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Changes in fibre and follicle characteristics related to wool bulk during the lifetime of Perendale ewes

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ABSTRACT

Wool and skin samples were collected annually at hogget shearing in October and thereafter in July for a further four shearings, from a total of 32 Perendale ewes born in 1990 and 1991 within lines selected for or against wool bulk. Time to form a crimp, follicle curvature and the proportion of para-meso cortical cells, increased towards an asymptote with increasing age. Proportion of fibres with a bilateral arrangement of cortical cells was maximal at 2 years of age and clean fleece weight, staple length and fibre diameter were maximal at 3 years of age. Fibre curvature decreased linearly, crimp frequency and follicle length decreased curvilinearly but wool bulk did not change with increasing age. The repeatability of individual characteristics decreased with increasing age. There was no significant difference in the relationship between core bulk and a combination of fibre curvature, fibre diameter and fibre diameter variation within each age group.

Keywords: wool bulk; age; fibre characteristics; follicle characteristics; Perendale.

INTRODUCTION

Wool bulk, the space filling capacity of an assembly of fibres, is positively associated with processing performance of Romcross type wool as well as the performance of the resultant end product (Sumner *et al.,* 1991). As a consequence processors of Romcross type wools prefer wools with increased bulkiness. Bulk is strongly inherited and controlled by relatively few genes (Sumner *et al.,* 1995; Wuliji *et al.,* 1995). Its expression is largely dependent on single fibre crimp in a fibrous mass and its response to pressure (Stobart and Sumner, 1991). Fibre crimp is in turn related to other fibre and follicle characteristics. Relationships between fibre and follicle characteristics affecting bulk in Romcross type wool have been exclusively studied in hogget wool (Sumner *et al.,* 1993; Dick and Sumner, 1995, 1996). However, as many wool characteristics are known to change with age (Sumner and Bigham, 1993) it is important to understand how the interaction between fibre and follicle characteristics related to bulk may change with increasing age. Such changes in individual characteristics may be of sufficient magnitude to impact, positively or negatively, on processing and end product performance of wool from sheep of different ages.

This study investigated the changes in wool bulk and related fibre and follicle characteristics during a sheep's productive life.

MATERIALS AND METHODS

Sampling

Wool and skin samples were collected from a flock of Perendale ewes selected for or against wool bulk at hogget shearing which has been maintained at Whatawhata Research Centre since 1989 (Sumner *et al.,* 1995). Individual sheep were first shorn as lambs in mid December at approximately three months of age. They were next shorn as hoggets the following October and thereafter once yearly in mid July before lambing, until they were culled from the flock at 5 years of age. All sheep were live weighed (LW) prior to shearing. Midside fleece and snip skin biopsy (Parry *et al.*, 1992) samples were taken from all ewes born in 1990 and 1991 at weaning, before their hogget shearing and at each subsequent shearing while they remained in the flock. The detailed measurements used in this study were carried out on samples from 16 ewes born in 1990 which survived to 1995 and 16 ewes born in 1991 which survived to 1996. Ewes were selected by restricted randomisation to balance for bulk selection line and birth/rearing rank.

Wool measurements

Individual fleece weights were recorded at each shearing. Staple length (SL) of the greasy wool sample was measured and the total number of crimps along the staple counted. Crimp frequency (CFreq) was calculated as total number of crimps along the staple/staple length, and time to form a crimp (CTime) was calculated as days since last shearing/total number of crimps along the staple. The midside wool samples were aqueous scoured and the washing yield calculated to derive the clean fleece weight (CFW). Mean fibre diameter (FD), standard deviation of fibre diameter (FDSD) and fibre curvature were measured by optical fibre diameter analyser (OFDA) (Edmunds, 1995). Fibre curvature, which was measured as degrees/mm, was converted to radius of curvature (μm) (RadC) by the proportional relationship, fibre curvature / 360 = 1000 / 2 π RadC. Measurements of loose wool bulk (Bigham *et al.,* 1984) were converted to core bulk (CB) values using a predictive equation (core bulk = 0.93 loose wool bulk + 6.7) developed for Whatawhata fibre metrology laboratory data (R.M.W. Sumner, G.R. Burling-Claridge and M.P. Upsdell, unpublished data) as insufficient sample remained to measure CB after introduction of a New Zealand standard core bulk test method in 1994.

