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# Studies on the Basic Characteristics of South African Merino Wool. IV.—Scaliness.

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WOOLMEN have, on several occasions, referred to the well-developed felting property of South African Merino wool. Rausch (1935), asserted that " the extraordinarily numerous and narrow scales, so frequently noted in Cape wool, point to a connection with the greater felting capacity of Cape wools ".

The problems of felting and milling and scaliness have been studied by several workers, including Shorter (1923), Barker and Marsh (1928), Arnold (1929), Speakman and Stott (1931), Speakman, Stott and Chang (1933), and Schofield (1938). Arnold showed that when wool was subjected to a rubbing process, the fibres tended to creep in the direction in which the scales did not oppose motion, while Shorter showed how such a motion could cause shrinkage of fabrics. The work of Speakman, Stott and Chang (1933), led to the conclusion that " the determining factor in milling is the surface scale structure of the fibres, but the rate and extent of shrinkage due to this cause are not determined solely by different degrees of scaliness in various wools ".

Little work has, however, been done on this characteristic from the wool producer's point of view. In problems connected with the scaliness of Merino wool, particularly in those dealing with breeding, nutrition and environment, it is not possible for the wool producer to exercise any influence over this characteristic in his methods of production. It is for this reason that studies on the scaliness of South African Merino wool from production aspects have been initiated.

The present contribution deals with the technique of determining scaliness, and with the results obtained on a series of South African Merino wool samples. Later contributions will deal with such aspects as breeding and nutrition in relation to scaliness.

## METHOD.

For studies of this nature it was necessary to use a method giving quantitative expression to the scaliness of a sample of raw wool, and the friction method was chosen in preference to other methods such as counting the number of scales per unit length of fibre. The apparatus and methods used were essentially those described by Speakman and Stott (1931), with modifications in the methods of sampling and the technique of mounting of the fibres.

The apparatus, shown in Fig 1, consisted of a platform capable of being rotated about a horizontal axis at one end, the slowly tilting action of the platform being controlled by an electric motor and reducing gear in such a manner that an even and smooth action was ensured. It was found necessary to mount the motor and gearing on the floor since vibration of the platform gave rise to erratic results. The platform was tilted at the rate of about 30° per minute.

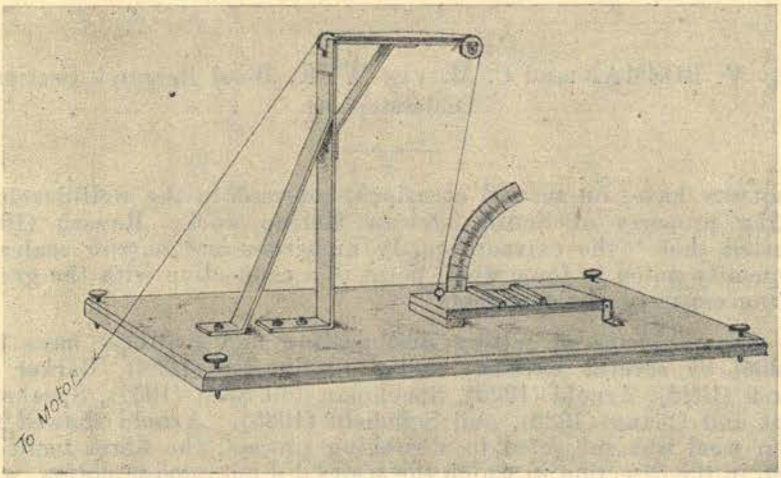


Fig. 1.—The apparatus used for determining the scaliness of wool.

As Speakman and Stott have pointed out, the ideal surface for the friction measurements would be one composed of fibres from the same sample as those mounted on the frame, but the amount of work involved in constructing a surface for every sample would be prohibitive. One such surface was constructed by mounting a large number of fibres with the scales of alternate fibres pointing in opposite directions, but this surface, while giving uniform results, was found to deteriorate rapidly with usage. Various materials were tested, and a surface consisting of billiard cloth was found to give the least variable results for successive determinations with any one frame.

