OPTIMISING SELECTION ON GROWTH AND CARCASE DEVELOPMENT TRAJECTORIES IN LAMB

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SUMMARY
Net benefit of response to selection for weight, fat and eye muscle depth measured at different ages was optimized for lamb production systems. Optimised selection response and profit were compared for an index based on random regression coefficients relating to the whole growth trajectory and an index based on breeding value for weight, fat and muscle at 200 days. Three different price structures were considered with various premiums for fat and muscle. No significant additional benefit was gained from using random regression breeding value over selection for traits at 200 days of age for a terminal sire breeding objective. However more additional benefit might be expected for a case where maternal performance is considered in the objective or when feed costs are high.
Keywords: selection, weight, fat, muscle, covariance function

INTRODUCTION
Australia's national breeding program for meat sheep, LAMBPLAN, currently uses breeding value (BV) estimates for BW, FD and EMD at 200 days of age. If measures at different ages were available a RR approach as an alternative genetic analysis is likely to provide more accurate evaluations and additionally provide information about genetic differences in growth and development. Estimated BV arising from RR analysis could be directly included in selection indexes. Selection emphasis on BV at different ages changes the growth pattern and optimized selection weights can be compared with selection for a single age point, e.g. slaughter age. The aim of this study is to assess the benefit of using information from different ages for improvement of growth and carcase development in lambs and compare optimal strategies with current selection indices.

MATERIALS AND METHODS
An optimal selection strategy requires finding index weights for selection on different traits measured at different ages along the trajectory such that profit of genetic response is maximized. Trait values along each point of a trajectory affect cost and income. Deriving the economic value of change at many different ages is difficult when using linear profit functions, because these trait values are interdependent, i.e. the value of BW_t depend also on BW_{t-1}. Instead, a differential evolution (DE) algorithm was used to find optimal index weights. This approach was described by Van der Werf (2002) for selection on beef cattle body weights. In this paper, it is applied to selection for BW, FD and EMD at multiple ages in lambs. Economic assessment of genetic change was based on a cost-benefit analysis of an average growth curve as well as the alternative curve that arises after selection. The cost-benefit of a given growth curve was based on estimated feed costs incurred and income derived from given trait means at different ages, with a fixed slaughter age at 200 days. Net profit of different growth curves can thus be compared, therefore allowing the DE to evolve a set of index weights that maximizes the economic value of a selection response.

Energy requirements to maintain body weight and gain carcase components. Total energy requirement in MJ was based on energy for growth and maintenance. Maintenance was based on BW and calculated using the approach described by Brody (1945), with no significant effect of a change in the ratio of fat to muscle in one round of selection assumed. The proportion of lean, fat and bone in the carcase at selected ages were determined using regression equations proposed for lamb by Kempster *et al.* (1986). Calculation of energy needed for deposition of fat and muscle was based on parameters developed by Agricultural Research Council (1980).

Cost of pasture production and income from the carcase. The parameters used to calculate the costs of feed (per MJ of metabolizable energy (ME)) were assumed to be representative of an Australian sheep farm with an improved pasture system (L. Kahn, *pers. comm.*). The feed price was calculated as 0.25c/MJ ME, which is similar to the costs used by Amer *et al.* (1999) for New Zealand grazing systems (0.1-0.2c/MJ ME). Feed costs were accumulated over the life of the animal to slaughter at a fixed age of 200 days to quantify costs of maintaining and growing the animal. Carcase revenues were calculated for three price scenarios with 1) a base price of $3.00 per kg carcase weight (S1); 2) additionally a payment based on deviations from the base price (-$0.05 per additional mm of fat and +$0.13 per additional mm of EMD) (S2) and 3) as S2 but with higher premiums and penalties ($0.25/kg/mm for fat; $0.55/kg/mm for EMD) (S3). Price incentives in S2 and S3 were based on Banks and Ross (2003).

Selection response and selection indices. In this study we were interested in finding economic weights that maximize profit and we compared selection for BV at different ages versus selecting on BV at one give age. We assumed perfect selection and did not vary information to calculate EBV, thus simply assuming selection on true BV. This ignores the potential advantage of RR on selection accuracy, which would be absent if measurements are available on fixed points across the trajectory and appropriate multivariate models for genetic evaluation are used. Selection response for BV of traits at ages 60 to 200 days (with 10 day intervals) (**a**) was calculated by regression of **a** on index: $R_a = \mathbf{b}'\mathrm{cov}(\mathbf{x}, \mathbf{a})/\sqrt{(\mathbf{b}'\mathrm{var}(\mathbf{x})\mathbf{b})}$ where **x** is a vector of selection criteria and **b** are index weights. Selection criteria were either BV for BW, FD and EMD at 200 days or BV for polynomial coefficients that describe genetic covariance functions for these traits along the growth trajectory (as estimated by RR models). DE was used as an efficient search procedure to find the set of weights that maximises profit of selection response (Van der Werf, 2002).

To predict selection response for many ages for BW, FD and EMD ($\mathbf{a}'=[\mathbf{a}_{BW}' \ \mathbf{a}_{FD}' \ \mathbf{a}_{EMD}']$, with each subvector containing BV at 10 days intervals from 60 - 200 days), a covariance function was estimated. Genetic covariances on the observed scale (i.e. var(**a**)), were derived from $\mathbf{\Phi}'\mathbf{K}\mathbf{\Phi}$, where $\mathbf{K} = \mathrm{var}(\alpha)$ is the covariance matrix among RR coefficients (α) and the matrix $\mathbf{\Phi}$ contains Legendre polynomials evaluating $\boldsymbol{\alpha}$ for the ages in the breeding objective. Values for **K** were estimated by Fischer *et al.* (2005) with order 7 (3 coefficients for BW and 2 for each of FD and EMD).

