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Fleece weight:fibre diameter ratios and sheep selection.

DJ Cottle*

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FLEECE WEIGHT: FIBRE DIAMETER RATIOS AND SHEEP SELECTION

D. J. Cottle
Department of Wool Science, Lincoln College, New Zealand

SUMMARY

The relationship between fibre diameter (D) and staple length (L) which remained constant between diets in individual superfine Merino sheep was L/D^2, rather than L/D as reported previously in studies of medium Merino sheep. Thus in individual superfine sheep the ratio Clean Fleece Weight (CFW)/D^4 remains constant over a range of dietary conditions and has a high repeatability (0.7).

When comparing the Australian Merino Society's (A.M.S.) empirical selection index (CFW/D^n) with formal selection indices of the form (CFW x **c**) - D, using current wool market values, the appropriate indices for fine, medium and strong wool Merinos were calculated to be CFW/$D^{4.1}$, CFW/$D^{2.2}$ and CFW/$D^{1.2}$ respectively.

It appears coincidental that these indices tend to remain constant within individual animals over a wide range of nutritional regimes. While having the practical disadvantage that producers are more likely to capriciously change **c** than n, linear selection indices have a number of mathematical advantages.

Introduction

The Australian Merino Society (A.M.S.) was commenced in 1967 by Jim Shepherd in W.A. (Anderson, 1982). This group breeding scheme now claims to involve three million Merino ewes (over 5% of Australian Merino ewes), with the one millionth ewe being inseminated in 1986/87 (Winter, 1986).

Each year all members of the A.M.S. contribute their top 1% of ewe hoggets to their Ram Breeding Co-operative based on the formula (greasy fleece weight (GFW) x 10) + hogget body weight (HBW) (Anderson, 1982). The selection of rams bred in the ram breeding co-operatives is currently based upon the formula (Winter, 1986).

$$\frac{\text{clean fleece weight}}{\text{diameter (D)}^3}\text{(CFW)} + \text{HBW x } \mathbf{a}$$

Initially the selection of rams was based upon the formula

$$\frac{\text{CFW}}{\text{D}^3} + \text{(HBW x } \mathbf{a}$$

(Anderson, 1982). Ponzoni (1985) compared the use of this formula with formal selection indices and the formula used by J. Maple-Brown and reported by Ponzoni (1985). Ponzoni (1985) found the A.M.S. formula described by Anderson (1982) agreed closely with formal selection indices and placed more emphasis on fibre diameter than the formula of Maple-Brown.

The A.M.S. formula using CFW/D^3 (I) is based on work of Ferguson and co-workers at Prospect. Ferguson (1981) found that the Length/Diameter (L/D) ratio of wool produced by sheep appeared to be constant for a given animal throughout its life, regardless of changes in the level of nutrition. Taking this one step further the ratio of CFW/D^3 was found to be relatively constant also. If L/D is constant, it can be expected that CFW/D^3 will be relatively constant as the weight (W) of an individual wool fibre is proportional to cross sectional area (A) x L. A is proportional to $D^2/4$ (r^2), and if L is proportional to D (i.e. L/D is constant) then W would be proportional to D^3. Therefore assuming the number of fibres does not change on a sheep throughout its lifetime, CFW/D^3 would be constant in an individual animal, given L/D is constant. Sheep with a higher I (index) value for a given D produce a higher wool return. Blockey (1987) analysed the 18 strain Merino wether trial run at Hamilton and found the correlations between CFW/D^3 and fleece value to be very high (0.99 — 1986 prices, 0.90 — 1982 prices).

The use of the formula CFW/D^n has some perceived sociological advantages over a formal selection index formula (**c** x CFW) — FD, in that individual producers are less likely to change the value of n according to personal opinion than **c** (Winter, pers. comm.). Blockey (1987) claimed the high correlation between CFW/D^3 and fleece value justifies its use as an index. This is a phenotypic relationship and takes no account of genetic responses, although a response to selection of 1.6%/year in CFW/D^3 (23c/year in fleece value) in the AMS central nucleus flock is reported.

Gunsett (1984) compared the theoretical consequences of selecting for a ratio with linear index selection. For a ratio with the components (CFW and D) having similar heritabilities, index selection and ratio selection result in similar responses. However as CFW has a lower heritability than D and they are positively correlated, the analysis of Gunsett (1984) suggests the high selection pressure placed on rams will cause slight over-emphasis on CFW resulting in less than optimum responses.

The experiments reported in this paper were primarily conducted to study the effects of various feed supplements on wool production in housed superfine Merinos. Details of the effectiveness of the various supplements are reported by Cottle (1987a). During these studies CFW, GFW, D and L of wool produced by the same group of sheep were measured at six consecutive shearings. This enabled an analysis of the relative constancy of various ratios of interest, i.e. L/D, L/D^2, L/D^3, CFW/D^2, CFW/D^3 and CFW/D^4 within sheep between different nutritional regimes.

