BODY WEIGHT ADJUSTED TESTIS SIZE AS A SELECTION CRITERION TO IMPROVE PRODUCTION EFFICIENCY IN SHEEP

G.J. Lee and C.S. Haley

AFRC Institute of Animal Physiology and Genetics Research,
Edinburgh Research Station, Roslin, Midlothian, EH25 9PS, UK

SUMMARY

Young male sheep were selected on an index of testis diameter adjusted for body weight. There was a direct response to selection with a realised heritability of 0.53. Sheep in the High-selected line became earlier maturing but had a smaller mature weight than those in the Low line. Ovulation rate did not respond to selection. However, due to higher fertility and lamb survival, High line ewes produced more lambs per ewe mated and reared more lambs to 210 days. This, combined with the changes in growth patterns, leads to a greater predicted production efficiency of ewes in the High line compared to those in the Low line.

INTRODUCTION

Land (1973) postulated that the genetic variation in traits affecting reproductive performance was influenced by genes acting in both sexes through their endocrine system. Therefore, reproduction traits in the two sexes should be genetically correlated and it may be possible to identify selection criteria in the young male, which could be used to improve reproductive performance in the adult female. Walkley and Smith (1980) demonstrated that if such a trait had a moderate heritability and a high genetic correlation with the female trait, substantial gains could be made. In the experiment reported here, young male sheep were selected on an index of weight adjusted testis diameter on the hypothesis that testis size forms an integrated measure of sensitivity to endocrine activity in the male as does ovarian function (ovulation rate) in the female.

MATERIAL AND METHODS

Body weight and testis diameters were recorded on Finn-Dorset male lambs at at 6, 10 and 14 weeks of age. To take account of the high phenotypic correlation with weight at each age, a weight-adjusted testis diameter was calculated thus:

$$T_a^* = T_a - bp(T_a, W_a)\ (W_a - W_{am})$$

where T_a and T_a^* are the observed and adjusted testis diameter, $(W_a - W_{am})$ is the individual's deviation from the mean weight at *a* weeks and $bp(T_a, W_a)$ is the phenotypic regression of testis diameter on body weight at *a* weeks. To give equal weight to to the three records, the individual's deviation from the mean adjusted diameter at each age was standardised to unit variance, and the mean of the three deviations formed the selection criterion.

Two divergent lines were created in 1972 by selecting 7 High and 7 Low males (out of 97) on the above criterion and mating to ewes chosen at random. For 10 subsequent years, 7 males were chosen in each line on the index and used in their first breeding season only. Each year the index was calculated using the regression on body weight and variance appropriate to the year, line and age in question. About 40 females were retained in each line each year and lambed at one and two years of age. Ovulation rate was recorded for each female at the oestrus of mating in their first and second breeding seasons (7 and 19 months of age). The survival of female lambs and their body weight at the start of each breeding season was also recorded. A proportion of females was retained in some years for a third breeding season, providing weight records at 31 months. Litter size was recorded for all animals.

RESULTS

The line mean values for the selection criterion diverged steadily over the 11 years of selection and the estimated difference in breeding values in the final year was 3.59±0.04, (High line mean being +2.1, Low line -1.5). The realised heritability, as calculated by the method of Thompson and Juga (1989) was 0.53±0.013.

Female traits were regressed on the individual's predicted breeding value for the selection criterion calculated by the method of Thompson and Juga (1989), using the LSML76 program (Harvey,1977). This regression is an estimate of the genetic regression of the female trait on the selection criterion. The standard errors of these regression coefficients do not include the effects of genetic drift and will therefore be underestimated slightly, although the estimates of the coefficients themselves will not be affected. The main conclusions drawn in this paper are based upon highly significant regression estimates and will therefore be unaffected by this proviso.

The regressions for body weight at ages from birth to 43 months on the selection criterion are shown in table 1. At birth, there was no difference in weight, but Low line animals became progressively relatively heavier than those in the High line, the regressions on breeding values becoming more significant. By the start of the third breeding season (31 months), Low line animals were 12 kg heavier than those in the High line after 11 years of selection. Studies of linear measurements in live animals and in carcasses have revealed no line differences in body shape or fatness (Lee *et al.*, 1990).

Table 1. Female body weights. Overall means and regression on breeding values of the selection criterion with predicted values for the High and Low lines after 11 years of selection.

Age at measurement	Mean	Regression	Low	High	High/Low
Birth	2.71	0.015	2.69	2.74	1.02
10 weeks*	17.40	-0.202	17.70	16.98	0.96
14 weeks*	21.80	-0.409	22.41	20.94	0.93
7 months	30.41	-0.777***	31.58	28.78	0.91
19 months	47.44	-1.990***	50.43	43.26	0.86
31 months	58.94	-3.340***	63.95	51.93	0.81
43 months*	60.70	-3.700***	66.25	52.93	0.80

*from a small sample in a sub-experiment (Lee *et al.*,1990)

The growth of ewes in the High and Low lines is shown in figure 1 relative to the mature weight in that line estimated as the 43 month weight. Also shown in figure 1 is the weight of the High line relative to that in the Low line. These data provide evidence that selection has altered the growth curve as ewes in the High line approach their mature weight more rapidly than ewes in the low line.

