Histological differences in the skin and fibre characteristics of ten white-woolled sheep breeds

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Skin and wool samples of fully grown white-woolled rams of ten different sheep breeds were investigated. An index was constructed according to which the breeds could be classified into three groups, taking 11 characteristics into consideration. This classification is discussed with reference to individual breeds. The Merino, which was the only breed in Group 1, proved to have the most favourable values for the traits regarded as important from an economic point of view (follicle density 43,5/mm^2; S/P ratio 20,8:1 fibre diameter 24,1 µm in histological sections and 21,0 µm according to lanametric measurements). The Bleu de Maine had the lowest follicle density (10,0/mm^2), whilst the Border Leicester possessed the lowest S/P ratio (3,9). Fibre diameter had the highest value in Group 3 varying from 30,8 µm to 38,8 µm in histological sections and from 36,2 µm to 41,3 µm with lanametric measurement. Medullation (33,6%) and pigmentation (22,6%) were least favourable in the German Whitehead. The latter breed occupied the highest index for all traits combined. An indication of follicle use for fibre production was obtained by expressing the fibre diameter as a percentage of the inner follicle diameter. On this basis the Ile de France proved to be the most productive (93,2%). The follicle wall of this breed was thicker (23,9 µm) than any other breed involved. The German Whitehead proved to be the least productive (86,5%) to be followed by the Merino (87,3%) for average fibre diameter per follicle diameter.
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Vel- en wolmonsters van volwasse witwol-ramme van tien verskillende rasse is ondersoek. 'n Indeks, wat 11 eienskappe in ag neem, is uitgewerk, waarvolgens die rasse in drie groepe verdeel kon word. Die groepe word bespreek met verwysing na individuele rasse. Die Merino, wat die enigste ras in Groep 1 was, het die beste waardes getoon vir die meeste vasgestelde eienskappe (follikeldigtheid 43,5/mm^2; S/P-verhouding 20,8:1; veseldeursnit 24,1 µm in histologiese sneë en 21,0 µm onder die lanameter). Die Bleu de Maine het die laagste follikeldigtheid getoon (10,0/mm^2), terwyl die Border Leicester die laagste S/P-verhouding getoon het (3,9). Veseldeursnit was die hoogste in Groep 3 en het varieër van 30,8 µm tot 38,8 µm in histologiese sneë en van 36,2 µm tot 41,3 µm onder die lanameter. Die hoogste medullering (33,6%) en pigmentasie (22,6%) het by die Duitse Witkop voorgekom. Laasgenoemde ras het die hoogste indeks behaal vir alle eienskappe gekombineerd. Om 'n aanduiding van die benutting van follikeldeursnit te verkry, is die veseldeursnit uitgewerk as persentasie van die binneste follikeldeursnit. Op grond hiervan het die Ile de France die hoogste produktiwiteit getoon (93,2%) vir veselproduksie. Die follikelwand van hierdie ras was dikker (23,9 µm) as dié van ander rasse. Die Duitse Witkop het die laagste gemiddelde produktiwiteit per follikel getoon (86,5%) gevolg deur die Merino (87,3%).
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Introduction

The biology and in particular the histology of the skin and fibre of the Merino has been described in great detail (Carter, 1943; Nay & Johnson, 1967; Nay, 1970; Nay & Jackson, 1975). Similar information on other breeds is also available (Fraser, 1952a; 1952b; Burns, 1953; 1954a; 1954b; Margolena, 1954; Ryder & Shephenson, 1968; Fayes, Marai & Taha, 1976). The follicle and fibre traits of a variety of well-known breeds have been studied on a comparative basis (Ryder, 1957; 1968; Carter, 1955; 1959; Fraser & Short, 1960; Pasecvnik, 1968; Lyapina, 1971).

Efforts are under way to identify and develop the most suitable genotypes for intensive production of wool and meat in high potential regions of South Africa, using the Merino as a standard for comparison (Hofmeyr, 1980). A wide range of composite genotypes has been produced for comparative studies.

