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Fleece tenderness — a review

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ABSTRACT

Fleece tenderness is a serious fault of New Zealand crossbred wool costing the sheep industry between $50 and $100 million annually. Wool fibres break at the point where fibre diameter is at its minimum and factors which influence minimum fibre diameter will influence the incidence of fleece tenderness, e.g., breed and strain of sheep, age of ewe, level of feeding and reproductive status.

Tender fleeces are on average lighter than sound fleeces and often have other associated faults such as cotting and yellow discolouration. Variation in minimum winter fibre diameter accounts for only about 40% of the variation in staple strength within a flock suggesting that factors other than fibre diameter may be involved. There are fibre structural and compositional differences between sound and tender wools of the same diameter and these may be associated with fleece tenderness.

The wool producer can influence the incidence of fleece tenderness by the level of feeding during mid pregnancy but it may not always be economic to feed better. Choice of shearing time will also influence the level of fleece tenderness.

A preliminary estimate of the heritability of fleece tenderness of 0.58 ± 0.15 indicates that it would respond rapidly to selection. Where the price differential between sound and tender wools is small it may not be economic to select for fleece soundness.

Fleece tenderness is the most serious fault of New Zealand crossbred wools. Ross (1982) estimated that the occurrence of tender (weak stapled) wools results in a loss to New Zealand wool producers of 5 to 10% of the value of the national clip, i.e., $50 to $100 million annually.

Modern high speed processing machinery demands strong yarns. Strength of the yarn is primarily related to fibre length in the yarn; the longer the mean fibre length in the yarn the stronger the yarn. While all wools suffer some degree of fibre breakage during processing, tender wools break more easily than sound wools, resulting in shorter fibres after carding. Typical mean fibre lengths after carding for very tender and very sound wools with a mean staple length of 100 mm were 50 and 70 mm, respectively (Ross, 1982). Such a difference is of considerable manufacturing significance, explaining in part why tender wools are discounted in price.

Under tension individual wool fibres usually break where fibre diameter is at its minimum. Fibre diameter is not constant throughout the year but varies in phase with the wool growth cycle. A typical mean fibre diameter of a Romney wether maintained on a constant plane of nutrition may be 42 μm in summer and 30 μm in winter (Bigham *et al.*, 1978 a).

Factors which influence the minimum fibre diameter in winter will therefore influence staple strength, e.g., breed (Bigham *et al.*, 1978 a), age of ewe (Sumner, 1969), level of feeding (Sumner and Wickham, 1969; Monteath, 1971; Horton and Wickham, 1979; Sumner, 1983) and pregnancy (H. Hawker, unpublished; R. M. W. Sumner, unpublished). Their effects are discussed with reference to possible ways of reducing the incidence of tenderness through management and breeding.

Measurement of Staple Strength

Staple strength has traditionally been estimated by the 'ring' of the staple when it is flicked between the fingers, or by the pull required to break it.

Two objective methods of measuring staple strength are employed (Heuer, 1979). The first measures the force in newtons required to break the staple relative to its linear density in kilotex, where 1 kilotex is the density of a standard yarn weighing 1 g/m (N/Ktex). The second method measures the force in kilograms required to break a staple relative to the weight of clean wool in the staple (kg/g).

Fleeces can vary in staple length from 0 to 90 N/Ktex yet the finger test only detects wools of less than about 25 N/Ktex (Heuer, 1979). Processing studies have shown that for average staple strengths below about 45 N/Ktex there is a significant relationship between fibre length in the processed top and average staple strength (Andrews and Lunney, 1982).

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Factors Affecting the Incidence of Fleece Tenderness in a Flock

Breed

Table 1 shows the proportions of tender fleeces by breed for a number of trials in which breeds have been run together. There is little evidence of breed differences particularly amongst Romney, Coopworth and Perendale, the 3 major breeds growing crossbred wool.

TABLE 1 Effect of breed of ewe on the percentage of fleeces graded as tender (number of fleeces assessed).

Locality	Breed	Percentage tender
Whatawhata[1] 1959/67	Romney	59 (3127)
	BorderLeicester × Romney F_1	55 (1158)
	F_2	58 (962)
	F_3	79 (338)
Whatawhata[2] 1969/75	Romney	18 (1247)
	Coopworth	16 (1291)
	Perendale	15 (1495)
	Cheviot	23 (802)
	Dorset × Romney	10 (1138)
Templeton[3] 1973/8	Romney	35 (1462)
	Corriedale	35 (1480)
	Dorset	34 (983)
Woodlands[3] 1973/8	Romney	46 (1078)
	Border Leicester	49 (916)
	Cheviot	47 (1119)
	Merino	59 (773)

[1] Hight *et al.*, 1976.
[2] Bigham *et al.*, 1978 b.
[3] D. L. Johnson *et al.*, unpublished.