Materials and Methods

Sixty, 4-tooth, offshears superfine Merino wethers (Winton/Merryville bloodline) were allocated randomly to individual pens in a sheep shed in August, 1982. Between August, 1982 and August, 1985 the sheep were fed different basal rations (oats, lucerne chaff) and different protein and amino acid supplements (see Cottle (1987a) and Table 2). Each group of 20 sheep (10 defaunated, 10 faunated) received 6 different rations. The sheep were allocated randomly to the three groups at the beginning of the trials. A few sheep were reallocated to different groups between each run due to individual feed intake problems.

Every six months the sheep were shorn and midside samples of wool sent to the University of NSW Flock Testing Service where they were analysed for yield and mean fibre diameter. Greasy fleece weight and staple length were determined at shearing.

Repeatabilities and the standard error of the repeatability estimates were calculated from an analysis of variance with unequal numbers of measurements per sheep as described by Becker (1984). This was preferred to the method of Turner and Young (1969) since in the present context the aim was not to estimate repeatability in the usual sense as the correlation between repeated records, but to measure variation within sheep, including that due to years and rations, relative to that between sheep. Thus repeatability as used in this paper is not directly comparable with normal repeatability.

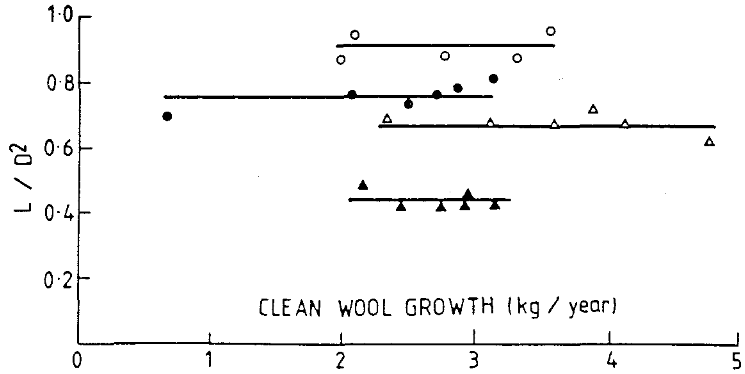

Figure 1: The relationship between L/D^2 and clean wool growth for four sheep fed diets differing widely in nutritive value: the horizontal lines represent the mean for each animal. (Unpublished data)

Results

An example of the calculation of repeatability is given in Table 1. The repeatability of the various ratios in the different groups of sheep are shown in table 2. L/D^2 and L/D^3 were more constant between diets than was L/D. Fig. 1 gives the relationship between L/D^2 and wool growth for four individual animals chosen for their different average values and illustrates the extreme constancy of this ratio within animals but large differences between animals.

Of the fleece weight: fibre diameter ratios analysed, CFW/D^4 had the highest repeatability.

TABLE 1
CALCULATION OF THE REPEATABILITY OF L/D FROM THE POOLED DATA

	Analysis of Variance		
Source	**d.f.**	**S.S.**	**M.S.**
Correction term	1	55504.50	—
Individuals	64	438.691	6.855
Measurements	260	294.277	1.132

k = 4.994 2 $= \frac{6.86 - 1.13}{4.994} = 1.146$

$$\text{Repeatability} = \frac{1.146}{1.146 + 1.132} = 0.5$$

$$\text{s.e. (Repeatability)} = \frac{2(324)\,(0.5)^2\,[1+(3.99)\,(0.5)]^2}{4.99^2\,(325\text{-}65)\,(64)} = 0.059$$

Discussion

L/D^2 changed less between diets in individual sheep than L/D as reported by Ferguson (1981). The cross-sectional area of a fibre is proportional to D^2. The relatively constant L/D^2 ratio suggests that when more wool bulb cells are being produced by mitosis in response to increased nutrient supply (Black and Reis, 1979), the increased upward migration of cells is equalled by the increase in area of cells in the wool follicle bulb due to increases in cortical cell volume or number. When nutrition increases, the turnover time of bulb cells decreases and cortical cell volume increases (Black and Reis, 1979).

This poses the question — why should the longitudinal increase in fibre cortical cells equal the area increase? Black (1987) suggests that because the proportion of bulb cells entering the fibre is constant, the ratio of increase in cross-sectional area of fibre producing bulb cells (D^2) to increase in number of migrating cells (L) should remain constant. There is no obvious physical or biochemical reason why longitudinal increase should equal diameter increase. L/D may change in individual sheep when different amino acids become limiting on different rations (Black, pers. comm.). Williams (1987) has reported significant interactions between genotype and nutrition for CFW, L and D. Rams selected for fleece weight responded to increased nutritional levels with a proportionately greater response in D than rams from a

TABLE 2
REPEATABILITY ESTIMATES OF PARAMETER RATIOS
(± s.e.)

