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Wool Follicle And Skin Characters -Their Potential To Improve Wool Production And Quality In Merino Sheep

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Summary

This paper investigates the relationships between objectively assessed skin and follicle characters, and objectively measured fleece characters, in the South Australian Strongwool Merino strain. The relationships between objectively-assessed skin characters and classer assessed skin and staple characters were also investigated.

The results of these and other studies indicate that genetically high producing sheep with low fibre diameter, tend to be those with high follicle density, high secondary/primary follicle ratio, evenly-seated follicles arranged in distinct, large follicle groups. The follicles of these sheep tend to have a low degree of curvature and produce fibres with low crimp frequency, low paracortex content, low sulphur content, but with well-defined crimp. Somewhat surprisingly, we found that sheep with light (thin?) skins tended to produce more wool of lower diameter than heavy (thick?) skinned animals. This is in direct contrast to previous findings of moderate positive genetic correlations between skin thickness and both fleece weight and fibre diameter.

Skin quality, subjectively assessed by a classer, had a moderate to high heritability (0.36 and 0.24 at 10 and 16 months of age, respectively) and was closely genetically associated with clean fleece weight ($r_g = 0.65$ and 0.57 at 10 and 16 months of age, respectively). As such, skin quality could be a useful indirect indicator of fleece weight. It also means that selection for clean fleece weight should result in an improvement in skin quality. The latter is contrary to the belief of some in the industry, that selection for fleece weight will result in a deterioration in skin quality.

It is recognised that a number of skin characters (objectively and subjectively assessed) are associated with economically important wool traits. However, it is doubtful that an increased (or sole) emphasis on them will bring about rates of genetic gain greater than what can be achieved by direct measurement of, and selection for, the economic traits in question.

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Keywords: Wool follicle, skin characters, Merino sheep

Introduction

The breeding objective of many wool producing enterprises is to increase the production of finer, stronger fibres with improved style characteristics, on sheep which have high live weight and which are resistant to fleece rot, fly strike and internal parasites. The selection criteria used to achieve these objectives should be as direct as possible because the closer the association between the selection criteria and the traits in the breeding objective, the more accurate will be the selection of genetically superior animals, and consequently the faster will be the genetic progress.

However, the use of indirect selection criteria can be useful in the following circumstances:

*When the heritability of the indicator trait is sufficiently greater than that of the trait of interest and the genetic correlation between both traits is also sufficiently high.

*When an indirect measure is a cost-effective alternative to a directly measured trait (e.g. coefficient of variation of fibre diameter appears to be a cost-effective alternative to staple strength measurement).

*When early selection of animals is required, and fleece measurements at an early age are poor indicators of adult performance (Atkins and Mortimer 1987).

*When additional information not available by any other means can be obtained by an indirect trait (e.g. fibre diameter variability as an indirect indicator of fleece rot susceptibility).

*When a final selection decision is required between animals which have similar objective measurements.

Often classers use visual assessment of characteristics believed to provide an alternative to, or adjunct to, objective measurement. Characters such as handle, lock, crimp definition, crimp frequency, dust penetration, tip structure and skin quality are frequently part of the assessment.

This paper examines the genetic relationships derived in the South Australian Strongwool Merino Resource flock experiment at Turretfield, between objectively measured skin traits, subjectively assessed skin and fleece characters, and objectively measured fleece characters. First an examination is made of the logic behind skin measurements.

Why Skin Characters?

Over the years, sheep classers have emphasised the importance of considering skin characteristics as indirect criteria in sheep selection programmes. This emphasis on skin is well-placed in that it is the skin that nourishes and supports the massive population of fibre-producing follicles. A wide range of skin characters has thus been measured and their relationships with important economic characters determined. Follicle density, secondary/primary (S/P) ratio, skin thickness, primary follicle density, follicle curvature, follicle depth, and follicle group size have been measured in a number of selection flocks, and the genetic correlations determined between these traits and fleece traits (Brown and Turner 1968; Gregory 1982; Davis and McGuirk 1987).

