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Relationships between loose wool bulk and follicle and fibre characteristics in yearling Perendale sheep

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ABSTRACT

Midside skin and wool samples were taken at hogget shearing in October 1991 from 58 Perendale ewe hoggets which were the progeny of 2 lines of Perendale sheep selected for, or against, loose wool bulk at hogget shearing.

Wool from the high line was 50% more bulky, with a 17% lighter clean fleece weight (CFW), 29% shorter staple length (SL), 25% shorter fibre length (FL), 14% greater within sample variation in fibre diameter (SDFD), 72% higher crimp frequency (CFreq), 61% higher proportion of paracortex (Para%), 92% higher follicle curvature grade (FolC) and 7% shallower follicle depth (FolD) than the low line. Character grade (Char) was 14% lower and sulphur content (S) 3% higher in the high line, each approaching 5% significance, while there was no significant difference in live weight (LW) or mean fibre diameter (FD).

Bulk was most strongly correlated, in decreasing order, with FolC, CFreq, SL, FL, Para%, CFW, SDFD, Char and FolD. In decreasing order CFreq, Char, FD, SL, FL, Para% and FolD explained a total of 90% of the variation in bulk. With deletion of the subjectively assessed characteristics of FolC and Char, CFreq, SL and FL were the only characteristics selected as being significant, explaining a total of 85% of the variation in bulk. The strong association between bulk and both SL and FL can be considered to be a reflection of associations between the length parameters and other fibre characteristics which impact on bulk rather than a direct effect of the length of fibre being measured for bulk.

These data indicate the biological basis of differences in loose wool bulk for coarse wool Perendale sheep are, as for the fine wool Merino, primarily associated with single fibre crimp.

Keywords: Loose wool bulk, follicle characteristics, fibre characteristics, Perendale.

INTRODUCTION

The compressional characteristics of wool are an important component of wool quality. Different end-uses and processing conditions have different requirements. Compressional characteristics have been quantified as either specific volume of a defined mass under a defined pressure, referred to as bulk, or the load required to compress a sample of known mass to a fixed volume, referred to as resistance to compression. Bulk tends to be generally applied to Romcross wools and considered a desirable characteristic for most end-uses of this wool type while resistance to compression is generally applied to Merino wools and considered a less desirable characteristic for apparel end-uses. Bulk and resistance to compression are highly correlated (P. G. Swan, unpublished data).

Australian work has shown crimp to be the most important characteristic affecting resistance to compression in Merino wool, as reviewed by Stobart and Sumner (1991). There has been little work to describe the underlying biological mechanisms responsible for within and between breed differences in bulk for Romcross wools.

The aim of this investigation was to study the relationships between fibre and follicle characteristics for a group of Perendale hoggets exhibiting a wide range in loose wool bulk

and to identify the key characteristics linked with the expression of bulk in this type of Romcross wool.

MATERIALS AND METHODS

Sampling

Wool and skin samples were taken from 58 Perendale ewe hoggets as all the surviving ewe hoggets born in 1989 within the lines of Perendale ewes established at Whatawhata Research Centre in 1987 and selected for and against loose wool bulk at hogget shearing (Sumner *et al.*, 1991).

The hoggets were live weighed and a mid-side wool sample taken prior to hogget shearing in mid-October 1990. Individual greasy fleece weights were recorded at shearing and fleece free live weight (LW) calculated. Skin samples were taken by snip biopsy in late November 1990 and preserved in 10% buffered formalin.

Measurements

Staple length (SL), total number of crimps along the staple and washing yield were measured in the greasy mid-side sample. Crimp frequency (CFreq) and clean fleece weight (CFW) were calculated. Clarity of staple crimp within the

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greasy staple was assessed as a character grade (Char) on a scale of 1 = Very bad to 7 = Excellent.

Scoured sub-samples of the mid-side sample were measured for loose wool bulk (Bulk) (Bigham *et al.*, 1984), mean (FD) and variation (SDFD) in fibre diameter (Lynch and Michie, 1976), mean fibre length (FL), mean proportion of cross-section of fibre cortex in the butt region of the staple occupied by the combined meso- and paracortex (Para%) and sulphur content of the butt region of the staple (S) (Lee, 1983). FL was obtained from 60 lightly stretched fibres, drawn at random from a single staple, by an image analysis procedure applying the algorithm :-

$$\text{fibre length} = (\text{perimeter}/2) - (2 \times \text{area}/\text{perimeter})$$

Para% was obtained using a digitising board to measure 60 individual fibre cross-section images from within a single staple, following modifications to the sectioning and staining technique for bundles of fibres developed by Orwin *et al.*, (1984).