For determining the number of fibres to be mounted on a frame, six frames of fifty fibres each were constructed from a single sample, and the angles of slip in the directions of the root and tip ends of the fibres respectively determined fifty times in succession. The same procedure was followed with five frames containing 100 fibres each. The observations were divided into successive groups of ten and the percentage differences in friction calculated from the means of ten pairs of angles. In this way five successive values were obtained for each frame, and the variance between frame means could be compared with the variance within frame means by the $z$ test. Table 1 gives the results obtained. The value of $z$ is highly significant at the 0·1 per cent. probability level in the case of 50 fibres per frame, and significant at the 5 per cent. probability level in the case of 100 fibres per frame. The variations were considered to be due to inadequate sampling with even 100 fibres per frame, and frames were therefore constructed with 200 fibres each. Duplicate frames were constructed for each sample. The adequacy of this number of fibres was shown by a comparison of the variances between and within frames, after the variance between samples had been eliminated. For the first twenty samples analysed, the value of $z$ was 0·1709 ($n_1 = 20$. $n_2 = 160$), which was insignificant at the 5 per cent. probability level.

TABLE 1.

| Number of Fibres on Frame. | z. |
|---|---|
| 50 | 1·538 ($n_1$ = 5, $n_2$ = 24). |
| 100 | 0·733 ($n_1$ = 4, $n_2$ = 20). |

In all cases therefore, 200 fibres were mounted on each frame and duplicate frames constructed for each sample. The standard error of the difference of the two means obtained for each sample was ±3·75, so that in 20 per cent. of cases duplicate frames could be expected to give values differing by more than 5 per cent. Actually in the samples analysed it was found that in 24 per cent. of the cases duplicate frames gave values differing by more than 5 per cent. In such cases a third frame was constructed.

The frame on which the fibres were mounted (Fig. 2) consisted of an aluminium plate with two rectangular strips of wood firmly screwed to it at a distance of just over an inch apart. The surfaces of the strips were covered with thick squared paper, which was folded over the edge and secured to the inner surface of the strips. A shallow cut with a razor blade along the edge gave a straight, square-edged corner. The squares on the two strips corresponded exactly with one another.

Strands were selected at random from the sample to be determined and grouped together in a bundle with the tip ends of the fibres all pointing in the same direction. The bundle was then thoroughly cleansed in benzene. A preliminary investigation showed that the percentage difference in friction was lowered by subsequent washing in water, an effect which could not be ascribed merely to a decrease in the angle of slip against the scales, since in several cases the angle of slip with the scales favouring motion, increased.

The effect of alkaline reagents on felting properties has been studied by Mercer and Freney (1940). The whole question of treatment with various liquids is being investigated, but for the purpose of the present study, where comparative results were aimed at, a thorough cleansing in benzene was considered sufficient.

Two hundred fibres were drawn at random from the bundle of strands and mounted on the frame. The fibres were stretched just sufficiently to remove the crimping and the ends were secured by adhesive wax to the outside edges of the wooden strips. Four fibres were mounted to each millimetre division, the result being an even distribution of fibres across the frame. The fibres were finally glued to the surface of the paper by means of "Durofix" adhesive, and the adhesive wax was removed.

The problem of ascertaining the exact point at which slipping occurred was solved by driving a pin into the tilting platform and bending its upper extremity horizontally so as to cover a line drawn on the reverse side of the frame, (shown by "A" in Fig. 2). The angle of slip was determined fifty times in each direction alternately; the coefficient of friction was taken as the tangent of the angle of slip, and the results were calculated as the difference between the coefficients of friction in the two directions expressed as a percentage of the coefficient of friction with the scales favouring motion.

