WOOL STUDIES WITH RAMBOUILLET SHEEP

by

Fred S.Hultz

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A Thesis Submitted to the Graduate Faculty

for the Degree of

DOCTOR OF PHILOSOPHY

Animal Husbandry

Signature was redacted for privacy.

In charge of Major Work

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Head of Major Department

Signature was redacted for privacy.

Dean of Graduate College

Iowa State College

1 9 2 7

Iowa State College of Agriculture

And Mechanic Arts

Doctoral Thesis No. 56

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By Fred S. Hultz

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Introduction

The Rambouillet breed of sheep is the most popular as a source of supply for rams used on the great western sheep breeding ranges. It is known that at the present time, a high percentage of all purebred Rambouillets are bred west of the Missouri River. A few laboratory studies have been conducted at the Texas and U. S. Sheep Experiment Stations pertaining to fleece weights and scouring characteristics of fleeces from this breed (13). No studies which deal with the relationship between such fleece characteristics as staple length, fiber length, crimp, fineness, density, scoured content, and uniformity of fleece, have been found in the literature. The experiments with Rambouillets reported here were undertaken in order to throw light upon:

a. How much emphasis a competent judge places upon each of the fleece characteristics usually accepted as important in the selection of Rambouillet breeding stock, and

b. What represents a high standard of excellence in Rambouillet sheep when mechanical measurements are used as a basis for differentiation.

The selection of a judge for making the rankings was based upon reputation as a successful judge and breeder of Rambouillets, scope of Rambouillet sales at home and abroad, and the extent of show yard winnings at the major exhibitions.

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Besides the main objectives it was hoped that some information might be contributed which would add to our knowledge of fiber measurements, crimps in wool fibers, variation in density of fleece, and fleece uniformity.

Measurements of diameter of fine wool fibers are recorded in textbooks (14). It appears that these records originate from measurements taken several decades ago and that recent literature contains meager information on the subject. In teaching sheep judging, we have, for example, for years assumed that the number of crimps in a wool fiber determines to a considerable degree the fineness of that fiber, but laboratory evidence confirming this assumption is very limited. The degree of variation in fineness, in density of fiber, and in crimps, as found on various body localities, is quite noticeable in some Rambouillets. This variation is reflected in the price paid for the wool when it appears on the market. The parts of the fleece containing coarser fibers, such as the breech, must be sorted out, or the whole fleece may go into a lower grade. The questions arise, "Do the better purebred Rambouillet sheep show more or less variation in these characteristics? Has the breeder been successful in eliminating variation and substituting uniformity?"

The judge of Rambouillets may attempt to determine the degrees of fineness, density, staple length, crimp, yield of clean wool, uniformity of fiber throughout the body, and fiber length when he examines the fleece on a sheep. The judge's final aim is toward the greatest amount of clean wool of the highest quality. All of the factors enumerated above may be associated with weight and quality of fleece. It should be instructive to know which of these factors receives the greatest emphasis in judgement.

The Wyoming Experiment Station has studied wool in the field and in the laboratory continuously since 1907. These studies, some of them as yet unpublished, form a background for the experiments reported in this paper.

Methods

The services of Mr. J. H. King, of King Brothers Company, Laramie, Wyoming, were secured for the purpose of ranking both the sheep and the fleeces on the sheep's backs. Each sheep was ranked on fleece alone as being first, second, third, or fourth class. Each sheep was then ranked on body conformation (including "type" but not fleece) as being first, second, third, or fourth class. Mr. King was not informed as to what characteristics would be studied in the laboratory, nor was the ranking discussed by those who were present when he ranked the sheep. The forty-two head on which his judgment was obtained consisted of sheep owned by King Brothers Company and by the University of Wyoming. Many of the King sheep had show records, including:

Champion, 1st, 2d, 3d, 4th, and 5th, International Livestock Exposition.

Champion, 1st, 2d, 3d, 4th, and 5th, Kansas City Royal.

Champion, 1st, 2d, and 3d, Wyoming and Colorado State Fairs.

Reserve Champion, 1st, and 2d, Ogden Winter Stock Show.

Since several of the King sheep sampled were lambs and had not been shown and since none of the University sheep had been shown, no attempt was made to correlate show yard winnings with laboratory studies. These winnings are, however, evidence of the extreme high quality of the sheep studied, for