Further investigation of the data found in histological skin sections of these studies is required to round off the study on parent breeds. Preliminary results on the parent breeds have been published (Steinhagen, Dreyer & Hofmeyr, 1984) whilst histological results on the first crosses will be published at a later stage. This article is an attempt to contribute supplementary information on the skin and fibre traits of ten sheep breeds.

Material and Methods

Skin and wool samples from mature rams of the following breeds were examined (number of animals in each breed are indicated in brackets) — German Whitehead (2), Dorset Horn (3), Merino (3), Bleu de Maine (4), Border Leicester (4), Finnish Landrace (4), Ile de France (4), Cheviot (5), Merino Landrace (5), and Texel (5).

Measurements and analyses of skin samples were performed by the method of Carter & Clarke (1957). Two measurements were taken to determine the fibre diameter, namely fibre diameter as measured within the follicle in histological skin sections and measurements carried out with the lanameter on wool samples taken from the sampling area as introduced by Bosman & Van Wyk (1939).

Inside and outside follicle diameters were measured across the widest part of the follicle. From these measurements the thickness of the follicle wall could be calculated.

An index was calculated to classify the different breeds into three groups

$$\text{Index} = (x_1\, n_{(1-11)} + x_2\, n_{(1-11)} + \ldots x_{10}\, n_{(1-11)})$$

where $x_{(1-10)}$ is the sequential position (Table 1) for any characteristic for the different breeds and $n_{(1-11)}$ is the number of times any specific breed occupies a certain position of individual characteristics. The lowest index would indicate the breed theoretically ideal for the combined quantified traits. The groups were randomly divided as follows: Group 1 : Index 0–29; Group 2 : Index 30–59; Group 3 : Index 60–100.

Results and Discussion

According to the index (Table 1) the breeds were classified as follows

GROUP 1	GROUP 2	GROUP 3
Merino	Merino Landrace	Cheviot
	Finnish Landrace	Texel
	Ile de France	Border Leicester
	Dorset Horn	Bleu de Maine
		German Whitehead

Carter (1959) used S/P ratio, fibre diameter and medullation to obtain a similar method for classification.

Follicle traits

Density and S/P ratio

The average follicle density (per mm²) of the Merino (43,5) was much higher than that of the breeds in Group 2, whose average densities varied from 14,7 to 18,5. Densities of the three Merino rams were low in comparison to those found by Carter (1955), but similar to counts of fibre density found by Turner (1958). The difference between Group 2 and Group 3 (range 10,0/mm² – 13,1/mm²) was comparatively small (Table 1).

The average follicle densities (per mm²) of the Dorset Horn (14,7), the Border Leicester (12,9) and the Cheviot (12,2) were lower than the respective values (18,5; 15,8; 14,6) found by Carter (1955).

The high follicle density of the Merino was due to the high number of secondary follicles (41,5/mm²). The correlation between secondary follicle density and overall follicle density was a high 0,99 ($P \leq 0{,}01$). Follicle measurements were much smaller and more in proportion to the follicle and follicle group size in the Merino than in the other breeds. Subjectively judged the skin space in the Merino appears to be used more effectively for follicle development and fibre production than in other groups. The follicle wall thickness of the Merino was the lowest of all breeds (11,3 μm; Table 1) which contributed to the high follicle density ($r = -0{,}91$, $P \leq 0{,}01$; Table 3) and S/P ratio ($r = -0{,}90$, $P \leq 0{,}01$; Table 3) respectively. The follicle wall thickness, however, did not influence primary follicle density ($r = 0{,}38$) which varied between breeds from 1,8/mm² to 2,6/mm². Again these values are lower than values estimated by Carter (1955). Carter & Clarke (1957) suggested different shrinkage percentages for skins with differing follicle densities owing to dehydration taking place during processing. In this study a shrinkage rate of 0,5 was allowed according to Carter & Clarke (1957) and might be the reason for the lower than expected values.