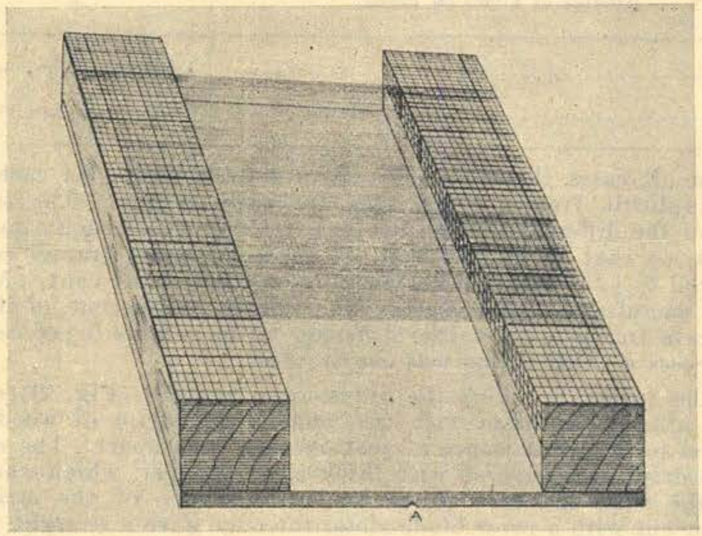


Fig. 2.—The frame on which 200 fibres were mounted for determining the coefficient of friction of the fibres.

The angle of slip in either direction decreased with increasing load on the fibres, a result in agreement with the observations of Speakman and Stott (1931), who found, however, that the percentage difference in friction was independent of the load. Table 2 gives the results of loading the frames used in the present investigation.

TABLE 2.

*The percentage difference in friction obtained on three samples by using differently weighted frames.*

| Load. | Sample. | | |
|---|---|---|---|
| | 1. | 2. | 3. |
| 20 gm. | 57·5 | 24·4 | 55·0 |
| 25 gm. | 55·4 | 24·0 | 57·0 |
| 30 gm. | 54·0 | 23·3 | 58·1 |
| 35 gm. | 51·0 | 23·4 | 52·5 |
| 40 gm. | 47·4 | 21·8 | 51·7 |

The tendency for the percentage difference in friction to be reduced as the load on the frame is increased, is apparent. The effect could not be attributed to a reduction in friction with usage, since the readings were taken in succession with increasing loads on the frame, the order being repeated until the required number of observations had been obtained. The effect was, however, considered to be of little importance for comparative purposes, consequently all the results were obtained without loading the frames. The weights of all the frames used lay between 19·0 and 19·5 gm.

For the determination of the fineness of the fibres, a glass slide was placed beneath the fibres and the ends of the fibres were secured by shellac to the edges of the slide. "Euparal" mounting medium was applied and a cover slip pressed down. On cutting the ends of the fibres adhering to the frame, the fibres were left parallel on the slide, being held in position by the shellac. The thickness of the fibres was measured at three points, corresponding to the root, middle and tip of the fibres. At the same time any fibre which had been mounted in the wrong direction could be detected, but such cases were rarely found.

All determinations were carried out in a constant humidity chamber, maintained at 70 per cent, relative humidity at 70° F. temperature. (The relative humidity of this humidity chamber has since been altered to 65 per cent. to conform to the standard practice, and a test on twelve samples showed that the percentage difference in friction obtained at 65 per cent. relative humidity, was 6·5 per cent. less than that obtained at 70 per cent. relative humidity. The necessity for performing the tests under controlled conditions is thus obvious).

## Experimental Results.

### *Fine and Coarse Fibres within the Staple.*

Bosman, Waterson and Van Wyk (1940), found that the fine fibres of a staple had a higher tensile strength than the coarse fibres, and it was considered probable that the fine and coarse fibres were produced respectively from the "primary" and "secondary" follicles, as shown by Carter (1939). The same procedure was followed in order to investigate possible differences between the scaliness of the fine and coarse fibres within a staple.

The fibres of a staple taken from each of three samples were separated into three groups according to fineness as judged by eye, and the scaliness of the groups determined separately. The results are given in Table 3.

The results show that the difference in the scaliness between the various thicknesses of fibres within the same staple is insignificant. It is concluded that the value obtained for a selection from a sample is characteristic of the sample as a whole. This does not, however, mean that no variability exists within a sample, since two frames, each with 200 fibres, were considered necessary to obtain a reliable estimate of the scaliness of the sample.

TABLE 3.