TABLE 2 Mean staple strength (N/Ktex) and mean fibre diameter (μm) for ewe hoggets in the Rotomahana Strains trial.

	No.	Staple strength (SE)	Fibre diameter (SE)
Industry Romney	82	35.9 (1.3)	35.8 (0.3)
Ruakura High Fert.	76	32.6 (1.3)	34.2 (0.3)
Strain A	87	33.6 (1.2)	34.7 (0.3)
B	82	34.2 (1.3)	34.9 (0.3)
C	91	34.4 (1.2)	34.8 (0.3)
D	99	38.4 (1.1)	35.2 (0.3)
Coopworth	11	40.2 (1.1)	36.8 (0.2)
Border L. × Rom.	84	38.8 (1.2)	37.5 (0.2)

Strain

Table 2 shows mean staple strengths and fibre diameters of the ewe hoggets born 1980 for 6 Romney strains in the Strains trial at Rotomahana Research Station together with those from the Coopworth and the Border Leicester × Romney strains. The Ruakura High Fertility strain produced weaker wool ($P < 0.05$) than the Coopworth, Border Leicester × Romney and Romney D strains. These differences may be related to mean fibre diameter as that of the Ruakura High Fertility strain was approximately 1.5 to 3.5 μm finer than that of the Coopworth, Border Leicester × Romney and the Romney D strains.

Ewe Age

In the 'on farm' situation ewe hoggets tend to have a lower incidence of fleece tenderness than older ewes. Whilst this may be due partly to the hoggets being preferentially fed, hoggets have less seasonal variation

TABLE 3 Effect of ewe age on the percentage of fleeces graded as tender (number of fleeces assessed).

Locality	Year	Breed	Ewe age (years) 2	3	4	5
Whatawhata[1]	1969/75	Romney	27 (350)	15 (277)	19 (254)	12 (365)
		Coopworth	24 (392)	15 (256)	15 (230)	14 (413)
		Perendale	21 (508)	11 (358)	12 (261)	13 (368)
		Cheviot	29 (224)	23 (166)	19 (132)	21 (280)
		Dorset × Romney	18 (299)	8 (268)	4 (241)	7 (330)
Templeton[2]	1973/8	Mixed[3]	76 (879)	63 (833)	64 (794)	59 (1401)
Woodlands[2]	1973/8	Mixed[4]	71 (797)	48 (830)	42 (678)	46 (704)

[1] Bigham *et al.*, 1978 b.
[2] D. L. Johnson *et al.*, unpublished
[3] Romney, Corriedale, Dorset.
[4] Romney, Border Leicester, Cheviot, Merino.

in fibre diameter than older ewes (Bigham *et al.*, 1978 a). Two-tooth ewes consistently show more fleece tenderness than older ewes which are generally similar (Table 3). This difference may possibly be explained where two-tooth ewes are actively growing and the demands of pregnancy reduce the amount of nutrients available for wool growth.

Level of Feeding

Increased stocking level (Sumner and Wickham, 1969) submaintenance winter feeding (Monteath, 1971) and winter feeding of forage crops (Horton and Wickham, 1979) all increase the incidence of fleece tenderness in flocks of mature sheep. Inverse relationships between pasture allowance and the incidence of fleece tenderness have been demonstrated for both hoggets at Whatawhata and mixed-age ewes at Woodlands (Table 4).

TABLE 4 Effect of pasture allowance on fleece tenderness (number of fleeces assessed).

Hoggets[1]			Ewes[2]	
Allowance g DM/kg lwt/d	Tender fleeces (%)	Fibre diameter (μm)	Allowance kg DM/ewe/d	Tender fleeces (%)
50	70 (152)	30.2	0.7	80
75	55 (85)	31.9	1.2	65
100	46 (98)	32.3	1.7	46
150	52 (61)	33.0	2.2	28
200	16 (79)	33.9		

[1] Allowance offered January to September.
[2] Allowance offered 6 weeks mid pregnancy.

Total 460 live fleeces assessed.