The skin samples were both vertically and transversely sectioned, and stained with Polychrome Methylene Blue (Maddocks and Jackson, 1988). Mean follicle depth (FolD) was derived from 3 measurements, by a micrometer eyepiece (Nay and Jackson, 1973), on 3 consecutive vertical sections per sample. Mean follicle curvature (FolC) was derived from 15 assessments on a graded scale of 1 = straight to 7 = very curved (Nay and Jackson, 1973) by 3 operators each independently scoring the same set of 5 consecutive vertical sections per sample.

Statistical

Multivariate techniques were used to evaluate the relationship between bulk and the measured follicle and fibre characteristics.

RESULTS AND DISCUSSION

Basic statistics for live weight and follicle and fibre characteristics for the 2 bulk selection lines at ewe hogget shearing in 1990 are given in Table 1. The high line had a 17%

lighter CFW, 29% shorter SL, 25% shorter FL, 14% greater SDFD, 72% higher CFreq, 61% higher Para%, 92% higher FolC and 7% shallower FolD than the low line. There was also a trend, approaching 5% significance, for the high line to have 14% lower Char ($P=0.065$) and 3% higher S ($P=0.054$) than the low line. LW and FD were not significantly different between the 2 lines. Similar trends were reported for some of these characteristics measured at the 1989 ewe hogget shearing of the same flock (Sumner *et al.*, 1991). There was however, a 2-fold increase in the difference between the high and low lines for both Bulk and CFW between the 1989 and 1990 hogget shearings (Sumner *et al.*, 1991) associated with between year variation in the expression of phenotypic differences between selection lines.

Phenotypic correlations for the whole population, between the measured follicle and fibre characteristics are given in Table 2. Correlations between Bulk, CFW, SL and FD, are within the range of previously published estimates (Sumner and Bigham, 1993), with the possible exception of Bulk x CFW and Bulk x SL. In these cases the present estimates are more strongly negative, -0.61 and -0.83 versus -0.2 and -0.5 respectively, than the 1 previously published estimate, derived from Romney sheep which inherently produce a low bulk type wool (Bigham *et al.*, 1983). The stronger relationships in this data set may be a reflection of the greater range of variation in the present study. Bulk was most strongly correlated, in decreasing order, with FolC, CFreq, SL, FL, Para%, CFW, SDFD, Char and FolD, with the first 5 listed characteristics individually explaining in excess of 40% on the variation in bulk, namely FolC (71%), CFreq (70%), SL (69%), FL (51%) and Para% (42%). As many of the measured characteristics were themselves interrelated their combined effect on bulk was assessed by multiple regression analyses. A summary of results indicating the proportion of variation in bulk explained by the stepwise inclusion, or exclusion, of follicle or fibre characteristics, based on the change in residual mean square, is given in Table 3. Critical F-statistics for variable selection were set at a 5% significance level ($F=4$). FolC and CFreq, the 2 variates with

TABLE 1: Least square means of each selection line, standard error of difference between lines, and overall standard deviation and coefficient of variation, for live weight and follicle and fibre characteristics.

Characteristic	Abbreviation	Selection line		SED	Overall	
		High bulk	Low bulk		SD	CV%
Number of hoggets		30	28			
Loose wool bulk (cm ³ /g)	Bulk	31.3	20.8	0.7	5.8	22.8
Live weight (kg)	LW	40.2	41.2	1.2	4.3	10.6
Clean fleece weight (kg)	CFW	1.89	2.29	0.09	0.40	18.8
Staple length (mm)	SL	98	139	4	25	20.9
Fibre length (mm)	FL	115	154	5	27	19.7
Fibre diameter (mean) (µm)	FD	34.2	33.3	0.6	2.3	7.0
Fibre diameter (SD) (µm)	SDFD	8.2	7.2	0.2	1.0	13.3
Character grade (1-7)	Char	4.5	5.2	0.4	1.4	29.0
Crimp frequency (crimp/cm)	CFreq	2.4	1.4	0.1	0.7	35.1
Proportion paracortex (%)	Para%	33.6	20.8	2.2	10.0	37.3
Sulphur content (mg/g)	S	31.7	30.9	0.4	1.6	5.2
Follicle curvature grade (1-7)	FolC	4.0	2.1	0.2	1.1	37.6
Follicle depth (mm)	FolD	2.04	2.18	0.06	0.21	10.2

TABLE 2: Total phenotypic correlation coefficients between measured follicle and fibre characteristics (n = 58). Abbreviations for traits given in text and Table 1.

