercial producer can be expressed as:

$$CV = CWT \times [(1 - m)p_N + mp_L \Sigma_i v_i r_i]$$

where CWT is carcass weight (kg), p_L is the price of lean meat for MSA grade 3 ($/kg), p_N is the price of the residual carcass component ("non-lean", $/kg), m is the ratio of lean meat yield, v_i is the probability of a carcass achieving MSA grade i from the base distribution of eating quality defined above, and r_i is the price relativity for MSA grade i as shown in the willingness to pay column of Table 1. Increasing tmsa by 1 score changes the MSA grade probabilities, increasing the probability of achieving a higher grade, and reducing the probability of ungraded meat. The carcass price premium associated with a 1 score increase in tmsa can be expressed as:

$$\Delta p_C = mp_L \Sigma_i (v_i^* - v_i) r_i$$

where v_i^* is the probability of achieving MSA grade i in the improved flock. The economic value for tmsa on a per carcass basis is now:

$$REV_{eq} = CWT \times \Delta p_C$$

Table 1. Lower threshold tmsa value for each MSA grade (Min tmsa), probabilty of MSA grade in base (v_i) and improved (v_i^*) flocks, and willingness to pay price relativities

MSA grade	Min tmsa	v_i	v_i^*	Willingness to pay
Ungraded	0	0.4079	0.3658	0.5
3	50	0.5140	0.5388	1.0
4	65	0.0722	0.0874	1.5
5	75	0.0059	0.0080	2.0

Breeding objectives including eating quality. A terminal sire breeding objective targeting a terminal sire x Merino dam commercial enterprise was developed using the SheepObject system (Swan *et al.*, 2007), based on growth (post-weaning body weight, pwt) and carcass traits including lean meat yield (lmy), dressing percentage (dress), carcass eye muscle depth (cemd), and carcass fat depth (cfat). The key price and production variables were carcass weight = 23kg, lean meat yield ratio = 0.56, and carcass price received by the producer = $4.50/kg. The eating quality economic value was added to the objective and converted to a per ewe joined basis by multiplying by a weaning rate of 0.95 lambs weaned per ewe joined, and discounted using a discount rate of 7%. This objective is denoted LMY_EQ. It was extended to include imf as a desired gains trait accounting for 5% of the total economic gain, and this objective is denoted LMY_EQ_IMF.

Genetic parameters for breeding objective and selection index traits. Genetic parameters were estimated using the IN animals in the eating quality trial. To increase confidence in the consistency of correlations, a multivariate analysis was performed using the R package MCMCglmm (Hadfield, 2010) simultaneously including the breeding objective traits pwt, lmy, dress, cemd, cfat, and tmsa, and potential selection index traits weaning weight (wwt), post-weaning eye muscle (pemd) and fat depth (pfat), imf, and sf5.

Prediction of genetic gains. Genetic gains from index selection over 10 years were calculated for the LMY_EQ and LMY_EQ_IMF objectives and compared to gains from the current Carcass+ (CPLUS) industry objective. Gains were calculated for a terminal sire breeding flock of 300 ewes with 10 sires mated annually and a weaning rate of 1.3 lambs per ewe joined. Selection intensities were 2.328 for males and 0.860 for females and generation intervals were 2.6 for males and 3.2 for females. These figures were derived from the LAMBPLAN genetic evaluation database. For each objective response was calculated from two scenarios. In the first, phenotypes were available on the base traits of wwt, pwt, pemd, and pfat. The second added genomic predictions on young males for base traits (all objectives) and the carcass traits lmy, cemd, cfat, dress, imf and sf5 (LMY_EQ and LMY_EQ_IMF only) using the accuracies for genomic predictions currently used in the LAMBPLAN genetic evaluation system (Swan *et al.*, 2014).

RESULTS AND DISCUSSION

Economic values for the LMY_EQ and LMY_EQ_IMF breeding objectives are shown in Table 2. The economic value for eating quality was $3.21 per ewe joined. Relative to a carcass price of $4.50 per kg, the price premium for a 1 score increase in eating quality was $0.15 per kg. This premium is currently not realised by commercial producers as there is no supply chain feedback for eating quality at the level of individual carcasses.

Genetic correlations for lmy and tmsa with other economic and selection criteria traits are also shown in Table 2. There was a small antagonistic correlation between lmy and tmsa (-0.12), and large antagonisms involving lmy, tmsa, imf and sf5. The latter two traits are important selection criteria for eating quality, with improved eating quality associated with higher imf (0.31) and lower sf5 (-0.31). However, the reverse is true for lmy, which is strongly associated with lower imf (-0.55) and higher sf5 (0.40). These antagonisms limit the genetic gain which can simultaneously be made in lean meat yield and eating quality.

Mortimer *et al.* (2015) estimated genetic correlations for a wider range of sensory scores and found that eating quality in the loin was more strongly associated with imf, while for the topside, shear force had the stronger association. We note that it is possible to extend the approach outlined above to calculate economic values separately for different carcass cuts.