Skin measurements

Longitudinal sections (1mm thick) were cut by hand with a razor blade from half of the skin biopsy sample, stained with 0.25% nile blue sulphate and graded for follicle curvature (FolC) (Dick and Sumner, 1995). Curved length (FolL) of all the whole follicles in one microscope field per sheep (between 12 and 24 follicles) were measured by image analysis. The other half of the skin biopsy sample was processed through an ethanol gradient, embedded in wax, cut in transverse sections (7(m thick) and stained with 0.1% janus green. The proportion of para-meso cortex within the total fibre cortex (%P-M) and the proportion of fibres classified as having a bilateral arrangement of cortical cell types (%Bilat) were measured by image analysis (Dick and Sumner, 1995).

Statistical analysis

Data measured at each sampling were analysed by least square regression analysis fitting effects of year born, birth rank and selection line. The effects of pregnancy and lactation status during the year preceding sampling were evaluated after adjustment by covariance for live weight at sampling. Individual sheep data were analysed for age effects within each of the selection lines, by Bayesian smoothing (Upsdell, 1994). Correlations (repeatability) between measurements of samples taken at hogget and each subsequent shearing were calculated. A measure of the overall repeatability, or intra-class correlation, between measurements at each shearing with each other shearing was derived by residual maximum likelihood procedures (GENSTAT, Lawes Agricultural Trust, 1993). This was calculated as the square root of (between sheep variance / (between sheep variance + residual variance)) (Turner and Young, 1969). The square root of the variance ratio was taken to make the estimate comparable to the derived correlation coefficients. As the measured fibre and follicle characteristics associated with wool bulk are interrelated and exhibit different ageing patterns, their effect on bulk was assessed by multiple regression at each year of age (GENSTAT, Lawes Agricultural Trust, 1993). Initially the effect of step-wise adjustment to include each characteristic was evaluated based on the change in residual mean square. The critical F-statistic for variate selection was set at $F = 2$. The multiple regression analysis was then repeated for each characteristic individually. Linear combinations of RadC, FD and FDSD were used to generate predictive models for core bulk at each age.

RESULTS

Birth/rearing rank effects were not significant for any of the measured characteristics at each sampling and will not be further discussed. There was no consistent significant relationship between LW and any of the measured characteristics across all samplings. While there was a trend for ewes which did not sustain a pregnancy, nor rear a lamb, to have a higher CFW the effects of pregnancy and lactation status were not significant across years for all measured characteristics. The adjusted mean values for LW within each selection line group over time are plotted in Figure 1. Adjusted mean values for wool, follicle and fibre structural characteristics within each selection line group over time are plotted in Figure 2. There was no significant difference between bulk lines at any sampling for LW, FD or CTime (Figs. 1 and 2). The %Bilat was consistently lower in the high bulk line but the difference was not significantly different at any age (Fig. 2). Fleeces in the high bulk selection line had a lighter CFW, shorter SL, higher CB, shorter RadC, higher CFreq and a higher %P-M for fibres which grew from more curved and shorter follicles than fleeces in the low bulk selection line (Fig. 2).

Correlation coefficients between the value of each measured characteristic at hogget shearing and the value at each subsequent shearing are given in Table 1. Also included is an estimate of the overall repeatability across all shearings. The extent to which the measurement of each of the characteristics at hogget shearing indicated a sheep's ranking at later shearings decreased with increasing age. There was no significant relationship between the hogget fleece and later fleeces after 2 years of age for %Bilat, after 3 years of age for Ctime and %P-M, and after 5 years of age for FolL. The overall repeatability for %Bilat was not significantly different from zero. Generally characteristics where either human judgement was involved in assessment or there was a low within flock variation, tended to have lower repeatability estimates than either objectively measured characteristics or characteristics with a marked difference between the bulk selection lines.

The proportion of variation in CB explained by both a combination of RadC, FD and FDSD, and the combination of characteristics where the stepwise inclusion of an additional characteristic did not significantly change the residual mean square, are given in Table 2. A combination of RadC, FD and FDSD consistently explained a major proportion of the variation in CB. The proportion explained decreased with increasing age. While an increased

FIGURE 1: Mean values for live weight within each bulk selection line group over time. Open symbols are low bulk selection line group and solid symbols are high wool bulk selection line group. Plotted lines are significantly different at 5% level where confidence bands do not overlap.