In Group 2 the Finnish Landrace (18,5/mm²) and Ile de France (15,3/mm²) had higher follicle densities than the Merino Landrace (17,2/mm²) and Dorset Horn (14,7/mm²; Table 1) respectively, whilst their S/P ratios were lower (7,3 and 5,0 respectively) than the latter breeds (7,6 and 6,9 respectively). In Group 3 this situation is more clearly illustrated where the Border Leicester has a higher follicle density (12,9/mm²) but lower S/P ratio (3,9) when compared to the Bleu de Maine (10,0/mm² and 4,3 respectively; Table 1). These measurements were obtained in spite of the high phenotypic correlation coefficient between follicle density and S/P ratio ($r = 0{,}97$, $P \leq 0{,}01$; Table 3), possibly owing to the small number of animals per breed available for this investigation. A significant correlation coefficient ($r = 0{,}48$, $P \leq 0{,}01$) was also calculated for density and S/P ratio by Jackson, Nay & Turner (1975). The above-mentioned differences can be ascribed to the relationship of primary to secondary follicles being low in an area of high follicle density.

Follicle diameter

The Merino (Group 1) produced the smallest average inner (27,6 μm) and outer (50,3 μm) follicle diameters, whilst the follicle wall average was thinner (11,3 μm) as compared to other groups (Table 1). The correlation coefficient between average inner and outer follicle diameters was calculated

Table 1 Counts and measurements of follicle and fibre traits from mature rams of ten white-woolled sheep breeds

	Follicle counts (per mm²)				Follicle measurements (μm)			Fibre traits				
								Fibre diameter (μm)				
Breed	Secondary	Primary	(S + P) density	S/P ratio	Inside diameter	Outside diameter	Wall thickness	Histological section	Lanameter	Medullation (%)	Pigmentation (%)	Index (%)
Merino	41,5	2,0	43,5	20,8	27,6	50,3	11,3	24,1	21,0	2,9	3,7	16
Merino Landrace	15,2	2,0	17,2	7,6	29,8	71,1	20,6	27,2	39,8	2,7	2,9	30
Finnish Landrace	16,3	2,3	18,5	7,3	33,4	68,8	17,7	29,3	27,3	4,1	4,3	36
Ile de France	12,6	2,6	15,3	5,0	30,9	78,7	23,9	28,8	29,7	4,0	2,3	52
Dorset Horn	12,8	1,8	14,7	6,9	32,9	72,5	19,8	29,9	34,6	17,4	17,4	52
Cheviot	9,9	2,3	12,2	4,3	34,9	79,7	22,4	30,8	36,2	30,3	1,8	73
Texel	10,8	2,3	13,1	4,9	36,1	80,2	22,1	32,3	36,6	24,0	5,0	76
Border Leicester	10,3	2,6	12,9	3,9	42,9	82,2	19,7	38,8	36,7	11,8	6,1	64
Bleu de Maine	7,9	2,1	10,0	4,3	35,1	82,8	23,9	31,9	36,8	9,6	8,1	85
German Whitehead	9,5	2,3	11,8	4,2	44,7	87,7	21,5	38,6	41,3	33,6	22,6	97

S = Secondary follicles; P = Primary follicles; S/P ratio = Secondary to primary follicle ratio

Table 2 Fibre and follicle traits with indication of follicle productivity from mature rams of ten white-woolled sheep breeds