Table 2: Economic values for LMY_EQ and LMY_EQ_IMF breeding objectives ($/ewe joined), and genetic correlations used in index predictions for lmy (r_g lmy) and tmsa (r_g tmsa)

Trait	Units	LMY_EQ	LMY_EQ_IMF	r_g lmy	r_g tmsa
pwt	kg	1.834	1.834	0.10	0.03
lmy	%	1.879	1.879	1.00	-0.12
dress	%	2.042	2.042	0.00	-0.10
cemd	mm	3.267	3.267	0.10	-0.17
cfat	mm	-0.966	-0.966	-0.66	-0.05
tmsa	0 – 100	3.211	3.211	-0.12	1.00
imf	%		15.727/7.867[A]	-0.55	0.31
sf5	Newtons			0.40	-0.31

[A]Index dependent (15.727 with base traits measured, 7.867 with genomic predictions added)

Genetic gains in Table 3 show that the current industry objective CPLUS is predicted to produce significant gains in growth rate (pwt), lean meat yield and carcass eye muscle, at the expense of a reduction in eating quality. The base and genomic testing scenarios produce very similar outcomes for CPLUS. For the LMY_EQ objective, gains in growth and lean meat yield were further enhanced compared to CPLUS and while eating quality gain was still negative, it was closer to zero. Genomic testing increased economic gain for this index by 9%, and compared to the CPLUS scenarios by up to 20%. When only base traits were available, including the restriction on imf in LMY_EQ_IMF resulted in a negative response in lean meat yield, a strong positive response in carcass fat, and a small positive response in eating quality. Compared to the economically optimum index, economic gain was reduced by 29%. By adding genomic testing in LMY_EQ_IMF favourable responses were achieved in lean meat yield, eating quality, imf and sf5, and economic gain was reduced by only 9%.

Table 3: Trait gains over 10 years for CPLUS, LMY_EQ and LMY_EQ_IMF objectives with base and genomic selection criteria, total dollar gain and economic efficiency

Trait	Units	CPLUS		LMY_EQ		LMY_EQ_IMF	
		base	genomic	base	genomic	base	genomic
pwt	kg	4.28	4.46	5.36	5.30	5.41	4.98
lmy	%	1.07	1.10	1.43	1.46	-0.50	0.19
dress	%	1.19	1.27	0.63	0.80	0.72	0.81
cemd	mm	1.55	1.66	0.71	0.85	0.39	0.62
cfat	mm	0.24	0.27	-0.25	-0.21	0.48	0.29
tmsa	0 – 100	-1.25	-1.34	-0.44	-0.19	0.10	0.64
imf	%	-0.26	-0.27	-0.34	-0.28	0.04	0.10
sf5	Newtons	1.14	1.17	1.88	1.16	0.55	-0.68
$ gain		13.11	13.66	14.93	16.47	11.61	14.95
Efficiency		80	83	91	100	71	91

CONCLUSIONS

The breeding objectives presented in this study demonstrate that terminal sire breeders can simultaneously improve growth, meat yield and eating quality, albeit with restrictions due to antagonistic genetic correlations between traits. To realise the benefits of the breeding objectives it is necessary to increase the accuracy of genetic evaluations of carcass traits and eating quality traits including intra muscular fat and shear force. Genomic testing is one way to achieve this increased accuracy.

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REFERENCES

Hadfield, J., D. (2010) *J. Stat. Softw.* 33:1–22.

Johnston, D. J., A. Reverter, D. M. Ferguson, J. M. Thompson, and H. M. Burrow. (2003) *Aust. J. Agric. Res.* **54**:135.

Mortimer, S. I., A. A. Swan, L. Pannier, A. J. Ball, R. H. Jacob, and J. H. J. Van der Werf. (2015) In: *Proc. Assoc. Advmt. Anim. Breed. Genet.* Vol. 21.

Pannier, L., G. E. Gardner, K. L. Pearce, M. McDonagh, A. J. Ball, R. H. Jacob, and D. W. Pethick. (2014) *Meat Sci.* **96**:1076.

Swan, A. A., D. J. Brown, and R. G. Banks. (2009) In: *Proc. Conf. Assoc. Anim. Breed. Genet.* Vol. 18. p. 326.

Swan, A.A., D. J. Brown, H.D. Daetwyler, B.J. Hayes, M.J. Kelly, N.Moghaddar, and J.H.J. Van der Werf. (2014) In: *Proc. 10th World Congr. Genet. Appl. Livest. Prod.* p. 334.

Swan, A. A., J. H. J. van der Werf, and K. D. Atkins. (2007) In: *Proc. Conf. Assoc. Anim. Breed. Genet.* Vol. 17. p. 483.

Van der Werf, J., B. Kinghorn, and R. Banks. (2010) *Anim. Prod. Sci.* **50**:998.