Despite moderate to high heritabilities of many of the follicle characters and moderate to high genetic correlations with fleece characters, selection based on individual follicle characters such as S/P ratio has not resulted in the anticipated changes in fleece characters (Jackson *et al.* 1975; Rendel and Nay 1978). We hypothesised that compensating changes in other characters not under selection were negating the positive movements in the character under selection. For example, selection for high S/P ratio would be accompanied by corresponding changes in the size of follicle bulbs, the result being no overall gain in the total amount of follicular tissue in the skin, hence no change in the total amount of fibre produced per unit area of skin. Similarly, selection for increased follicle depth would be expected to result in increased bulb size with a concomitant decrease in follicle density, the result again being no change in total follicle tissue per area of skin. Interestingly, tandem selection for follicle depth and density did increase fleece weight, supporting our contention that the only programmes which will increase fleece weight are those that result in more follicle tissue in the skin.

Skin thickness assessment was considered for some time to be a useful indirect indicator of the productive capacity of the sheep. Indeed, Gregory (1982) provided data which indicated that there was a moderate, positive genetic correlation (0.39) between skin thickness and clean fleece weight in SA Merinos. He concluded that skin thickness could be a useful early selection criterion for high producing animals. Recently, Ponzoni *et al.* (1995) showed that there was a high genetic correlation between subjectively assessed skin quality and clean fleece weight, suggesting that skin quality might be a useful indicator of fleece weight. There is currently considerable interest in the idea of selecting sheep which display the so-called 'soft rolling skins'. It is claimed that breeding from these animals results not only in dramatically increased fleece weights, but also in large fibre diameter decreases, and in an improvement in staple structure, staple character, and processing performance (J. Watts, personal communication). This issue is discussed further in other papers in this Wool Forum.

Before indicating the relationships between skin and follicle characteristics from the Turretfield flock, we need to examine the biology underlying follicle development in the foetus and the determinants of fleece weight.

Follicle Initiation In The Foetus

Follicles are formed from epidermal cells which have been stimulated by, as yet unidentified, chemicals produced largely under genetic controls. The positioning and size of the primary follicles is determined as early as day 60 in the foetus, but this appears then to determine the subsequent positioning and size of the secondary follicles which form from day 86 to 90. Again genetic controls operate to instigate branching of these original secondaries from day 100 to birth. The extent to which follicle branching occurs is a significant determinant of follicle density, S/P ratio, fibre diameter, fibre length, and clean fleece weight (discussed below).

Determinants Of Fleece Weight

The quantity of wool produced per annum (W) by a sheep is determined quite simply by the formula:

$$W = (L \times N \times CSA \times S \times A) \times 365$$

L = fibre length growth rate ($\mu\text{m}/\text{d}$)

N = follicle density (follicles/ mm^2)

CSA = mean fibre cross section area (μm^2)

S = specific gravity of wool

A = the fleece-bearing skin area (mm^2)

By far the greatest determinant of CFW, within a strain or flock of Merino sheep producing wool of a similar type, is wool per unit area (i.e. the product of CSA, L and N) (Williams 1987). We need to examine how these 3 components relate to each other, and how we might manipulate the relationships to increase output without increasing fibre diameter too greatly. However, first it is necessary to know to what extent the skin and follicle characters are determined genetically (i.e. what are the heritabilities of the characters). These are indicated in Table 1.

Table 1 Heritability and standard error estimates for skin and follicle characters measured at ten months of age in the Turretfield sheep.

Character	Heritability	standard error
Skin weight	0.17	0.06
Follicle density	0.18	0.06
Mean bulb area	0.25	0.07
Total bulb area	0.26	0.07
Bulb area standard deviation	0.22	0.06
Bulb area coefficient of variation (%)	0.09	0.05
Paracortex %	0.33	0.07
Mean fibre area	0.45	0.08
Fibre area standard deviation	0.25	0.07

The heritabilities of skin weight, follicle density, and bulb area coefficient of variation were low (<0.20), while mean bulb area, total bulb area, bulb area standard deviation, fibre area standard deviation and paracortex percentage were low to moderate (0.20 to 0.35). Only mean fibre area was highly heritable (0.45).