Breed	Fibre diameter (μm) (histologic measurement)		Inner follicle diameter (μm)		Outer follicle diameter (μm)		Fibre diameter to inner follicle diameter		
	Primaries (P)	Secondaries (S)	Primaries (P)	Secondaries (S)	Primaries (P)	Secondaries (S)	Primaries (P)	Secondaries (S)	Mean
Merino	23,5	24,8	26,7	28,6	47,6	53,0	87,9	86,7	87,3
Merino Landrace	27,5	27,0	31,3	28,3	72,3	69,8	87,8	95,2	91,3
Finnish Landrace	31,2	27,4	36,2	30,5	69,2	68,4	86,3	89,7	87,9
Ile de France	28,9	28,6	31,8	30,0	78,3	79,0	91,1	95,4	93,2
Dorset Horn	30,2	29,6	33,9	31,9	70,3	74,7	89,0	92,9	90,9
Cheviot	31,6	30,0	36,2	33,6	77,2	82,2	87,1	89,5	88,3
Texel	31,7	32,9	35,8	36,5	80,4	80,1	88,7	90,1	89,4
Border Leicester	38,5	39,0	42,8	43,0	81,0	83,7	90,0	90,8	90,4
Bleu de Maine	31,8	32,0	36,0	34,3	82,8	82,9	88,3	93,5	90,8
German Whitehead	39,6	37,6	47,0	42,5	89,2	86,3	84,3	88,6	86,5

Table 3 Phenotypic correlation coefficients for fibre and follicle from mature rams of ten white-woolled sheep breeds

	Sec/ mm²	Prim/ mm²	Density/ mm²	S/P	P Fibre Ø μm	S Fibre Ø μm	Av Fibre Ø	Fibre Ø Lanam.	P Inner Foll. Ø	S Inner Foll. Ø	Av Inner Foll. Ø	P Outer Foll. Ø	S Outer Foll. Ø	Av Outer Foll. Ø	Medullation %	Pigmentation %	Wall thickness
Wall thickness	-0,91[b]	0,38	-0,91[b]	-0,90[b]	0,44	0,42	0,44	0,69[a]	0,34	0,29	0,36	0,88[b]	0,87[b]	0,88[b]	0,37	0,10	
Pigmentation %	-0,25	-0,03	-0,27	-0,20	0,54	0,49	0,53	0,55	0,50	0,51	0,56	0,36	0,34	0,35	0,53		
Medullation %	-0,47	0,05	-0,39	-0,46	0,61[a]	0,61[a]	0,60	0,78[b]	0,55	0,64[a]	0,66[a]	0,55	0,63[a]	0,59			
Av Outer Foll. Ø	-0,94[b]	0,49	-0,93[b]	-0,94[b]	0,81[b]	0,79[b]	0,81[b]	0,92[b]	0,74[b]	0,70[a]	0,76[b]	0,99[b]	0,99[b]				
Sec. Outer Foll. Ø	-0,93[b]	0,71	-0,92[b]	-0,93[b]	0,81[b]	0,80[b]	0,81[b]	0,93[b]	0,73[a]	0,72[a]	0,76[b]	0,97[b]					
Prim. Outer Foll. Ø	-0,95[b]	0,47	-0,93[b]	-0,94[b]	0,80[b]	0,77[a]	0,80[b]	0,90[b]	-0,73[a]	0,68[a]	0,75[b]						
Av Inner Foll. Ø	-0,59	0,43	-0,58	-0,61[a]	0,98[b]	0,96[b]	0,99[b]	0,82[b]	0,98[b]	0,98[b]							
Sec. Inner Foll. Ø	-0,50	0,45	-0,50	-0,53	0,94[b]	0,98[b]	0,97[b]	0,79[b]	0,94[b]								
Prim. Inner Foll. Ø	-0,60	0,48	-0,59	-0,63[a]	0,99[b]	0,94[b]	0,98[b]	0,79[b]									
Fibre Ø Lanam.	-0,88[b]	0,23	-0,85[b]	-0,82[b]	0,83[b]	0,84[b]	0,84[b]										
Av Fibre Ø	-0,66[a]	0,49	-0,65[a]	-0,68[a]	0,99[b]	0,99[b]											
S Fibre Ø μm	-0,61[a]	0,49	-0,79[b]	-0,63[a]	0,94[b]												
P Fibre Ø μm	-0,68[a]	0,47	-0,89[b]	-0,71[a]													
S/P	0,99[b]	-0,46	0,97[b]														
Density/mm²	0,10[b]	-0,34															
Prim./mm²	-0,35																
Sec./mm²																	

[a] $P < 0,05$; [b] $P < 0,01$; Ø Diameter (μm)

(r = 0,76; $P \leq 0,01$). Inner and outer follicle diameter of Group 2 varied between 29,8 μm – 33,4 μm and 68,8 μm – 78,7 μm respectively. Follicle walls in Group 2 were therefore expected to have a large variation in thickness (17,7 μm – 23,9 μm). The Ile de France had an exceptionally thick follicle wall (23,9 μm).