Two indexes were compared; 1) an index based on BV for the three traits at 200 days as currently used in LAMBPLAN's Carcase Plus (C+) index, and 2) an index based on RR coefficients (RR). Both indexes used weights optimized for selection profit. Profit (Table 1) and response to selection (per unit of selection intensity) are presented in Table 2 for a fixed slaughter age (200 days) and for three pricing strategies (S1-S3). Full details of materials and methods can be found in Fischer (2004).

RESULTS AND DISCUSSION

Table 1 illustrates feed costs and income from the lamb as well as profit under the three price scenarios when selling at a fixed age. Comparing costs and income from the optimised indexes with no selection highlights that selection yields increased income due to a heavier carcase and better composition with a marginal increase (12%) in feed cost. Feed costs were low and remained relatively constant across the different price scenarios. The income due to improved carcass weight as well as carcass quality increased from scenario S1 to S3. Interestingly, when moving from S1 to S3, response for growth decreased and for carcase composition it increases (Table 2) but this shift is not translated into a decrease of feed costs. The result is a very small (<1%) difference in cost between the three pricing scenarios. Feed cost and income for single age selection (C+) was almost identical to trajectory (RR) selection. This is also reflected by the similar response achieved by each index as shown in Table 2.

Table 1 Cost, income and profit using different scenarios for RR* when selling at 200 days

Index and Scenario	Feed Costs for Lamb	Income from Sale of Lamb	Extra Profit from one round of selection	Price ($/kg Cwt)
No Selection S1	$5.23	$70.82	-	$3.00
RR* S1	$5.87	$76.27	$4.81	$3.00
RR* S2	$5.86	$80.42	$8.97	$3.17
RR* S3	$5.83	$94.85	$23.43	$3.76

RR = selection on whole curve, C+ = selection at one age, * = Optimised index weights, S1-S3 = no, limited and extensive carcase premiums respectively, Responses represented per unit of selection intensity.

Feed costs were only a small proportion of the total income (6-7%) and there appeared to be little benefit in altering the curve as different growth paths incur relatively similar costs. Hence, it mattered little whether muscle (efficient) or fat (inefficient) was grown, as feed is relatively inexpensive.

Amer *et al*. (1999) compared the feed costs of a mature ewe in a prime lamb enterprise relative to the lamb(s) she raises and showed that the ratio of cost incurred is around 5:1. Based on this, there is more scope for reducing feed costs by focussing on the costs incurred by the dam rather than the lamb. This could be achieved by selecting for an animal that grows rapidly early in life (to maximise carcase weight in her lambs) and has a lower mature weight, and hence 'bend' the growth curve. It is likely that trajectory selection will be more beneficial when mature weights are economically important. However, also in that case, selecting on a combination of 200 day and mature weight may provide a result close to optimal.

Selection responses were compared for 100 and 200 days (Table 2). Optimal selection under S1 yielded the largest increases in BW and in FD and the smallest increase in EMD. This is expected, as S1 has no premiums or discounts for muscle or fat hence the sole driver of this index is weight at market age (200 days). S2 and S3 show a decrease in optimal response to BW at the expense of improved response in EMD and smaller increase in FD. The S2 and S3 results are driven by financial incentives for leaner, more muscular carcases. Within each price scenario, there was no significant difference in response for any of the traits between single point (C+*) and trajectory (RR*) selection.

Table 2 Mean and change of weight (kg), fat (mm) and muscle depth (mm) after selection with different indexes when slaughter is at a fixed age of 200 days

Trait / Age	BW100	BW200	FD200	EMD200
Mean	32	47	2.5	27.9
C+* S1	2.45	3.64	0.25	1.22
RR* S1	2.46	3.64	0.25	1.23
C+* S2	2.51	3.48	0.21	1.41
RR* S2	2.52	3.48	0.21	1.42
C+* S3	2.41	3.19	0.17	1.46
RR* S3	2.40	3.17	0.16	1.47

RR = selection on whole curve, C+ = selection at 200 days, * = Optimised index weights, S1-S3 = no, limited and extensive carcase premiums respectively, Responses represented per unit of selection intensity.

Scope to bend the curve was limited by the short age trajectory and the high and positive genetic correlations between traits used in this study (correlations between days 60 and 200 were 0.51, 0.76 and 0.86 for BW, FD and EMD, respectively. As the age distance between measures increases, correlations decline, hence there is more scope to 'bend' the curve through selection at more distant ages. Van der Werf (2002) considered a 600 day growth trajectory in beef cattle with a correlation of 0.46 between the most distant ages and there was more scope to alter growth patterns.

CONCLUSION

Selection on multiple traits at multiple ages could be used to select for optimal growth. However, trajectory selection produced no significant improvement in response over single point selection when considering a meat sheep breeding objective with low costs. The superiority of trajectory selection over single point selection is likely to be seen when considering industries with high feed costs (e.g. dairy, feedlot) or body measurements beyond 200 days (e.g. maternal breeding objectives).

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