Pregnancy and Lactation

Wool production of the breeding ewe is depressed by from 10 to 14% compared with that of non-breeding ewes due to the demands of pregnancy and lactation (Corbett, 1979). The reduced wool growth is due to both a reduced fibre length growth rate and reduced fibre diameter with a resultant increase in the susceptibility to tenderness. Observations from flocks in which all ewes are exposed to the ram suggest however, that barren ewes are as prone to fleece tenderness as those that produce single lambs (Table 5). Such ewes tend to be lighter than those pregnant ones due to a variety of reasons (e.g., poor health) which may explain why they are as prone to fleece tenderness as ewes producing single lambs. Ewes giving birth to and rearing twin lambs tend to have a higher proportion of tender fleeces than those producing and rearing a single lamb (Table 5).

It has been suggested that the development of the tender region along the staple is associated with the 'stress' of parturition, the so-called 'lambing break'. Minimum fibre diameter usually occurs some weeks before parturition and it is therefore unlikely that the hormonal and/or physiological changes associated with parturition contribute towards the development of fleece tenderness. Whatawhata observations have clearly shown that the effects of differential feeding levels in mid pregnancy have a greater effect on the incidence of fleece tenderness than differential feeding levels during late pregnancy.

Shearing Time

Choice of shearing time has a major effect on staple strength. Shearing in winter, when the minimum fibre diameter is near skin level, will result in a stronger

TABLE 5 Effect of reproductive performance level on the percentage of fleeces graded as tender (number of fleeces assessed).

Locality	Year	Breed		Lambs born/reared 0/0	1/1	2/2
Whatawhata[1]	1959/65	Romney		49	59	71
		Border Leicester × Romney	F_1	54	50	63
			F_2	56	54	71
			F_3	70	76	89
Whatawhata[2]	1969/75	Romney		26 (377)	14 (585)	17 (68)
		Coopworth		19 (236)	14 (743)	21 (159)
		Perendale		15 (202)	14 (947)	17 (158)
Templeton[3]	1973/8	Mixed[4]		64 (447)	64 (1948)	69 (1530)
Woodlands[3]	1973/8	Mixed[5]		47 (572)	51 (2265)	52 (1049)

[1] Hight *et al.*, 1976.
[2] Bigham *et al.*, 1978 b.
[3] D. L. Johnson, unpublished.
[4] Romney, Corriedale, Dorset.
[5] Romney, Border Leicester, Cheviot, Merino.

Woodlands proportions by numbers of lambs reared only.

TABLE 6 Effects of shearing time and frequency on the percentage of fleeces graded as tender (number of fleeces assessed).

	Time of shearing	Romney Annual shorn	Romney Double shorn	Coopworth Annual shorn	Coopworth Double shorn	Perendale Annual shorn	Perendale Double shorn
1978/82	May	—	0	—	0	—	0
	November	24	3	29	7	26	3
		(235)	(219)	(237)	(220)	(224)	(205)
1980/2	February	—	0	—	0	—	0
	September	12	18	16	15	5	16
		(122)	(133)	(124)	(113)	(133)	(140)

fibre than shearing in summer when the minimum diameter is about halfway up the staple. Story and Ross (1959) reported a mean staple strength of 69 ± 7 kg/g for Romney ewes shorn in August (pre lambing) and 27 ± 7 kg/g for similar ewes shorn in November (post lambing).

At Whatawhata large differences have been observed between ewes shorn once or twice each year in the proportion of fleeces assessed as tender (Table 6). No second-shear fleeces shorn in February or May have been assessed as tender. For September shearing more second-shear than full length fleeces were tender, with the opposite the case for November shearing. As Bigham (1974) was unable to show any effect of shearing frequency on fibre diameter this apparent difference may be due to the limitations of subjective staple assessment.

Associated Fleece Characteristics

Tenderness predisposes the fleece to cotting (Hight *et al.*, 1976) which in turn predisposes it to develop unscourable discolouration (Sumner, 1969). Tender fleeces are lighter than sound fleeces, with the trend consistent for each breed studied (Table 7). Preliminary evidence indicates that sheep producing tender fleeces have a lower wool growth rate in winter than those producing sound fleeces. This lowered wool growth rate is due to a reduction in both fibre diameter and length growth rate with the reduced fibre diameter contributing to reduced staple strength.

TABLE 7 Mean greasy fleece weight of sound and tender fleeces within flocks (number of fleeces in each category).