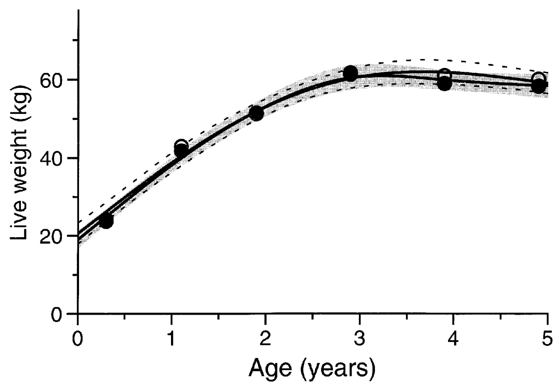

FIGURE 2: Mean values for wool, follicle and fibre structural characteristics within each wool bulk selection line group over time. Open symbols are low wool bulk selection line group and solid symbols are high wool bulk selection line group. Plotted lines are significantly different at 5% level where confidence bands do not overlap.

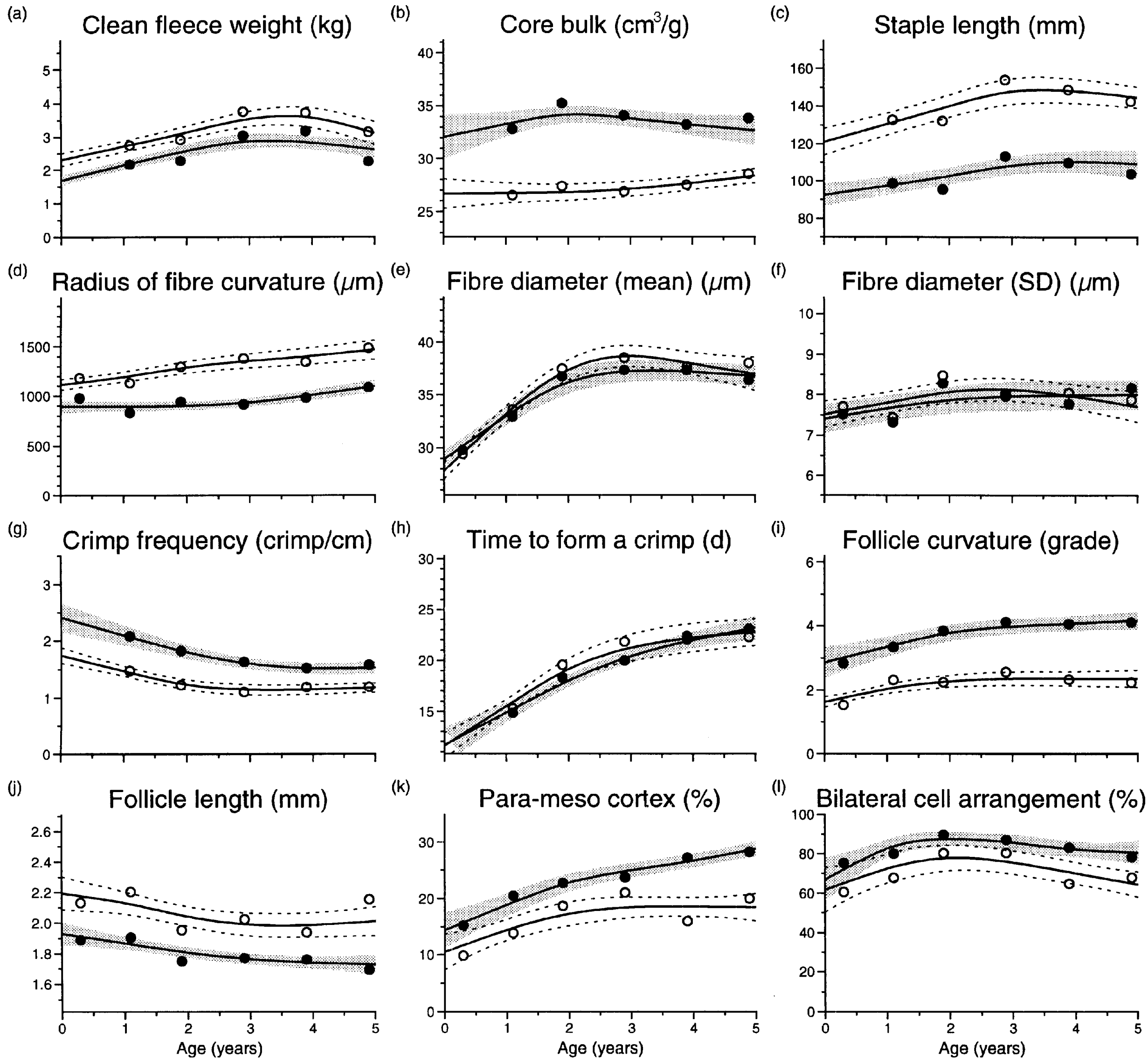

TABLE 1: Correlation coefficients (±SE) between measurements taken at hogget shearing and each of the subsequent shearings and the overall correlation coefficient (±SE) between all measurements, in order of decreasing values for the overall correlation coefficient.

Characteristic	Age (years)				Overall
	2	3	4	5	
Staple length (mm)	0.90±0.03	0.89±0.04	0.85±0.05	0.81±0.06	0.88±0.03
Radius of fibre curvature (μm)	0.93±0.02	0.84±0.05	0.79±0.07	0.74±0.06	0.83±0.04
Core bulk (cm^3/g)	0.87±0.04	0.82±0.06	0.75±0.08	0.72±0.07	0.76±0.05
Crimp frequency (crimp/cm)	0.85±0.05	0.70±0.09	0.67±0.10	0.63±0.10	0.75±0.06
Follicle curvature grade	0.76±0.07	0.70±0.09	0.64±0.09	0.65±0.10	0.72±0.06
Fibre diameter (mean) (μm)	0.78±0.07	0.68±0.10	0.59±0.12	0.42±0.11	0.66±0.07
Clean fleece weight (kg)	0.78±0.07	0.69±0.09	0.59±0.12	0.58±0.10	0.64±0.07
Fibre diameter (standard deviation) (μm)	0.75±0.08	0.56±0.12	0.62±0.11	0.50±0.10	0.63±0.07
Live weight (kg)	0.63±0.11	0.57±0.12	0.50±0.13	0.40±0.12	0.47±0.09
Follicle length (mm)	0.53±0.13	0.48±0.14	0.43±0.14	0.28±0.16	0.42±0.09
Time to form a crimp (d)	0.59±0.12	0.41±0.15	0.24±0.17	0.10±0.18	0.38±0.09
Para-meso cortex (%)	0.55±0.12	0.37±0.15	0.28±0.16	0.24±0.16	0.30±0.09