*Showing the difference in friction obtained from fine, medium and coarse fibres within the same staple (on three different staples).*

| Sample. | Fine. | | Medium. | | Coarse. | |
|---|---|---|---|---|---|---|
| | Percentage Difference in Friction. | Fibre Fineness ($\mu$). | Percentage Difference in Friction. | Fibre Fineness ($\mu$). | Percentage Difference in Friction. | Fibre Fineness ($\mu$). |
| 1.......... | 55·8 | 16·3 | 48·4 | 17·5 | 49·8 | 18·4 |
| 2.......... | 49·9 | 19·8 | 53·7 | 21·8 | 53·8 | 24·8 |
| 3.......... | 32·4 | 23·7 | 35·2 | 26·1 | 36·8 | 30·6 |
| MEAN.... | 46·0 | 19·9 | 45·8 | 21·8 | 46·8 | 24·6 |

INFLUENCE OF AGE OF SHEEP ON SCALINESS.

The influence of the age of the sheep on scaliness was determined on three sheep that had not been shorn for four, five and six years respectively. The sheep were given a constant feed, and it had been shown by Bosman (1937), that the fineness of the wool and the weight of wool grown on a unit area of the skin remained constant over these periods. For the determination, a small staple was selected from each sheep and cut into equal lengths, each portion coinciding with a year's growth. The results are summarised in Table 4.

TABLE 4.

| Period of Growth. | Sheep No. 1. | | Sheep No. 2. | | Sheep No. 3. | |
|---|---|---|---|---|---|---|
| | Percentage Difference in Friction. | Fibre Fineness ($\mu$). | Percentage Difference in Friction. | Fibre Fineness ($\mu$). | Percentage Difference in Friction. | Fibre Fineness ($\mu$). |
| First year.. | 87 | 18·7 | 60 | 21·4 | 96 | 18·3 |
| Second year | 76 | 17·6 | 79 | 23·1 | 95 | 18·9 |
| Third year.. | 76 | 17·5 | 66 | 22·6 | 89 | 17·8 |
| Fourth year | 65 | 18·1 | 57 | 21·8 | 85 | 17·6 |
| Fifth year.. | — | — | 55 | 22·1 | 77 | 19·1 |
| Sixth year.. | — | — | — | — | 68 | 19·1 |

The variations in fineness did not exceed sampling errors but a definite decrease in percentage difference in friction with age occurred, the decrease from the second to the fourth year varying from 10 per cent. to 22 per cent. In estimating the scaliness of the wool grown by any sheep, therefore, the age of the sheep should be taken into account.

## The Scaliness of a Range of Samples of South African Wool.

A series of representative wool samples from different wool-growing areas of the Union was selected and their scaliness determined. The results obtained on 87 samples are given in Table 5.

TABLE 5.

*The coefficients of friction and mean fineness of 87 samples of South African Merino wool from different wool-growing areas.*

| Sample No. | Percentage Difference in Coefficient of Friction. | Mean Fibre Fineness of Fibres selected ($\mu$). |
|---|---|---|
| 31 | 34 | 26·8 |
| 35 | 34 | 23·2 |
| 30 | 39 | 24·2 |
| 77 | 39 | 22·4 |
| 33 | 41 | 25·1 |
| 28 | 42 | 27·3 |
| 37 | 43 | 24·3 |
| 8 | 44 | 19·9 |
| 25 | 45 | 23·0 |
| 86 | 45 | 21·3 |
| 87 | 47 | 22·2 |
| 82 | 47 | 22·9 |
| 73 | 47 | 24·1 |
| 27 | 48 | 24·4 |
| 119 | 48 | 18·8 |
| 14 | 49 | 18·6 |
| 76 | 50 | 25·0 |
| 75 | 51 | 26·6 |
| 57 | 51 | 22·6 |
| 90 | 51 | 20·8 |
| 79 | 53 | 25·4 |
| 29 | 53 | 27·0 |
| 51 | 55 | 19·2 |
| 81 | 55 | 24·7 |
| 74 | 56 | 21·6 |
| 88 | 57 | 25·0 |
| 34 | 58 | 20·0 |
| 6 | 58 | 14·8 |
| 122 | 58 | 19·8 |
| 124 | 58 | 21·7 |
| 26 | 59 | 24·4 |
| 83 | 60 | 24·9 |
| 3 | 61 | 17·9 |
| 113 | 61 | 23·1 |
| 78 | 61 | 24·6 |
| 36 | 61 | 22·6 |
| 4 | 62 | 19·7 |
| 120 | 62 | 23·5 |
| 23 | 63 | 22·2 |
| 10 | 64 | 21·9 |
| 115 | 65 | 20·5 |
| 111 | 65 | 19·5 |
| 71 | 65 | 26·6 |
| 58 | 65 | 22·3 |
| 46 | 65 | 22·0 |
| 32 | 65 | 21·1 |
| 114 | 66 | 17·9 |

