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Wool characteristics in the Meat and Wool New Zealand Central Progeny Test flocks

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ABSTRACT

The Meat and Wool New Zealand Central Progeny Test programme (CPT) was established to demonstrate the relative breeding merit of leading sires in the New Zealand sheep industry. Here we describe the wool grown over the summer by the 2007 born one-year-old ewes within the CPT. Within fleeces, staple strength varied between farms as shown by the mean difference of 23 N/ktex in offspring of the link sire. Staple strength correlated positively with midside fibre diameter ($r = 0.26$), medullation ($r = 0.23$) and negatively with fibre curvature ($r = -0.61$). Staple strength was similar on anterior (74 ± 24 N/ktex) and midside (75 ± 24 N/ktex) body-sites, but was weaker on the hindleg (64 ± 21 N/ktex; $P < 0.001$). Overall mean staple strength was 72 ± 20 N/ktex, while individual fleeces ranged from 19 to 121 N/ktex. Ten percent of fleeces measured below 45 N/ktex leaving them prone to excessive fibre breakage during processing. Some fleeces varied up to 40 N/ktex across body-sites. Even within one flock, offspring of individual sires differed by a mean of 29 N/ktex, suggesting a consistent weakness of wool in the progeny of some highly ranked sires which will negatively affect processing and end-product performance.

Keywords: wool characteristics, MWNZ Central Progeny Test, staple strength.

INTRODUCTION

The Meat and Wool New Zealand (MWNZ) Central Progeny Test programme (CPT) was established to demonstrate the relative breeding merit of leading sires in the New Zealand sheep industry (Young & Newman, 2009). The CPT objectives to date have been primarily focussed on carcass merit, animal health and fecundity traits regardless of breed. Although fleece weight has been recorded, little emphasis has been placed on the attributes of these fleeces. With present wool markets rewarding almost solely on weight of wool sold (Sumner *et al*., 2008), growers have been content with the existing formulae. However stock selection based on fleece weight alone may lead to the growth of longer and coarser fleeces. These attributes conflict with the needs of processors and manufacturers who are now requesting more highly specified raw wool in order to fulfil direct supply agreements (McDermott *et al*., 2006). With multiple breeders participating in the CPT programme, the opportunity exists to provide ongoing assessment of fleece quality in genetically well-characterised stock linked to the Sheep Improvement Limited (SIL) database. The potential to use modern genomic tools including genome wide association studies will aid the calculation of genomic breeding values (McEwan, 2009) that incorporate processor-defined wool characteristics.

One such attribute of wool that is important during processing of the fleece into yarn and also in the quality of the end product is the tensile strength of staples within each fleece (Maddever *et al*., 1994). Tender fleeces decrease the mean length of fibres after carding, resulting in reduced efficiency of processing in subsequent operations such as spinning, tufting and weaving. Excessive breakage of fibres during carding usually restricts tender wools to woollen processing rather than the higher quality worsted and semi-worsted routes. Few growers objectively monitor their wool quality and anecdotal evidence suggests changes in their wool clip are creeping in as many introduce new genetic lines with the goal of better lamb production.

Here we present data describing the fleeces of the 2007 born ewes from all three CPT farms comprising: On-Farm Research's Poukawa Research Station in the Hawkes Bay, Lincoln University's Ashley Dene Pastoral Systems Research Farm in Canterbury, and AgResearch's Woodlands Research Farm in Southland. The ewes were sampled as one-year-olds and represent offspring of 13 elite dual-purpose rams. This paper presents the first year's data from a multiyear project linking wool phenotype with genomic information. Due to the limited data set, the results are preliminary with respect to final conclusions. Sires are selected for use in the CPT based on performance and genetic linkage to other flocks recorded in the SIL database regardless of breed. This includes a sire used to provide linkage across years and between the three farms. As such, Romney, Coopworth, Perendale, GrowBulk (Romney/Poll Dorset/Texel), and Textra (Texel/East Friesian/Poll Dorset) were represented in the sires while the base ewe flock consisted originally of Coopworth and Romney-cross ewes (McLean *et al*., 2008). The ewes described here join the breeding flocks for subsequent cohorts of progeny tests and contribute to the diverse composite nature of the CPT flocks with contemporary elite genetic backgrounds. As such, these ewes contain genetic material from 20 CPT sires of various commercially important dual purpose breed lines sourced over the previous five years. The wool sampling period covers the spring and summer period and is therefore uncomplicated by environmental factors such as adverse wintering or reproductive influences.