The regressions on breeding values for reproduction traits and their estimated line differences at the end of the experiment are shown in table 2. There was no significant response in ovulation rate in either the first or second breeding season, nor in the number of lambs born per ewe lambing. The number of lambs born per ewe mated and the number of female lambs surviving to 210 days per ewe mated (LS210) both had significant regressions on breeding value.

The predicted line difference in LS210 was combined with the increasing divergence in body weight with age to form a prediction of the number of ewes and weight of ewe required to produce 100 kg of lamb at 210 days (recorded weight nearest to a commercial slaughter weight) as:

Number of ewes =100 /(Weight of lamb at 210 days x LS210)

Weight of ewe =100 x (Pre-mating weight of ewe) /
(Weight of lamb at 210 days x LS210)

These criteria of comparative efficiency were calculated for ewes at 1, 2 and 3 years of age at -1.5 (Low line) and +2.1 (High line) units of estimated breeding value of the selection criterion.

The results (table 3) show that at 2 and 3 years of age, 0.85 High line ewes would produce the same weight of lamb as 1 Low line ewe and that 0.73 kg of High line ewe would produce the same weight of lamb as 1 kg of Low line ewe. On this latter criterion, 11 years of selection have resulted in a divergence of approximately 31% (comparitive to the mean of the two lines) in the efficiency of lamb production of 2 and 3 year old ewes, or 2.8% divergence per annum.

Table 2. Female reproductive performance for ewes lambing at 1, 2 and 3 years of age, overall means and regressions on the selection criterion, with predicted values in the High and Low lines after 11 years of selection.

Season	Trait	Mean	Regression	Low	High
1	Ovulation rate	1.82	0.036	1.77	1.89
	LS2	1.41	-0.009	1.42	1.39
	LS1	0.93	0.034	0.88	1.00
	LS210	0.63	0.083***	0.51	0.81
2	Ovulation rate	2.03	0.009	2.02	2.05
	LS2	1.84	0.011	1.82	1.86
	LS1	1.64	0.063*	1.54	1.77
	LS210	1.33	0.105***	1.17	1.55
3	LS2	2.08	-0.000	2.08	2.08
	LS1	1.93	0.068	1.83	2.07
	LS210	1.55	0.093	1.41	1.75

LS1 - lambs born per ewe mated; LS2 - lambs born per ewe lambing
LS210 - lambs at 210 days per ewe mated

The relative influences of the changes in output per ewe and of the changes in growth patterns on the overall change are shown in Table 3. Body weights were lower throughout in the High line, and therefore more ewes would be needed to produce 100 kg of lamb at all ages. However, because Low line ewes became progressively heavier than High line ewes with advancing age, 8 - 9 kg less weight of ewe at 2 and 3 years in the High line would be needed to produce 100 kg of lamb at 210 days. The changes in ewe output were solely responsible for increasing efficiency at 1 year of age and was much the more important factor at 2 and 3 years, reducing the weight of High line ewe required to produce 100 kg of lamb at 210 days by 32.7 kg and 25.6 kg respectively, compared to the Low line.

Table 3. Predicted number of ewes and weight of ewe which would be required to produce 100 kg of lamb at 210 days in the High and Low lines in the final year of the experiment, with the High - Low differences attributable to the changes in ewe output and to the changes in growth patterns.

						High-Low line differences		
							Contribution from:	
Season	Trait	Base	Low	High	High/Low	Overall	Ewe output	Growth
1	No. of ewes	5.68	6.81	4.63	0.68	-2.18	-2.61	+0.44
	Wt. of ewe	172.0	215.1	133.2	0.62	-81.8	-79.2	-2.8
2	No. of ewes	2.47	2.72	2.23	0.82	-0.49	-0.69	+0.21
	Wt. of ewe	117.0	136.7	96.5	0.71	-40.2	-32.7	-8.0
3	No. of ewes	2.04	2.12	1.94	0.92	-0.18	-0.43	+0.27
	Wt. of ewe	120.0	135.6	100.6	0.74	-35.0	-25.6	-9.7

DISCUSSION

Selection of males on this index of testis size did not improve ovulation rate in their female progeny as originally postulated. However, if the number of lambs at slaughter age per ewe mated is taken as the criterion of overall reproductive efficiency, the High line became significantly superior by the end of the experiment. Analyses within the population have shown that this difference arose because of higher fertility of females and improved lamb survival in the High line, (Haley *et al.*, 1990 , Lee *et al.*, 1990). These findings were unexpected and require experimental verification in other populations.

The increasing divergence in body weight between the lines with advancing age indicated a change in the growth patterns with selection, such that the High line was earlier maturing but had a smaller mature weight. Thus mature ewes in the High line would be smaller with a lower maintenance requirement and still produce lambs for slaughter of a comparatively similar weight to ewes in the Low line. The increase in efficiency attributable to changes in growth patterns increased with age of the ewe, becoming approximately one quarter of the total in ewes at 3 years of age. This combined with the increased numbers of lambs at slaughter age, shows the potential of using indices of testis size adjusted for body weight to improve the efficiency of lamb production.

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Figure 1. Growth in the High and Low selection lines relative to their mature weights and relative to one another.