In Group 3 the variation of inner follicle measurements (34,9 μm – 44,7 μm) differed from the variation in outer follicle measurement (79,7 μm – 87,7 μm) by 1,8 μm. Follicle wall thickness of this group could therefore be expected to vary to a lesser extent in comparison to Group 2 (19,7 μm – 23,9 μm). The Border Leicester (19,7 μm) as well as the German Whitehead (21,5 μm) both have a follicle wall thickness well within the range of Group 2. From Table 2 it appears that the difference of inner follicle diameter between primary and secondary follicles was least in the Border Leicester (– 0,2 μm), Texel (– 0,8 μm), and Bleu de Maine (1,8 μm). The correlation coefficient (r = 0,94) between primary and secondary inner follicle diameters was highly significant ($P \leq 0,01$). Secondary follicles of the Border Leicester, Texel as well as the Merino had larger inner diameters than the primary follicles by 0,2; 0,8 and 1,9 μm respectively.

The smallest difference in outer follicle diameter between primary and secondary follicles was found in the Bleu de Maine (– 0,1 μm), the Texel (0,3 μm) and the Ile de France (– 0,7 μm; Table 2). It can be concluded from Table 2, that in the German Whitehead (by 3,0 μm), the Merino Landrace (by 2,6 μm), the Finnish Landrace (by 0,8 μm), and the Texel (by 0,3 μm) the averages of the primary follicle outer diameters were larger than those of the secondary follicles. The correlation coefficient between primary and secondary outer follicle diameters was highly significant (r = 0,97, $P \leq 0,01$; Table 3).

The conclusion can be made that primary follicles are not necessarily larger than secondary follicles as is conventionally accepted (Cockrem & Rae, 1961), but that large primary follicles would occur with large secondary follicles regardless of sequence in size.

Fibre traits

Fibre diameter

Except for the values found on the Merino, the Finnish Landrace and the Border Leicester, the readings on the lanameter were higher than the measurements in histological section. Readings on the lanameter and in histological section have a correlation coefficient of $r = 0{,}84$ ($P \leq 0{,}01$). In both investigations the Merino produced on average the finest fibres (histologically 24,1 µm; lanameter 21,0 µm). These measurements agree with the estimates of medium to strong wool Merinos as found by Carter (1955).

The average fibre diameters of Group 2 varied from 27,2 µm to 29,9 µm as measured in skin sections and from 27,3 µm to 34,6 µm according to readings on the lanameter. Both such measurements of the Ile de France and Dorset Horn in this study are higher than the range of fibre diameters as estimated by Ryder & Stephenson (1968) but the lanametric measurements on the Dorset Horn agree with those determined by Carter (1955).

In Group 3 no specific pattern was found between the two determinations of fibre diameter. In histological section measurements the Cheviot produced on average the finest fibres (30,8 µm) whilst the Border Leicester produced on average the strongest fibres (38,8 µm). When measured on the lanameter, the fibres with the lowest average diameter originated from the Cheviot (36,2 µm) and the highest average was derived from the German Whitehead (41,3 µm). The average fibre diameter of the Border Leicester (histological section : 38,8 µm and lanameter : 36,7 µm) are higher than the quality coded values (31,0 µm – 34,4 µm) found by Ryder & Stephenson (1968), but the lanametric value agrees with the estimate (36,0 µm) by Carter (1955). Values for the Cheviot were reasonably higher in this study (histologically : 30,8 µm; lanameter : 36,2 µm) than the diameter found by Carter (1955; 21,0 µm) and the estimated range (26,4 µm – 29,3 µm) given by Ryder & Stephenson (1968). In this study the fibre diameter measurements (lanameter) for the Texel, Bleu de Maine and German Whitehead were higher than the estimated values given by Ryder & Stephenson (1968). Average fibre diameters have been found to be significantly correlated with average inner and outer follicle diameters ($r = 0{,}99$ and $r = 0{,}81$) for measurements in histological section or $r = 0{,}82$ and $r = 0{,}92$ according to lanametric measurement. All values were significant at $P \leq 0{,}01$ (Table 3).