MATERIALS AND METHODS

Wool grown between September 2008 and February 2009 was harvested from 479 one-year-old ewes from the three CPT farms described above. Using a conventional electric shearing hand-piece (Heiniger AG, Herzogenbuchsee, Switzerland), three body-sites along the midline of each sheep were sampled: fore-leg, midside and hind-leg. These sites were selected as best representing across-fleece variation in a number of wool attributes (Craven *et al.*, 2009), although staple strength was not analysed in Craven's study. These wool samples were individually analysed for staple length and tensile strength, as well as other common wool parameters including mean fibre diameter, fibre diameter standard deviation, mean fibre curvature and proportion of medullation using OFDA (SGS Laboratories, Wellington, New Zealand). At the time of sampling, all sheep were scored for bareness of face, belly and breech using a five point scale, where 1 = Covered and 5 = Bare (Scobie *et al.*, 2007). Prior to wool sampling, fleece weights for each sheep had been recorded at yearling shearing (September 2008) as part of the CPT programme. All manipulations of sheep were conducted under the approval of the Ruakura Animal Ethics Committee.

Differences in wool traits between farms, sire groups and body sites, were determined by one way analysis of variance. Means ± standard deviation are reported. Relationships between wool traits were determined by calculating the correlation coefficient in Microsoft Excel.

RESULTS

All stock were healthy and well managed, and fleeces were in good condition with no apparent cases of fleece damage, cotting, tenderness or excessive vegetable matter.

TABLE 1: Wool growth of the 2007 born ewes within the CPT flocks. The link sire (A) was used at all three farms. Mean values ± standard error of the mean are shown. LSD = Least significant difference.

Farm	Sire	No of progeny	Hogget fleece growth rate (g/d)	Mid-side staple length growth rate (mm/d)	Mid-side mean fibre diameter (µm)	Mid-side fibre diameter standard deviation (µm)	Mid-side medullation (%)	Mid-side fibre curvature (°/mm)
Poukawa	A	26	12.3 ± 0.3	0.45 ± 0.01	38.9 ± 0.5	7.5 ± 0.2	1.5 ± 1.9	35.0 ± 1.3
	B	45	12.8 ± 0.2	0.50 ± 0.01	37.6 ± 0.4	7.7 ± 0.1	3.8 ± 1.5	33.6 ± 1.0
	C	46	12.4 ± 0.2	0.52 ± 0.01	39.5 ± 0.4	8.6 ± 0.1	7.3 ± 1.4	34.7 ± 1.0
	D	43	11.5 ± 0.2	0.49 ± 0.01	36.6 ± 0.4	7.2 ± 0.2	3.3 ± 1.5	35.2 ± 1.0
	Mean	**(n = 160)**	**12.3 ± 0.2**	**0.49 ± 0.01**	**38.2 ± 0.4**	**7.8 ± 0.2**	**4.0 ± 1.6**	**34.6 ± 1.1**
Ashley Dene	A	15	11.6 ± 0.4	0.43 ± 0.02	38.6 ± 0.7	8.4 ± 0.3	3.3 ± 2.5	36.9 ± 1.7
	E	31	11.2 ± 0.3	0.44 ± 0.01	38.8 ± 0.5	8.0 ± 0.2	3.79 ± 1.8	36.5 ± 1.2
	F	46	11.7 ± 0.3	0.38 ± 0.01	34.8 ± 0.4	7.9 ± 0.1	3.5 ± 1.4	44.0 ± 1.0
	Mean	**(n = 92)**	**11.5 ± 0.3**	**0.42 ± 0.01**	**37.4 ± 0.5**	**8.1 ± 0.2**	**3.5 ± 1.9**	**39.2 ± 1.3**
Woodlands	A	26	10.5 ± 0.3	0.52 ± 0.01	44.6 ± 0.5	8.1 ± 0.2	3.8 ± 1.9	29.3 ± 1.3
	G	35	10.5 ± 0.3	0.56 ± 0.01	44.1 ± 0.4	8.5 ± 0.2	9.7 ± 1.7	27.1 ± 1.1
	H	28	9.4 ± 0.3	0.54 ± 0.01	40.0 ± 0.5	7.4 ± 0.2	2.1 ± 1.9	28.8 ± 1.3
	I	30	9.6 ± 0.3	0.49 ± 0.01	42.6 ± 0.5	7.9 ± 0.2	6.0 ± 1.8	32.4 ± 1.2
	J	13	9.9 ± 0.4	0.51 ± 0.02	43.0 ± 0.7	8.3 ± 0.3	9.2 ± 2.7	33.7 ± 1.9
	K	40	11.4 ± 0.2	0.57 ± 0.01	44.7 ± 0.4	8.8 ± 0.2	5.8 ± 1.6	26.0 ± 1.1
	L	36	8.5 ± 0.3	0.48 ± 0.01	42.0 ± 0.4	7.5 ± 0.2	21.2 ± 1.6	37.6 ± 1.1
	G	10	8.6 ± 0.5	0.56 ± 0.02	42.7 ± 0.8	8.9 ± 0.3	3.1 ± 3.1	30.0 ± 2.1
	Mean	**(n = 218)**	**9.8 ± 0.3**	**0.53 ± 0.01**	**43.0 ± 0.5**	**8.2 ± 0.2**	**7.6 ± 2.0**	**30.6 ± 1.4**
Overall mean		**(n = 470)**	**10.8 ± 0.1**	**0.50 ± 0.00**	**40.6 ± 0.2**	**8.04 ± 0.05**	**5.8 ± 0.5**	**33.4 ± 0.4**
Minimum			**6.1**	**0.22**	**27.8**	**4.6**	**0.2**	**15.8**
Maximum			**17.1**	**0.79**	**50.4**	**12.6**	**75.2**	**59.2**
LSD (5%)			**1.4**	**0.04**	**1.4**	**0.5**	**5.4**	**3.7**