Bilateral cell arrangement (%)	0.50±0.13	0.14±0.17	0.10±0.18	0.14±0.17	0.18±0.08

TABLE 2: Proportion of variation in core bulk explained by different combinations of characteristics at each age.

Age at shearing years	Variation explained by radius of fibre curvature, fibre diameter and fibre diameter variation (%)	Variation explained with "best fit" of a set of characteristics (%)
1 (Hogget)	84.3	89.0
2	79.6	93.8
3	78.2	92.7
4	56.9	88.4
5	65.4	80.2

TABLE 3: Individual coefficients ±SE and constant ±SE for the relationship between core bulk and a combination of radius of curvature, fibre diameter and fibre diameter variation at each age.

Age at	Terms			
shearing (years)	Radius of fibre curvature	Fibre diameter	Fibre diameter variation	Constant
1 (Hogget)	-0.019±0.004	+0.62±0.36	+0.86±1.05	+21.9±9.1
2	-0.017±0.004	+0.39±0.39	+0.10±1.04	+35.7±10.3
3	-0.015±0.003	+0.48±0.40	-0.66±1.10	+34.9±9.4
4	-0.013±0.004	+0.45±0.50	-0.13±1.12	+29.3±15.5
5	-0.014±0.006	+0.48±0.64	-0.78±1.51	+38.2±14.6
Overall	-0.011±0.002	+0.56±0.21	-0.38±0.64	+30.5±0.7

proportion of variation could be explained by different sets of characteristics, the particular characteristics included were inconsistent across ages. Accepting RadC, FD and FDSD as the set of characteristics most closely related to CB, the linear relationships between CB and this set of three characteristics at each shearing, are given in Table 3. As neither individual coefficients, nor the constant term, differed significantly with age, CB in adult sheep can be predicted by a single equation without regard to their age.