Medullation

In fibres of all the breeds (Table 1) medullation was present varying from 2,7% of all fibres (Merino Landrace) to 33,6% (German Whitehead). A correlation coefficient of $r = 0{,}66$ ($P \leq 0{,}05$; Table 3) was determined between medullation percentage and the average inner follicle diameter; the correlation with average fibre diameter in histological section was high ($r = 0{,}60$) but not significant, whereas the correlation with the average fibre diameter readings on the lanameter were significant ($r = 0{,}78$, $P \leq 0{,}01$). According to Ryder & Stephenson (1968) there is no close relationship between fibre diameter and the presence of medulla. Smuts, Hunter & Frazer (1983) came to the same conclusion, although these authors found a tendency of increasing medullation in thicker fibres. No significant correlation could be detected between primary and secondary follicle density and medullation.

The Merino Landrace had a slightly lower medullation percentage (2,7%) than the Merino (2,9%; Table 1). In Group 2 the Dorset Horn produced an inexplicable medullation rate (17,4%), whereas the percentage medullation in Group 3 varied from a low 9,6% (Bleu de Maine) to a very high 33,6% for the German Whitehead.

Pigmentation

No association could be identified between pigmentation and the other traits examined (Table 3). The Cheviot produced the lowest pigmentation rate (1,8%) followed by the Ile de France (2,3%). The pigmentation rate varied from 1,8% to 22,6%; the latter being found in the German Whitehead (Table 1).

Relationship between follicle and fibre diameter

As can be expected from the relatively small differences between the average diameter of the inner primary and secondary follicle diameters (1,8 µm and 1,8 µm respectively, Table 2), the Bleu de Maine and Ile de France produced the smallest differences between the averages of the primary and secondary fibre diameters (– 0,2 µm and 0,3 µm respectively). The Texel produced a large difference in average diameter of primary and secondary fibres (– 1,2 µm), although this difference in follicle diameter was small (– 0,8 µm). The Finnish Landrace produced the largest differences between primary and secondary fibres (3,9 µm), which was expected in view of the large follicular difference between these follicles (5,7 µm).

The secondary fibres of the Merino (by 1,3 µm), the Texel (by 1,2 µm), the Border Leicester (by 0,5 µm), and the Bleu de Maine (by 0,2 µm) were found to be of larger diameter on average in histological section than the primary fibres. Carter (1955) mentioned the secondary fibres of only the Dorset and Corriedale to have larger diameters on average than the primary fibres.

Average outer and inner follicle diameters were significantly correlated with average fibre diameters in histological section ($r = 0{,}81$, $P \leq 0{,}01$; $r = 0{,}99$, $P \leq 0{,}01$ respectively), as well as measurements with the lanameter ($r = 0{,}92$, $P \leq 0{,}01$; $r = 0{,}82$, $P \leq 0{,}01$ respectively). Average follicle wall thickness was significantly correlated ($r = 0{,}69$, $P \leq 0{,}05$) with fibre diameter as measured on the lanameter but not as measured histologically.