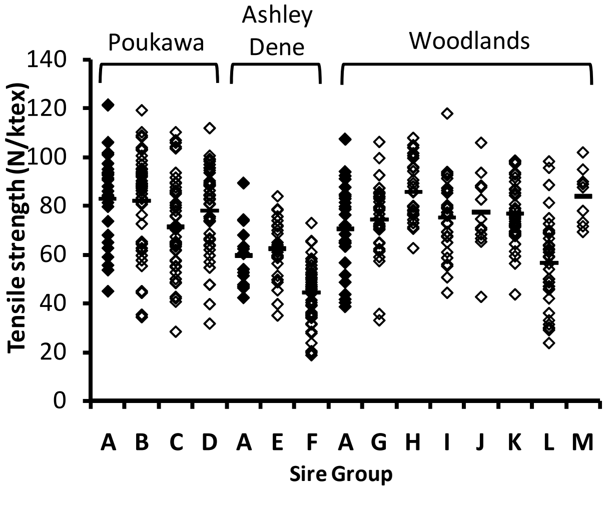
TABLE 2: Relationship between wool traits. Matrix shows the correlation coefficient when comparing each wool trait. Staple strength is the mean of three sites, all other characteristics are measured at the midside. Correlation coefficients in bold type are significant at the 5% level.

Characteristic	Yearling fleece weight (kg)	Staple length growth rate (mm/d)	Staple strength (N/ktex)	Mean fibre diameter (µm)	Fibre diameter standard deviation (µm)	Medullation (%)	Fibre curvature (°/mm)	Face score	Belly score
Staple length growth rate (mm/d)	**0.16**								
Staple strength (N/ktex)	**0.28**	**0.52**							
Mean fibre diameter (µm)	**-0.15**	**0.47**	**0.26**						
Fibre diameter standard deviation (µm)	0.02	**0.25**	0.05	**0.43**					
Medullation (%)	**-0.10**	**0.44**	**0.23**	**0.80**	**0.56**				
Fibre curvature (°/mm)	**-0.11**	**-0.72**	**-0.61**	**-0.59**	**-0.20**	**-0.54**			
Face score	**0.09**	-0.03	-0.01	**-0.17**	**-0.20**	-0.06	-0.02		
Belly score	**-0.14**	-0.04	-0.06	**0.13**	**-0.20**	-0.01	0.02	**0.42**	
Breech score	**-0.14**	**-0.26**	**-0.29**	**-0.10**	0.07	**-0.14**	**0.26**	**0.27**	**0.43**