Locality	Breed	Greasy fleece wt (kg) Sound	Greasy fleece wt (kg) Tender
Whatawhata[1] 1969/75	Romney	3.61 (1019)	3.14 (228)
	Coopworth	3.41 (1083)	3.13 (208)
	Perendale	3.17 (1269)	2.79 (226)
Templeton[2] 1973/8	Mixed[4]	3.65 (1428)	3.54 (2497)
Woodlands[2] 1973/8	Mixed[5]	3.37 (1952)	3.15 (1934)
Woodlands[3] 1978/80	Romney	3.90 (142)	3.52 (370)

[1] Bigham *et al.*, 1978 b.
[2] D. L. Johnson, unpublished.
[3] H. Hawker and S. F. Crosbie, unpublished.
[4] Romney, Corriedale, Dorset.
[5] Romney, Border Leicester, Cheviot, Merino.

Fleece Structure

Staple strength varies over the body of the sheep (Ross, 1982) being strongest on the neck and weakest on the back. Back wool is usually the most weathered wool which may account for its lowered intrinsic strength. Rottenbury (1979), in presenting data on the components of variation for staple strength in Merino flocks, has shown that 61% of the variation was due to that between fleeces, the remainder being within fleeces.

Fibre Structure and Composition

Despite the fibre breaking at the narrowest point there is a weak relationship between minimum mean fibre diameter and staple strength within a flock or group of sheep. Studies at both Woodlands and Whatawhata indicate that no more than about 40% of the variation in staple strength can be accounted for by variation in minimum mean fibre diameter, suggesting that other factors may also be involved in the production of tender wool.

Orwin *et al.* (1980) suggested that the cell structure of tender wools is different from that of sound wools of the same fibre diameter and that there are differences in protein composition. In cross section the cortex of the wool fibre may contain up to 3 cortical fibre types; ortho-, meso- and para-cortex. At the same fibre diameter tender wools at the point of break contain a higher proportion of ortho-cortex than do sound wools. Preliminary work at Whatawhata indicates that these structural differences within the fibre are present throughout the year.

Inheritance

A heritability of 0.58 ± 0.15 for staple strength has recently been estimated for ewe hoggets born 1980 in the Strains trial at Rotomahana indicating that staple strength would respond rapidly to selection. If, in a large population, the top 5% of rams with the highest staple strength were selected, progress per generation would be of the order of 7 N/Ktex (Table 8) with a correlated response of about 0.06 kg in greasy fleece weight. At present greasy fleece weight is the only wool trait included in the Sheeplan selection index as it is of major importance in determining gross income from wool. Direct selection for greasy fleece weight would increase greasy fleece weight by 0.32 kg per generation and staple strength by 1.3 N/Ktex per generation.

TABLE 8 Predicted direct and correlated genetic responses per generation by selecting the top 5% of rams for each trait with ewes selected at random.

Trait selected	Response: Staple strength (N/Ktex)	Response: Greasy fleece weight (kg)
Staple strength	7.2	0.06
Greasy fleece weight	1.3	0.32

Practical Considerations

Much of the information presented above relates to the finger test which can only detect very weak wools but differences are present for variables such as breed, ewe age, fertility status and nutritional level. It is likely that these differences may be greater on measured staple strength and work is required to delineate their influence.

The farmer has 2 management options by which he could increase the strength of his wool clip. Firstly by better feeding during winter and secondly by his choice of shearing times.

Rattray *et al.* (1982) indicate that, in terms of lamb production, the response to differential feeding is greater during lactation than during early and late pregnancy. Currently there is emphasis on controlled grazing during winter which allows some accumulation of pasture *in situ* for grazing after lambing. Because of the price differential between sound and tender wool and the extra returns obtainable from lamb production through controlled grazing, it would appear unlikely that it would be economic to feed the ewe flock better during pregnancy purely to reduce the incidence of fleece tenderness.

Choice of shearing time influences staple strength, with winter shearing when fibre diameter is at or near its minimum producing the strongest fibre. Shearing at this time can however, present a number of management problems due to prevailing weather conditions. Evidence suggests that shearing in September rather than November will reduce the incidence of fleece tenderness in full woolled sheep but further data are required for second shears.

Rapid genetic progress could be made through direct selection for staple strength although the economics of this are doubtful because of the current price differential between sound and tender wools. For example the response of 0.32 kg of greasy fleece weight per generation through direct fleece weight selection is currently worth approximately 70 cents per sheep whereas the 7 N/Ktex improvement in staple strength per generation of direct selection for staple strength is only worth approximately 13 cents per sheep.

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