	LW	CFW	SL	FL	FD	SDFD	Char	CFreq	Para%	S	FolC	FolD
Bulk	-0.10	-0.61**	-0.83**	-0.71**	0.23	0.54**	-0.41**	0.84**	0.64**	0.25*	0.84**	-0.38**
LW		0.44**	0.11	0.07	0.14	-0.12	0.15	-0.01	-0.12	-0.03	-0.14	0.09
CFW			0.63**	0.60	0.13	-0.43**	0.43**	-0.52**	-0.50**	-0.28*	-0.62**	0.27*
SL				0.94**	-0.12	-0.62**	0.35**	-0.71**	-0.56**	-0.20	-0.81**	0.42**
FL					0.01	-0.52**	0.31**	-0.66**	-0.48**	-0.22	-0.73**	0.42**
FD						0.34**	0.05	0.02	0.08	-0.05	0.25*	0.20
SDFD							-0.43**	0.32**	0.35**	0.03	0.66**	0.20
Char								-0.17	-0.13	-0.14	-0.30*	0.21
CFreq									0.58**	0.29*	0.74**	-0.52**
Para%										0.55**	0.62**	-0.40**
S											0.30*	-0.29*
FolC												-0.41**

the highest correlation with bulk, were selected first and together explained 80% of the variation in bulk. Char, FD and SL explained an additional 7% of the variation, at which stage there was no significant loss of accuracy of fit through deletion of FolC. A further 1.5% of variation was explained through the inclusion of FL and an additional 0.7% each for Para% and FolD giving a total of 90% of the variation in bulk explained by the 7 variables.

TABLE 3: Summary of multiple regression analyses of bulk on follicle and fibre characteristics.

Characteristic	Explained variation (%)
+ FolC	70.0
+ CFreq	80.3
+ Char	83.9
+ FD	85.7
+ SL	87.6
- FolC	87.1
+ FL	88.6
+ Para%	89.3
+ FolD	90.1

There was still a small effect of selection line, accounting for an additional 2% of the variation. Additional tests, including graphical inspection of the data, indicated that there were no significant non-linear terms or interactions between explanatory variables. Thus the interaction between FD and CFreq, as demonstrated by Whiteley *et al.*, (1978) in relation to resistance to compression, is not supported by these data for Perendale wool.

Within the individual selection lines, CFreq and Char consistently accounted for the greatest proportion of the variation in bulk explaining 40% and 53% of the variation for the low and high lines respectively and together with FolD, 62% of the variation in the high line. The lower values for the proportion of variation explained by these characteristics within the individual lines, relative to the total population, are possibly a reflection of the reduced discriminating ability among a smaller range of characteristic values within lines.

The magnitude of the individual relationships of FolC and CFreq with Bulk in the Perendale are similar to those reported for resistance to compression in the Merino (Whiteley *et al.*, 1978). Although hypotheses on the biological basis of the origin of crimp suggest a close association between CFreq and FolC (Nay and Johnson, 1967), Whiteley *et al.*, (1978) showed, as did this data, that CFreq was more important than FolC in explaining the variation associated with compressional properties when the additional characteristics of SL and FD were also included in the model. These results thus confirm Australian Merino studies, reviewed by Stobart and Sumner (1991), where despite marked differences in spatial configuration of follicles and fleece structure the compressional properties of Perendale wool are also principally dependent on single fibre crimp.

The negative correlation between staple crimp clarity, described by the traditional woolclassing term of character, and Bulk (-0.41) reflects the importance of crimp form, as well as CFreq, in explaining the variation in bulk. Fibres from high Char grade wools tend to have a planar crimp form whereas wools with a low Char grade tend to have a helical crimp form (Chaudri and Whiteley, 1968). There was also a negative correlation between Char and SDFD (-0.43) indicating a possible effect of variability in fibre diameter, and an associated variation in individual fibre CFreq, on the ability of the fibres to pack together within the staple. While Char was assessed in staple form it is of interest that it also explains a significant proportion of the variation in bulk when the latter is measured as a carded batt in which the staple form has been destroyed.

Although Char, and also FolC, are important characteristics in explaining a significant proportion of the variation in bulk, they are subjective assessments with no objective basis. There is therefore the potential for between operator variation to influence any derived relationships. To check the impact of these 2 characteristics in explaining the variation in bulk, the analyses were rerun deleting both Char and FolC. CFreq alone then explained 70% of the variation in bulk. SL explained an additional 11% and FL explained a further 4%, giving a total of 85% of the variation in bulk explained by 3 objectively measured variables. These results suggest the need for further investigation to determine the critical aspects

of single fibre crimp which influence bulk, as well as to quantify those characteristics implicated in the expression of bulk through the measurement of SL and FL.