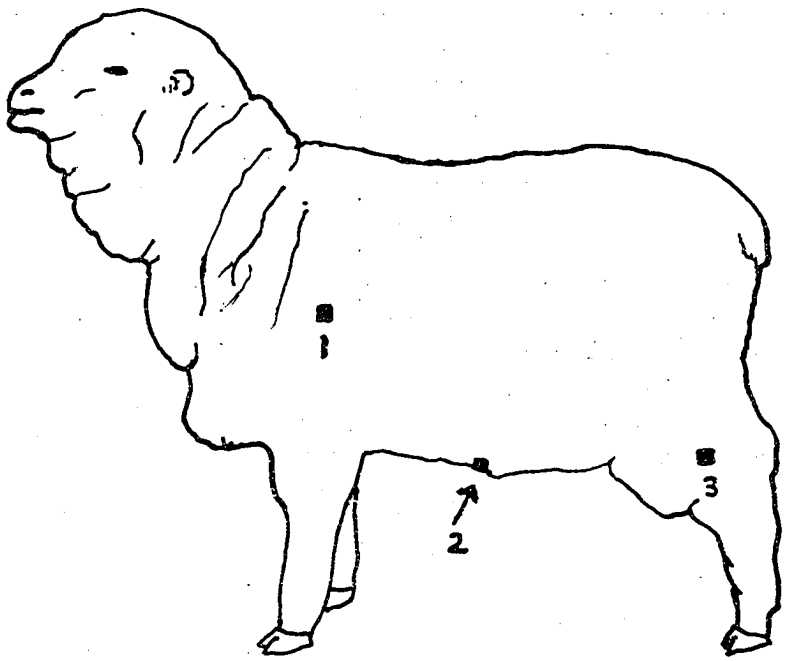

DIAGRAM SHOWING LOCATION OF WOOL SAMPLES.
1 Shoulder. 2 Belly. 3 Thigh.

the sheep that were not shown ranked as high in many instances as those which had been shown.

As each sheep was ranked, three samples of wool were taken, one each from the middle of the shoulder, bottom of the thigh, and mid-belly. These samples were taken from a one-half inch square of skin area measured with calipers, and were clipped close to the skin. Special care was observed to secure the samples from the same relative location on each sheep. Each sample was placed in a separate envelope, on which was noted:

a. The flock number, sex, and age of sheep.

b. The rankings of fleece and sheep made by Mr. King.

c. The location from which sample was taken.

d. The growth of fleece (in months).

e. The sheep's show record.

The laboratory studies were conducted with the use of technique which is given in detail below. These methods were developed by the Wool Department of the Wyoming Experiment Station. The analysis of one sample was completely run before another was begun.

Staple Length - Preparation of the Samples. Each sample was measured for staple length before scouring. A steel rule calibrated in tenths of inches was used for this purpose. Later each measurement for staple length was corrected to a basis of twelve months' growth.

Each sample was scoured in a stock soap solution, then dried in ordinary room temperature. Care was taken during scouring to keep the wool fibers parallel. The tip ends of fibers protruding from the general bulk of the sample were trimmed off after drying so the operator might not be inclined

to select these fibers first during the laboratory operations. The sample was then spread flat, the two outer edges placed together, the sample partially rolled toward the edges and placed in a U-shaped cardboard fold held firm with a paper clip.

Fiber Length and Crimps. Five fibers were pulled from the scoured sample, one at a time, and measured for length when stretched just sufficiently to straighten them. These five measurements were used for an average fiber length and were corrected to a basis of twelve months' growth.

Each of the above fibers was held against a background so that the number of crimps in a one-half inch section might be counted at three places on each fiber. An average of the three counts for each of the five fibers was used to describe the number of crimps per one-half inch.

Diameter of Fiber. A Brown and Sharpe machinist's caliper calibrated in ten-thousandths of an inch was used for measuring the diameter of the fibers. The fibers were taken from the two edges of the sample in such a manner as to eliminate any tendency on the part of the operator to select the larger fibers. Since the method of pulling and holding each fiber was always the same, the measurement was taken at nearly the same point on each fiber—about midway between tip and base. A Veeder counter was used, which furnished a constant tally of the number of fibers that had been counted. One hundred fibers were measured from each sample and the measurements were recorded in the form of a frequency distribution.

Density. In order to calculate the number of fibers in the one-half inch square area represented by the sample, the one hundred fibers used in measuring fineness of fiber were utilized. The formula used for the calcu-

lated density was:

$$\text{Calculated density} = \frac{\text{Wt. of sample including the 100 fibers}}{\text{Wt. of the 100 fibers}} \times 100$$

The wool samples were placed in a glass flask for weighing and were weighed in a room especially constructed to provide constant conditions of temperature and humidity. Since the large and small portions of the samples were weighed in the same flask at the same time, the same moisture conditions existed for both. Checks against the calculated density by actual count in the Wyoming wool laboratory show a small error--six-tenths of one per cent (17).

Results

Table I shows the complete results obtained by the laboratory analysis. It is included in this publication so that the tables showing averages which follow may be more comprehensible. Since each type of measurement will be discussed separately, Table I will serve as a reference table only.

Table I

Sex	Sheep No.	Rank of fleece	Rank of sheep	Location of sample	Adjusted to 12 months' growth: staple length (inches)	Adjusted to 12 months' growth: fiber length (inches)	Crimps per inch	Ave. diam. in 10-thousandths of an inch	Density ½ in. square
R	8921	I	II	Shoulder	2.05	3.42	15.6	6.01	9794
				Belly	2.22	3.85	16.4	6.25	7577
				Thigh	1.80	2.82	14.8	6.32	8886
R	222	I	I	Shoulder	2.82	3.50	17.2	5.78	10560
				Belly	1.88	3.17	16.4	6.32	7650
				Thigh	2.22	2.57	12.4	7.07	4750

Table I (continued)