By expressing the fibre diameter as a percentage of the inner follicle diameter, an approximate value is obtained by which the percentage of follicle diameter used for fibre production can be assessed (Table 2). Fibres in all breeds were oval to elliptical in shape making the cross-sectional area difficult to determine. The correlation coefficient of the average fibre diameter measured per histological section or per lanameter and average inner follicle diameter was highly significant ($r = 0{,}99$, $P \leq 0{,}01$ and $r = 0{,}82$, $P \leq 0{,}01$ respectively).

Judged by the percentage of fibre diameter occupying the follicle diameter, the secondary follicles proved to be of higher productivity as previously defined than the primary follicles in all breeds except the Merino, where this phenomenon was reversed (Table 2).

Ryder & Stephenson (1968) did not mention follicle diameter in relation to fibre diameter, but stated that primary follicles in double-coated, carpet-fleeced sheep produced longer and coarser fibres and were therefore more productive. More recent authors have found that the productivity of primary and secondary follicles of the Longwool and Down breeds are similar according to the length and coarseness of the fibres. However, no mention is made of follicle use for the production of fibres.

According to the above-mentioned parameter (fibre diameter/follicle diameter percentage; Table 2) the Ile de France was the breed which was most efficient in using the available space in the follicles with fibre diameter (93,2%). The average fibre diameter of the Merino occupied 87,3% of the inner follicle diameter. Only the German Whitehead (86,5%; Table 2) of the breeds under investigation was worse in this respect.

It is therefore possible that higher follicle densities, which are associated with smaller follicles (r = 0,93, $P < 0,01$: for density and average outer follicle diameter; Table 3) (Chapman, Moule & Richards, 1954; Carter 1955; Carter & Clarke, 1957) need not necessarily use the cross-section of the individual follicles more economically as compared to follicles in lower follicle densities.

In conclusion the Merino had the lowest index as a result of the more favourable values in most production traits analysed (Table 1). The cross-section of individual follicles seemed to be used by fibre diameter to a lesser extent (87,3%) as compared to other breeds (Table 2). Group 2 followed Group 1 with regard to the production traits discussed in relation to quality of wool and skin traits. The use of space of individual follicles in terms of fibre diameter was highest in this group, although the Finnish Landrace did not rank positively in this respect (87,9%).

Group 3 produced the lowest indices for the characteristics measured. The German Whitehead was the least desirable breed for all examined traits.

In respect to fibre diameter the Merino Landrace, Finnish Landrace and Ile de France compared most favourably with the Merino.

The Ile de France produced a low follicle density (15,3/mm^2) and S/P ratio (5,0) as compared to the Merino Landrace and the Finnish Landrace. Although the use of follicle diameter for fibre production was highest in this breed (93,2%), wool production can be expected to be lower, due to the lower S/P ratio (compare Steinhagen, Dreyer & Hofmeyr, 1984). To be consequent with this argument the conclusion must be drawn, that the Finnish Landrace would produce less wool than the Merino Landrace due to the lower S/P ratio. The latter breed also proved to use the inner follicle area more effectively (91,3%) than the Finnish Landrace (87,9%).

From a wool-producing point of view the Merino Landrace can be assumed to be most economical following the Merino and being followed by the Finnish Landrace and Ile de France in that order.

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References

BOSMAN, V. & VAN WYK, C.M., 1939. Notes on the determination of fibre fineness on a Merino wool sample. *Onderstepoort J. Vet. Sci.* 13, 401.

BURNS, Marca, 1953. Observations on the follicle population of Blackface sheep. *J. Agric. Sci.* 43, 422.

BURNS, Marca, 1954a. Observations on the development of the fleece and follicle population in Suffolk sheep. *J. Agric. Sci.* 44, 86.

BURNS, Marca, 1954b. The development of the fleece and follicle population in Herdwick sheep. *J. Agric. Sci.* 44, 443.

CARTER, H.B., 1943. Studies in the biology of the skin and fleece of sheep. Bull. Coun. Sci. Industr. Res. Aust. No. 164.

CARTER, H.B., 1955. Hair follicle groups in sheep. *Anim. Breed. Abstr.* 23, vol 2, 101.