While there is speculation as to the nature of the association between ortho- paracortex relationships and CFreq (Campbell *et al.*, 1972) these data showed a significant relationship between Bulk and Para% ($r=0.64$). Based on the 60 individual fibres measured for each sheep, there was a significant within-sheep relationship between individual fibre Para% and the diameter of the cortex. The regression of the individual fibre Para% on cortex diameter was -0.96 ± 0.03 with insignificant between-animal variation in either the slope or intercept. Transverse skin sections indicated the relationship between Para% and cortical diameter was not different for fibres derived from either primary or secondary follicles. Although individual fibre Para% has a strong negative within-sheep correlation with cortical diameter there was no significant between-sheep relationship for mean Para% and FD. This may be partly explained by the limited variation in FD and the method of measurement used for the respective characteristics. Para% was measured at a point just prior to shearing taking no account of possible changes along the length of the fibre, whereas FD was the mean over the growing period of the fibre encompassing within- and between-fibre effects.

SL and FL were strongly correlated (0.94). However FL gave a small improvement in fit after SL possibly because it is considered to be more associated with crimp form than SL alone. Within the range of lengths in this data set, neither SL nor FL would be expected to have a direct effect on bulk values as measured by bulkometer (Sanderson and Burling-Claridge, 1990). The strong association between bulk and both SL and FL can be considered to be a reflection of associations between the length parameters and other fibre characteristics which impact on bulk, rather than a direct effect of the length of fibre being measured for bulk.

On the assumption that individual follicle length may not be influenced by the extent of follicle curvature, a simple measurement of FoLD as the vertical depth of a mass of follicles within the dermis was taken rather than the technically more difficult mean of the actual length of a set of individual follicles. The negative relationship of FoLD with FoLC (-0.41) is indicative that while curved follicles may be shorter than straight ones, overall they are no longer. FoLD was also negatively related to CFreq and Para%.

Loose wool bulk is a complex biological property principally dependent on single fibre crimp. It is also influenced by, as yet undefined, characteristics associated with SL and FL as well as aspects of follicle and fibre morphology. Further work is required to quantify these interrelated characteristics in terms of follicle and fibre biology with a view to produce fibre to meet processor's specifications.

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REFERENCES

- Bigham, M. L.; Meyer, H. H.; Smeaton, J. E. 1983. The heritability of loose wool bulk and colour traits and their genetic and phenotypic correlations with other wool traits. *Proceedings of the New Zealand Society of Animal Production* 43: 83-85.
- Bigham, M. L.; Sumner, R. M. W.; Cox, N. R. 1984. The measurement of sources of variation of loose wool bulk in Romney, Coopworth and Perendale breeds. *New Zealand Journal of Experimental Agriculture* 12: 23-28.
- Campbell, M. E.; Whiteley, K. J.; Gillespie, J. M. 1972. Compositional studies of high and low crimp wools. *Australian Journal of Biological Science* 25: 977-987.
- Chaudri, M. A.; Whiteley, K. J. 1968. The influence of natural variations in fibre properties on the bulk compression of wool. *Textile Research Journal* 38: 897-906.
- Lee, J. 1983. Multi-element analysis of animal tissue by inductively coupled plasma emission spectrometry. I. C. P. Information Newsletter No.8. 553-561.
- Lynch, L. J.; Michie, N. A. 1976. An instrument for the rapid automatic measurement of fiber fineness distribution. *Textile Research Journal* 46: 653-660.
- Maddocks, I. G.; Jackson, N. 1988. Structural studies of sheep, cattle and goat skin. CSIRO Division of Animal Production, Blacktown, NSW, Australia. pp. 76.
- Nay, T.; Jackson, N. 1973. Effect of changes in nutritional level on the depth and curvature of wool follicles in Australian Merino sheep. *Australian Journal of Agricultural Research* 24: 439-447.
- Nay, T.; Johnson, H. 1967. Follicle curvature and crimp size in some selected Australian Merino groups. *Australian Journal of Agricultural Research* 18: 833-840.
- Orwin, D. F. G.; Woods, J. L.; Ranford, S. L. 1984. Cortical cell types and their distribution in wool fibres. *Australian Journal of Biological Science* 37: 237-255.
- Sanderson, R. H.; Burling-Claridge, G. R. 1990. Comparison of loose wool bulk and core bulk. *Wool* 8:(2)30-32.
- Stobart, R. H.; Sumner, R. M. W. 1991. Bulk and its structural basis: A review. *Proceedings of the New Zealand Society of Animal Production* 51: 339-346.
- Sumner, R. M. W.; Bigham, M. L. 1993. Biology of fibre growth and possible genetic and non-genetic means of influencing fibre growth in sheep and goats - a review. *Livestock Production Science* 33: 1-29.
- Sumner, R. M. W.; Maddever, D. C.; Clarke, J. N. 1991. Effect of selecting Perendale hoggets for loose wool bulk on fleece characteristics and wool end-product performance. *Proceedings of the New Zealand Society of Animal Production* 51: 347-351.
- Whiteley, K. J.; Watson, N. R.; Wilkins, O. D. 1978. The relationship between the resistance to compression of wool bulks and follicle curvature. *Journal of the Textile Institute* 69: 41-48.