Relationships Between Density, Diameter, Length And Clean Fleece Weight

Table 2 shows the genetic relationships between follicle density, fibre diameter, staple length and clean fleece weight in our experimental flock at the Turretfield Research Centre.

Table 2 Genetic correlations between follicle density and objectively measured fleece characters at 10^A and 16^B months of age

Character	Genetic correlation
Yield	0.37 ^A 0.24 ^B
Clean fleece weight	0.54 0.21
Fibre diameter	-0.37 -0.43
CV of fibre diameter	-0.09 0.06
Staple length	0.12 0.00
Staple strength	0.07 0.00
A Upper value represents correlation with fleece character measured at 10 months of age	
B Lower value represents correlation with fleece character measured at 16 months of age	

Selection of sheep on the basis of increased follicle density would be expected to result in an increase in the clean scoured yield, increased clean fleece weight and reduced fibre diameter. Clearly these are beneficial outcomes but how might one select high density sheep?

Table 3 shows the relationships between follicle density and some subjectively assessed characters 10 and 16 months of age. High density sheep can apparently be identified by selecting sheep with good skin quality (as assessed by the professional sheep classer involved in our project), good handle, and very well-defined crimp (a low score for crimp definition represents better crimp definition). Similarly selection for high follicle density will probably result in an improvement in all of these style characteristics.

Table 3 Genetic correlations between follicle density measured at 10 months of age, and subjectively assessed characters* at 10^A and 16^B months of age.

Characters	Correlation
Lock	0.06 ^A
	0.13 ^B
Skin quality	0.34
	0.37
Visual colour	0.07
	0.38
Handle	0.16
	0.20
Condition	0.05
	0.20
Crimp definition	-0.62
	-0.36

A Upper value represents correlation with fleece character measured at 10 months of age
 B Lower value represents correlation with fleece character measured at 16 months of age
 * See Appendix table for the scoring system used by the classer

Is Skin Weight (Thickness) A Useful Predictor Of Fleece Characteristics?

Given Gregory's (1982) finding that skin thickness was fairly strongly correlated with clean fleece weight, we expected a similarly strong relationship between skin weight (an indicator of thickness) and clean fleece weight in our experiment. This was not the case, and in fact there was a slight negative correlation between skin weight and clean fleece weight (Table 4).

Sheep with heavy skins tend to be genetically lower yielding, lower in clean fleece weight, higher in fibre diameter and higher in staple length and strength. Of the classer assessed characteristics, only crimp definition was moderately related to skin weight (sheep with heavier skins have poorer crimp definition i.e. a higher score). In summary these results suggest that sheep with lighter (= thinner?) skins, tend to be superior in terms of objectively measured fleece characters, and tend to have greater crimp definition.

Table 4 Genetic correlations between skin biopsy weight at 10 months of age, and objectively and subjectively assessed* characters at 10 and 16 months of age.

Character	Correlation
Yield	-0.29 ^A
	-0.06 ^B
Clean fleece weight	-0.37
	-0.07
Fibre diameter	0.38
	0.37
CV of fibre diameter	0.18
	0.07
Staple length	0.19
	0.15
Staple strength	0.27
	0.28
Lock	0.17
	0.11
Skin quality	-0.07
	-0.06
Visual colour	0.21
	0.12
Handle	-0.05
	-0.17
Condition	-0.04
	-0.23
Crimp definition	0.30
	0.49

A Upper value represents correlation with fleece character measured at 10 months of age
B Lower value represents correlation with fleece character measured at 16 months of age
* See Appendix table for the scoring system used by the classer

Is The Fibre Cell Type A Useful Predictor Of Fleece Type?

There is evidence indicating that genetically high producing animals tend to have distinct follicle groups comprising primary follicles in straight lines on the margins of the groups (Williams 1987). The follicles are uniformly seated and are relatively straight and deep in the skin (Nay 1966; Nay and Johnson 1967; Nay and Hayman 1969; Nay 1970). High crimp frequency arises from highly-curved follicles, and these crimped fibres contain a high proportion of paracortical cells (Fraser and Rogers 1955). These

paracortical cells contain a higher concentration of sulphur, a feature of low-producing sheep (Williams 1987). It was thought that for these reasons estimation of the paracortex percentage could provide a useful indicator of not only the genetic fleece growing potential, but also of some of the "style" characteristics. We took the opportunity to examine the genetic relationships between paracortex percentage in the fibres of our experimental sheep at the Turretfield Research Centre, and a range of objective and subjectively assessed fleece characters (Table 5).