Yearling fleece weights, standardised to 250 days of growth allowing comparison of flocks with different shearing regimes, varied between 1.5 and 4.2 kg (with bellies removed) with a mean fleece weight of 2.7 kg. This equates to a growth rate of 10.8 g/day. Mean fibre diameter of the one-year-old ewes was 40.6 µm indicating the coarse wool categorisation of the flock (Table 1). Individual sheep, however, ranged from 28 to 50 µm. Similarly, fibre curvature values ranged from 16 to 60°/mm.

There were differences in wool grown on each farm as demonstrated by the mean difference in fleeces from offspring of the link sire. For instance, Woodlands sheep exhibited the greatest staple length ($P < 0.01$) and mean fibre diameter ($P < 0.01$) but least fibre curvature ($P < 0.01$). There were also differences in staple strength ($P < 0.001$) between wool grown on each farm as demonstrated by the mean difference of 23 N/ktex in offspring of the link sire. These differences reflect environmental influences, as well as the varying base ewe flocks at each site.

FIGURE 1: Staple tensile strength of individual fleeces from 2007 born ewes of the Central Progeny Test flocks. Each diamond represents one ewe, while bars indicate the mean within each sire group. Solid diamonds indicate the link sire (A) utilised at all three farms.



Overall mean staple strength across the three body sites was 72 ± 20 N/ktex. However, individual sheep ranged considerably from 19 to 121 N/ktex (Figure 1). On average, staple strength was similar on anterior (74 ± 24 N/ktex) and midside (75 ± 24 N/ktex) body-sites, but was weaker on the hindleg (64 ± 21 N/ktex; $P < 0.001$). Staple strength correlated positively with midside fibre diameter ($r = 0.26$), medullation ($r = 0.23$) and negatively with fibre curvature ($r = -0.61$) (Table 2).

A variety of fleece cover patterns were observed. Wool growth on the head ranged from covering the cheeks and in front of the eyes (Face score 1) to only kemp present across the crown and down to the neck (Face score 5), reflecting their Coopworth origins. While wool cover on the hind legs varied, most sheep grew wool on their bellies (Belly score 1 to 3). Notable exceptions to this were some progeny of sire L that were relatively bare across the belly (Belly score 4 to 5) and also around the breech (Breech score 3 to 5).

DISCUSSION

The wide range in wool attributes within the CPT flocks reflects those currently developing in contemporary New Zealand dual purpose flocks. The mean fibre diameter of ewes studied at Poukawa, Ashley Dene and Woodlands farms were 38.2 µm, 37.4 µm and 43.0 µm respectively, somewhat coarser than the 36.5. µm average for adult fleeces recorded in the wool industry auction sale database between 2003 and 2007 (Sumner *et al.*, 2008). This suggests the national clip will become coarser as more commercial breeders utilise sires related to those tested in the CPT.

The within-flock variation observed is likely wider than typical commercial flocks due to the diverse range of sires used each year. On the other hand, these flocks demonstrate the diversity of wool types that could be harnessed for enhanced specification targeting higher value niche markets. Some sheep lacked wool on their bellies and points, and around the breech, demonstrating the presence of these desirable traits in highly valued commercial flocks. Animals with these traits are quicker to shear and have fewer dags and associated health problems (Scobie *et al.*, 2007).

Major components of staple strength include fibre diameter, fibre diameter variation, curvature and medullation. Each of these characters is known to vary across the fleece however the gradients differ in magnitude and direction (Sumner & Revfeim, 1973). Staple strength differences along the body reflect the integration of these patterns, with weaker wool on the hindleg where both fibre diameter variation and medullation were greatest. Further work is required to describe staple strength topography, especially with respect to dorso-ventral gradients.

The diameter of fibres within the staple and their levels of medullation directly influence the strength of each contributing fibre. The degree of curvature influences staple strength, as opposed to individual fibre strength, by dictating when mechanical stresses are exerted upon each fibre as stretching of the staple occurs. As such, sheep with high levels of fibre curvature, such as sire F, or medullation such as sire L, have lower staple strength as highlighted by the correlation analyses.