DISCUSSION

Age trends reported here for CFW, FD and CFreq in the Perendale wool bulk selection lines are similar in direction and magnitude, when expressed as a percentage deviation from the overall mean, to those reported for Merino ewes by Brown *et al.* (1966). Whereas Brown *et al.* (1966) reported SL in the Merino to continually decline from 1.5 years of age, these data indicated SL in the Perendale increased to a plateau at 3 to 4 years of age before declining, as previously reported for a range of Romney cross type breeds at Whatawhata (Bigham *et al.*, 1978; Hight *et al.*, 1976). Greasy fleece weight of these same breeds (Bigham *et al.*, 1978; Hight *et al.*, 1976) also plateaued at 3 to 4 years of age as reported here for CFW.

Age trends for CB, RadC, FDSD, CTime, FolC, FolL, %P-M and %Bilat have not been previously reported for New Zealand Romney cross type sheep. The observed trends for FDSD, %P-M and %Bilat are compatible with follicle output plateauing at 3 to 4 years of age. In contrast, attributes more directly related with crimping decreased after 1 year of age, specifically, RadC, CTime, CFreq and FolC. FolL was inversely related to FolC with curved follicles tending to be shorter than straight follicles at each shearing. With the exception of CB, all the fibre and follicle measurements taken in this trial apply to single fibres. CB, however, measures the behaviour of a mass of fibres and is dependent on single fibre crimp structure (Stobart and Sumner, 1991). Despite many of the measured crimp related characteristics changing with age, the trends expressed by the individual characteristics apparently compensated each other to the extent that CB did not change significantly with increasing age. The implications of this non significant age effect on CB are firstly that this study has confirmed that CB of hogget wool can be predicted from a combination of RadC, FD and FDSD (Edmunds and Sumner, 1996). Secondly this study has confirmed, for a wider range of age groups than Dick and Sumner (1997), that although these characteristics themselves change with increasing age the coefficients and constant in the predictive equation do not change significantly with increasing age in the Perendale wool bulk selection lines up to 5 years of age (Table 3). While the universality of such a relationship must be further checked, these data are suggestive that the use of a suitable predictive equation could significantly reduce costs of fleece testing where flocks are being selected for increased wool bulk.

Within each sampling, however, there was a significant difference between the two bulk selection lines for CFW, CB, SL, CFreq, FolC, FolL and %P-M (Fig. 2) as previously reported by Dick and Sumner (1996) and Sumner *et al.* (1993) and for RadC, with no significant selection line effect for FD or FDSD. It is of biological significance that CTime (Fig. 2 (h)), which has not been previously reported, was also not significantly different between the bulk selection lines, implying that wool follicles in these Perendales underwent the same number of crimp cycles per unit of time regardless of their wool type. This suggests that to increase bulk while maintaining fleece weight, selection pressure would need to be applied to increase both the frequency of crimp cycles and fibre length growth rate simultaneously while maintaining fibre diameter. The frequency of crimp cycles decreased with increasing age.

In selecting individuals at a young age to improve their lifetime productivity for a particular characteristic, it is desirable that the within group ranking for the characteristic changes little during the individual's life. Each of the objectively measured dimensional fibre characteristics which are closely related to processing performance, namely CB, SL, and FD, were highly repeatable between hogget shearing and each subsequent shearing and overall between all shearings (Table 2). Recent software developments for the OFDA (Edmunds, 1995) have made possible the simultaneous objective measurement of both fibre diameter and fibre curvature. Fibre curvature was expressed in this paper as RadC and was also highly repeatable.

Presently wool from mixed age breeding ewes is offered for sale in a mixed form. This study has shown that, with the exception of wool bulk, age trends in objectively measured fibre characteristics are of sufficient magnitude to potentially impact on processing and end-product performance. With increased contract production of wool in future, separating farm lines on the basis of age may assist processors to adjust processing and end product performance within specified limits while wool bulk of the lines will not be affected.

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