Ratio	Defaunated 1	Defaunated 2	Defaunated 3	Faunated 1	Faunated 2	Faunated 3	*Pooled
Group +	1	2	3	1	2	3	
L/D	0.53 ± 0.14	0.35 ± 0.15	0.62 ± 0.13	0.37 ± 0.16	0.36 ± 0.15	0.51 ± 0.14	0.50 ± 0.06
L/D^2	0.71 ± 0.10	0.61 ± 0.12	0.76 ± 0.09	0.61 ± 0.13	0.69 ± 0.10	0.73 ± 0.10	0.71 ± 0.04
L/D^3	0.68 ± 0.11	0.70 ± 0.10	0.79 ± 0.08	0.64 ± 0.12	0.76 ± 0.09	0.74 ± 0.10	0.74 ± 0.04
CFW/D^2	0.49 ± 0.14	0.54 ± 0.14	0.43 ± 0.15	0.40 ± 0.16	0.33 ± 0.15	0.31 ± 0.15	0.39 ± 0.06
CFW/D^3	0.66 ± 0.11	0.71 ± 0.10	0.64 ± 0.12	0.69 ± 0.11	0.57 ± 0.13	0.50 ± 0.14	0.60 ± 0.05
CFW/D^4	0.72 ± 0.10	0.79 ± 0.08	0.75 ± 0.09	0.78 ± 0.09	0.70 ± 0.10	0.60 ± 0.13	0.70 ± 0.05

Rations

\+ Group 1 received (1) oats (2) oats and methionine (3) lucerne chaff and Mepron (4) chaff and cottonseed meal and Mepron (CSMP) (5) 75% oats, 25% chaff (6) Ration 5 + CSMP.
Group 2 received (1) oats and lupins (2) oats and lupins (3) chaff (4) chaff (5) 50% oats, 50% chaff (6) Ration 5 + CSMP.
Group 3 received (1) oats and extracted lupins (2) oats and Ketionine (3) chaff and Ketionine (4) chaff and cottonseed meal (5) 25% oats, 75% chaff (6) Ration 5 + CSMP.

* Defaunation and feeding group disregarded (325 measurements).

flock with low fleece weight.

If one accepts that L/D^2 is relatively constant, then CFW/D^4 should be relatively constant in the individual. As the aim of the A.M.S. index is to select rams with high fleece weights relative to their fibre diameter, without using a linear index, a more appropriate ratio for fine wool sheep may be: CFW/D^4 + (HBW x **a**), due to its constancy over a range of diets. This formula places more emphasis on the fibre diameter of a ram, than CFW/D^3. For example, if RAM A has the figures 3.4 kg CFW 20 um and Ram B has the figures 4.0 kg CFW, 21 um, Ram A is superior using D^4, but Ram B is superior using D^3. Use of the formal selection index suggested by Cottle (1987b) results in Ram B having superior figures.

It can be shown, using the assumptions given by Cottle (1986) and Ponzoni (1979) that the coefficient **c** in the formula Index (L) = (**c** x CFW) — FD is approximated by k x a/b where k = 0.27, fine wool; 0.23, medium wool and 0.20 strong wool; a = net value of wool and b = fineness premium. The optimum power of n in the equation CFW/D^n (i.e. that which results in a similar ranking to using a linear index) D^n can be approximated by taking typical values for sheep in the various Merino strains and equating the linear index with the AMS index. Future market prices could be used to recalculate the appropriate index, with changing market conditions.

The results in Table 3 show that the most appropriate AMS indices for fine, medium and strong Merinos, assuming the a/b values of 6.25, 12.5 and 25.0 are $CFW/D^{4.1}$, $CFW/D^{2.2}$ and $CFW/D^{1.2}$ respectively.

It appears a coincidence that the ratio that remains stable in individual animals over a range of diets in superfine wool sheep (CFW/D^4 is similar to the AMS index that is closest to the appropriate linear index. If L/D is constant in medium Merino sheep, then it is also a coincidence that CFW/D^3 ranks sneep in a similar fashion to the linear index. Ponzoni (1985) found that CFW/D^2 ranked strong wool Merinos in a similar fashion to his linear index, which is in general agreement with these results. As CFW is more highly correlated with L than D in strong wool Merinos (Lewer and Wickham, 1986), $CFW/D^{1.2}$ may remain constant in strong wool sheep. However, L/D^2 appears to be more constant than L/D in Corriedale wethers fed at different energy levels (Rodriguez, unpublished data).

The analysis presented in this paper allows the calculation of an appropriate AMS-style index from wool market prices (a/b) by use of selection index theory. It should be noted that the non-linear nature of the AMS index makes it difficult to predict rate of response of CFW and D to the index (see Ponzoni, 1985), complicates the calculation of n when wool market prices change, and makes it difficult to incorporate additional information, e.g. body weight, pedigree and reproductive data.

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