CARTER, H.B., 1959. Wolleistung, Woll- und Pelzkwalität. *Handb. Tierz.* 2, 312.

CARTER, H.B., & CLARKE, W.H., 1957. The hair follicle group and skin follicle population of Australian Merino sheep. *Aust. J. Agric. Res.* 8, 91.

CHAPMAN, R.E., MOULE, G.R. & RICHARDS, M., 1954. Follicle groups in the skin of a mosaic Merino sheep. Queensland Dept. Agric. and Stock., Division Animal Industry, Bulletin 15.

COCKREM, F. & RAE, A.L., 1961. A Review of Work on Wool Growth. *Sheepfarming Annual*, 1961.

FAYES, I., MARAI, M. & TAHA, A.H., 1976. Wool follicle characteristics in the Awassi fat-tailed sheep. *Anim. Breed. Abstr.* 46, No. 3870.

FRASER, A.S., 1952a. Growth of wool fibres in sheep. *Aust. J. Agric. Res.* 3, 419.

FRASER, A.S., 1952b. Growth of the N-type fleece. *Aust. J. Agric. Res.* 3, 435.

FRASER, A.S. & SHORT, B.F., 1960. The Biology of the fleece. Anim. Res. Lab. Tech. Paper No. 3. CSIRO, Australia.

HOFMEYR, J.H., 1980. Implications of experimental results of crossbreeding sheep in the Republic of South Africa. *Proc. World Congr. on Sheep and Beef Cattle Breeding* 1, 157.

JACKSON, N., NAY, T. & TURNER, HELEN, N., 1975. Response to selection in Australian Merino sheep. VII. Phenotypic and genetic parameters for some wool follicle characteristics and their correlation with wool and body traits. *Aust. J. Agric. Res.* 26, 937.

LYAPINA, N.A., 1971. Skin histology of sheep of different constitutional types. *Anim. Breed. Abstr.* 40, No. 3206.

MARGOLENA, LUBOW, A., 1954. Sequence and growth of primary and secondary follicles in Karakulsheep. *J. Anim. Sci.* 13, 765.

NAY, T., 1970. Follicle characteristics in a group of Merino sheep selected up and down for fleece weight. *Aust. J. Agric. Res.* 21, 951.

NAY, T. & JACKSON, N., 1975. Effect of changes in nutritional level on the depth and curvature of wool follicles in Australian Merino sheep. *Aust. J. Agric. Res.* 24, 439.

NAY, T. & JOHNSON, HELEN, 1967. Follicle curvature and crimp size in some selected Australian Merino groups. *Aust. J. Agric. Res.* 18, 833.

PASECVNIK, N.M., 1968. General and breed characters of the skin structure of coarse-woolled, fine-woolled and crossbred sheep. *Anim. Breed. Abstr.* 38, No. 2600.

RYDER, M.L., 1957. A survey of the follicle population in a range of British breeds of sheep. *J. Agric. Sci., Camb.* 49, 275.

RYDER, M.L., 1968. Fleece structure in some native and unimproved breeds of sheep. *Zeitschr. Tierz. & Zuchtgsbiol.* 85 (2), 143.

RYDER, M.L. & STEPHENSON, S.K., 1968. Wool Growth. Academic Press: London.

SMUTS, F., HUNTER, L. & FRAZER, W., 1983. Medullation in mohair. 1. In measurements employing a photoelectric technique. SAWTRI Technical Report No 509.

STEINHAGEN, Ortrud, DREYER, J.H. & HOFMEYR, J.H., 1984. Contributing components of wool production for seven white woolled sheep breeds. Proc. 2nd World Congr. on Sheep and Beef Cattle Breeding. p. 718. Edited by J.H. Hofmeyr and E.H.H. Meyer, South African Stud Book and Livestock Improvement Association.

TURNER, HELEN, N., 1958. Relationships among clean wool weight and its components. I. Changes in lean wool weight related to changes in the components. *Aust. J. Agric. Res.* 9, 521.