TABLE 5. (*continued.*)

| Sample No. | Percentage Difference in Coefficient of Friction. | Mean Fibre Fineness of Fibres selected ($\mu$). |
|---|---|---|
| 85 | 67 | 24·5 |
| 5 | 69 | 19·8 |
| 7 | 69 | 24·4 |
| 49 | 69 | 21·4 |
| 123 | 69 | 20·4 |
| 2 | 70 | 20·2 |
| 54 | 70 | 22·5 |
| 99 | 70 | 25·5 |
| 1 | 72 | 20·9 |
| 55 | 72 | 21·9 |
| 121 | 73 | 19·3 |
| 62 | 74 | 27·2 |
| 19 | 75 | 21·2 |
| 112 | 75 | 17·4 |
| 11 | 76 | 21·4 |
| 24 | 76 | 18 0 |
| 48 | 76 | 19·0 |
| 52 | 76 | 19·9 |
| 84 | 76 | 23·7 |
| 100 | 76 | 19·3 |
| 116 | 76 | 22·5 |
| 47 | 77 | 18·2 |
| 118 | 77 | 21·0 |
| 9 | 78 | 23·0 |
| 144 | 78 | 20·4 |
| 21 | 79 | 23·6 |
| 40 | 82 | 17·4 |
| 22 | 83 | 22·9 |
| 80 | 83 | 22·0 |
| 110 | 83 | 21·1 |
| 18 | 85 | 18·5 |
| 53 | 86 | 19·2 |
| 20 | 87 | 23·9 |
| 98 | 87 | 20·3 |
| 92 | 95 | 21·8 |
| 12 | 99 | 21·3 |
| 13 | 103 | 16·4 |
| 16 | 108 | 19·6 |
| 17 | 117 | 20·9 |
| 15 | 128 | 22·3 |

The percentage difference in coefficients of friction, as averages obtained from the frames, ranged from 34 per cent. to 128 per cent. and are given in the table in increasing order from the lowest to the highest values. The fibre finenesses are given as averages of the fibres from the different frames of the sample.

These finenesses appear to be coarser than the fibres composing the whole sample, their average fineness being $22\mu$, or a 60's quality number. The mean fineness of the fibres chosen is coarser than the mean of the South African clip which has been classed as a 66's quality number (Bosman 1937.)

It has, however, been shown above that the coarse, medium and fine fibres within the staple do not differ significantly in their percentage difference in friction, and the values of percentage differences in friction given in Table V, thus apply to the whole staple.

A summary of the results of Table 5 is given in Table 6.

TABLE 6.

*The frequencies of the percentage difference in friction of the samples.*

| Class Interval. | Frequency. |
|---|---|
| 30– 40 percent | 4 |
| 40– 50 ,, | 13 |
| 50– 60 ,, | 15 |
| 60– 70 ,, | 20 |
| 70– 80 ,, | 21 |
| 80– 90 ,, | 8 |
| 90–100 ,, | 2 |
| 100–110 ,, | 2 |
| 110–120 ,, | 1 |
| 120–130 ,, | 1 |
| | 87 |

At 70 per cent. relative humidity and 70° F. the statistical constants are as follows:—

| | Per cent. |
|---|---|
| Mean percentage difference in friction ... ... | $=66 \cdot 0$ |
| Standard Deviation ... ... ... ... ... ... ... ... | $=\pm 17 \cdot 6$ |
| Coefficient of Variability ... ... ... ... ... ... | $=\pm 26 \cdot 6$ |
| Standard Error of Mean ... ... ... ... ... ... | $=\pm 1 \cdot 89$ |
| (At 65 per cent. relative humidity and 70° F. the mean is ... ... ... ... ... ... ... | $59 \cdot 5$) |