Many insights into wool characteristics have been obtained from flocks selected for and against single traits. Staple strength is no exception to this, with two Romney selection lines developed with 43 ± 11 N/ktex (low staple strength) and 71 ± 17 N/ktex (high staple strength) from a Control line (55 ± 16) N/ktex. Bray *et al.* (1992) showed that both staple length and fibre diameter increased with staple strength selection. Similarly, medullation was lower in the high staple strength line. Our data supports these observations. Half of the fleeces within the CPT were above the mean strength value of the high staple strength selection line developed by Bray *et al.* (1992). On the other hand, 10% of the CPT fleeces were below the low staple strength line average. This raises concerns for some recent stock selection programmes with respect to ensuring the supply of wool optimised for the woollen manufacturing industries.

Research using the staple strength selection lines demonstrated that processing and manufacture of some textiles was compromised when using fleeces with poorer staple strength (Maddever *et al.*, 1994). Even within the narrower staple strength range of the selection flocks, differences in scoured loose wool properties were observed, especially in length after carding. However variations in yarn, carpet and knitted fabric properties showed little commercially significant differences between the lines as the variability of processing parameters, such as yarn twist level, was thought to outweigh the contribution arising from variable fibre staple strength in the manufacture of some textiles. On the other hand, increased staple strength did provide greater uniformity in wool processing and higher combing yield. Knitted panels of fleeces with greater staple strength performed better in abrasion and pilling performance tests. Greater staple strength permitted spinning of the carded sliver at greater speeds (1,000 rpm) without producing more breaks, which equates to an increase of 10% or more in productivity. Stronger wool also performed better in the WIRA abrasion tests, suggesting better resistance to twisting, flexing and abrasion across the axis of the fibre (Maddever *et al.*, 1994). In summary, stronger wool produces a more uniform product with tangible advantages for processors and manufacturers of worsted and semi-worsted products and will likely be important in manufacturing premium products.

Weaker fibres arise from a combination of factors affecting the growth of the fleece. These include environmental influences which can, in part, be mitigated by optimising on-farm management practices such as maintaining adequate feed supplies and adjusting the time of shearing. However, genetic predisposition to growing tender fleeces also contributes greatly to the variation between fleeces. The heritability of this detrimental trait is relatively high (39%; Swan, 2008). We have demonstrated large differences between animals within a single flock exposed to similar environmental influences and management protocols. Individual sheep also differ with respect to tensile strength variation across their fleece and within staples.

At shearing, fleeces are roughly graded into bales which are subsequently grouped together into “sale lots” by the wool broker. There are many opportunities to make cost savings and to increase efficiencies in wool processing when wool is supplied in direct supply relationships. For example, minimising the breakage of fibre during carding and combing could improve yield for yarn spinners. At present, within a sale lot, weaker fibres are purchased at the same cost as the stronger fibres despite increased wastage, labour and costs to the processor. Yarns with a low proportion of inherently weak fibres are important in manufacturing high quality products upstream (Maddever *et al.*, 1994).

Ten percent of fleeces measured below 45 N/ktex, leaving them prone to excessive fibre breakage due to the severe action of the carding machine during processing (Swan, 2008). While some fleeces did not vary, others varied up to 40 N/ktex across body-sites. To our knowledge this is the first report of the variation of staple strength across the fleece. Given that mean fibre diameter and its standard deviation, as well as mean fibre curvature and proportion of medullation all vary across the body, this observation is not surprising. What is more enlightening is that some animals displayed very little topographical variation while others varied widely as previously reported for other wool traits (Craven *et al*., 2009). Selection for reduced variation within fleeces may improve the wool strength of sale lots if the trait proves heritable and financially worthwhile.

Of most significance, was that within one flock, the mean staple strength of offspring derived from individual sires differed by up to 29 N/ktex. This suggests a consistent weakness of wool in the progeny of some sires currently regarded as the best dual-purpose rams in the country. Through their high level of connectedness to a wide range of breeders throughout New Zealand, these sires will influence the genetic makeup of future generations and therefore wool quality from many thousands of sheep. Continuation of this trend will negatively affect the quality of manufactured woollen products.

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