Table 5 Genetic relationships between the paracortex percentage in fibres measured at 10 months of age, and objectively measured, and subjectively assessed* fleece characters measured at 10 and 16 months of age.

Character	Correlation
Yield	-0.47 ^A
	-0.25 ^B
Clean fleece weight	-0.31
	-0.06
Fibre diameter	0.15
	0.12
CV of fibre diameter	-0.13
	-0.06
Staple length	-0.17
	-0.12
Staple strength	-0.12
	-0.24
Crimp frequency	0.29
	0.44
Lock	-0.24
	-0.22
Skin quality	-0.27
	-0.38
Visual colour	0.03
	0.04
Handle	0.00
	-0.03
Crimp definition	0.11
	0.18
A Upper value represents correlation with fleece character measured at 10 months of age	
B Lower value represents correlation with fleece character measured at 16 months of age	
* see Appendix table for the scoring system used by the classer	

Sheep with a high paracortex percentage tended to have lower yield, lower clean fleece weights (at 10 months only), higher fibre diameters, lower staple lengths, lower staple strengths, and higher crimp frequencies. These sheep also had lower lock (i.e. more tippy, hairy staples), lower skin quality score (i.e. tighter, less pliable skin), and poorer crimp definition (i.e. higher score). We also found that there were high genetic correlations between paracortex percentage and follicle density (-0.40) and between paracortex percentage and total bulb area (-0.31).

These results are in accord with the findings of Jackson et al. (1975), that sheep with less curved follicles and fibres (i.e. less paracortex) tend to be the genetically high producing animals. The heritability of paracortex percentage was moderate (0.33 \pm 0.07), and it's variance high, suggesting that considerable progress should be achievable in decreasing the paracortex percentage and improving the fleece characters indicated in Table 5.

What Skin And Follicle Characteristics Should We Be Aiming For?

Summarising the above results it appears that the following genetic associations exist between fleece characters and skin and follicle traits:

High clean fleece weight	low skin biopsy weight high follicle density high total bulb tissue density low paracortex percentage
Low fibre diameter	low skin weight high follicle density low mean bulb area low variability of bulb area
High staple length	high skin weight high mean bulb area high total bulb tissue density low paracortex percentage
High staple strength	high skin weight low paracortex percentage

Can Skin Analysis Improve The Accuracy Of Selection Of Superior Animals?

As indicated in the Introduction, the most accurate means of selecting superior animals is usually to measure directly the traits in the breeding objective. While a number of indirect traits (skin and follicle characters) can be shown to be genetically associated with the important traits of fleece weight and fibre diameter as well as a number of style

characters, unless they provide substantial additional information which is properly used, selection procedures placing excessive emphasis on them could only serve to reduce the rate of genetic gain!

Of all the characters measured in this experiment, follicle density is the most promising in that it is genetically associated with high fleece weight, high clean scoured yield, and low fibre diameter. Such animals could be selected for indirectly by selecting sheep with high skin quality, or, more accurately by selecting sheep with good crimp definition (Table 3). However, either means would slow down the progress in relation to what could be achieved by directly selecting for high clean fleece weight and low fibre diameter!

It remains to be seen whether or not the additional cost of skin measurement is beneficial. At present the answer appears to be negative, although skin analysis is making an important contribution towards our understanding of the combination of characteristics likely to be desirable in sheep breeding programmes.

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Appendix

Scoring System Used For Subjective Assessment Of Characters.

Lock	1 (tippy, hairy), , 5 (square, blocky)
Skin quality	1 (very tight), , 5 (best, pliable)
Visual colour	1 (yellow), , 5 (lustrous, white)
Handle	1 (harsh, brittle), , 5 (very soft)
Condition	1 (very dry), , 5 (greasy)
Crimp definition	1 (very well defined), , 5 (crimp hardly visible)