The coefficient of correlation between percentage difference in friction and fibre fineness was found to be $-0 \cdot 3428 \pm 0 \cdot 1019$, a significant value, showing a tendency for the percentage difference in friction to increase as the wool becomes finer. This result is in agreement with that found by Speakman and Stott (1931), who stated that "up to 80's quality there is a well-defined rise of scaliness with quality, and the result is in keeping with the general trade impression that the milling efficiency of merino wools improves with quality".

When the fineness of the sample as a whole is considered and not merely that of the fibres used in the determination, the correlation between percentage difference in friction and fineness is even higher, viz., $-0 \cdot 4383$. This result confirms the view expressed in regard to the difference between fine and coarse fibres, viz., that the value obtained appears to be characteristic of the sample as a whole, and not of the fibres selected for a determination.

The correlation between the scaliness and the number of crimps per inch was $+0 \cdot 1012$, an insignificant value. Crimping, therefore, gives no indication of the scaliness of a sample.

The regression coefficient of percentage difference in friction on fibre fineness is $-2 \cdot 30 \pm 0 \cdot 682$, showing that on the average the percentage difference in friction decreases by 2·3 per cent. for an increase in fibre fineness of 1 micron.

By taking into account the regression coefficient and the fibre fineness of the chosen samples, it is possible to calculate average values for the wool standards of South Africa as defined by Duerden (1929). Such values serve as a guide in assessing the average scaliness of South African types of wool and are given in Table 7.

TABLE 7.

| Quality Number. | Mean Percentage Difference in Friction. |
|---|---|
| 80's | 76 |
| 70's | 74 |
| 66's | 72 |
| 64's | 69 |
| 60's | 66 |
| 58's | 61 |
| 56's | 54 |

These values are useful since they show the marked differences in the different types of South African wool. The values can also be used for determining normality or abnormality of any particular wool.

## WOOL GROWN BY RAMS AND EWES

Table 8 gives a comparison between the wool grown by rams and that grown by ewes and wethers.

TABLE 8.

| | Mean Percentage Difference in Friction. | Mean Fibre Fineness. |
|---|---|---|
| Rams | 54·8% | 24·3$\mu$ |
| Ewes amd wethers | 70·4% | 20·8$\mu$ |
| Difference | $-15 \cdot 6 \pm 3 \cdot 73\%$ | $+3 \cdot 5 \pm 0 \cdot 490\mu$ |

The wools from the rams gave a significantly lower value for percentage difference in friction, and a significantly higher value for fibre fineness, a result which is in keeping with the observation made above that the scaliness increases with increasing fineness of fibre. The lower value for percentage difference in friction obtained for rams' wool can therefore be expected from its coarser fibre.

## Summary and Conclusions.

A study of the scaliness of South African Merino wool samples showed that the percentage differences in friction between the two directions varied from 30 per cent. to 130 per cent. At 70 per cent. relative humidity and 70° F. the mean was 66·0 per cent., the standard deviation 17·6 per cent. and the coefficient of variability 26·6 per cent.

No difference in scaliness between different fineness groups within a staple was obtained. Between samples, however, a significant negative correlation of −0·3428 between percentage difference in friction and fibre fineness was obtained. The value obtained for a sample was concluded to be characteristic of the sample, and not of any particular group of fibres used for the determination.

The regression coefficient of percentage difference in friction on fibre fineness was −2·30, a significant value, showing that on the average the percentage difference in friction decreases by 2·30 per cent. for every micron increase in the fibre fineness of the sample.

The values for coefficient of friction for the different quality numbers of South African Merino wool are given.

Wool from rams gave a lower value for scaliness concordant with a coarser wool.

The scaliness of the wool grown by three sheep on constant feed decreased with age, though no corresponding changes in fibre fineness occurred.

## Acknowledgement.

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