E	8995	I	II	Shoulder	2.31	3.36	14.4	5.43	16678
				Belly	1.84	2.95	14.0	6.03	5502
				Thigh	1.92	2.95	14.0	5.40	10794
R	278	I	II	Shoulder	2.40	2.84	12.0	6.13	10800
				Belly	2.10	5.24	13.6	6.30	5120
				Thigh	2.40	3.00	13.6	5.91	5931
R	8102	II	II	Shoulder	2.57	3.08	13.6	6.13	8080
				Belly	2.48	2.82	15.6	6.69	9840
				Thigh	2.05	3.17	13.6	7.23	5662
R	21	II	I	Shoulder	2.54	3.90	13.6	5.53	8103
				Belly	1.94	3.74	15.2	5.75	3160
				Thigh	2.40	3.14	14.8	5.37	5615
E	87	II	III	Shoulder	2.84	3.74	14.0	5.59	6169
				Belly	2.24	3.74	13.6	5.78	3971
				Thigh	2.40	3.74	14.0	5.96	7200
E	9118	II	I	Shoulder	2.64	3.12	14.4	5.79	9376
				Belly	2.08	2.80	13.6	5.98	8336
				Thigh	1.99	2.88	12.8	6.50	7738
E	8961	II	II	Shoulder	2.64	4.08	14.8	5.61	9702
				Belly	1.92	2.71	10.8	6.00	5568
				Thigh	2.08	2.88	14.4	5.79	6032
E	280	II	III	Shoulder	2.88	3.19	16.0	5.81	9885
				Belly	2.08	4.08	14.4	6.65	5668
				Thigh	2.56	4.48	12.4	6.43	4545
E	61	II	II	Shoulder	2.40	3.00	14.0	6.31	5425
				Belly	2.24	3.30	13.6	7.22	3580
				Thigh	2.24	3.60	11.6	7.64	4031
E	446	II	II	Shoulder	2.94	4.46	15.6	5.06	9392
				Belly	2.06	3.16	12.4	5.67	4931
				Thigh	2.51	4.80	12.0	6.35	5712
E	379	II	II	Shoulder	2.94	4.36	15.2	4.46	5930
				Belly	1.63	3.16	14.0	5.28	3894
				Thigh	2.28	3.80	16.0	6.11	5997
E	104	II	II	Shoulder	2.54	3.44	14.0	5-91	5175
				Belly	2.54	4.20	13.2	6.86	4452
				Thigh	2.84	3.60	11.6	6.98	5388
E	356	II	II	Shoulder	2.51	3.59	16.0	4.54	7358
				Belly	2.17	3.37	15.6	6.71	5371
				Thigh	2.62	3.80	13.6	6.81	7380
E	447	II	II	Shoulder	2.83	3.80	14.8	5.65	12717
				Belly	2.06	3.92	13.2	5.83	4734
				Thigh	2.40	4.25	11.6	6.53	6546
E	385	II	III	Shoulder	2.62	3.59	13.6	6.22	9914
				Belly	1.96	3.37	14.8	7.25	5028
				Thigh	2.72	5.23	10.8	6.60	5367

Table I (continued)

E	260	III	II	Shoulder	2.16	2.88	13.6	5.77	10604
				Belly	1.99	3.43	14.8	6.91	5311
				Thigh	2.16	3.28	13.2	6.64	6264
R	2336	III	II	Shoulder	2.40	3.90	10.6	7.15	8165
				Belly	2.10	3.44	12.4	6.34	4966
				Thigh	2.54	4.34	12.8	6.54	5248
R	13	III	II	Shoulder	2.70	3.30	14.8	6.22	5417
				Belly	2.70	3.14	12.8	6.17	3977
				Thigh	2.84	3.60	12.4	6.65	4203
R	283	III	II	Shoulder	2.54	3.60	12.4	5.70	5536
				Belly	3.00	3.90	13.6	5.61	4466
				Thigh	1.80	2.24	13.6	5.86	5323
R	281	III	III	Shoulder	1.94	2.70	12.0	6.78	4510
				Belly	1.34	2.40	10.4	8.41	3741
				Thigh	1.64	2.54	10.0	8.47	3940
R	97	III	IV	Shoulder	2.54	3.00	12.0	6.33	8878
				Belly	1.80	3.44	14.0	6.94	3147
				Thigh	2.70	4.54	12.0	7.30	3322
R	119	III	IV	Shoulder	2.54	3.90	13.2	6.18	6993
				Belly	2.24	4.04	14.4	6.40	3102
				Thigh	2.54	3.60	12.4	6.13	7415
R	150	III	II	Shoulder	2.10	2.84	14.4	6.24	4262
				Belly	1.94	3.60	14.4	6.51	4010
				Thigh	2.10	2.40	14.0	6.48	4122
E	92	III	IV	Shoulder	2.40	4.04	13.6	6.92	10174
				Belly	2.70	3.60	10.8	7.02	7875
				Thigh	2.70	4.50	12.0	8.39	4874
E	19	III	II	Shoulder	2.54	3.44	15.2	7.03	7479
				Belly	2.40	3.90	15.6	7.12	3608
				Thigh	2.40	3.90	13.6	7.91	4545
E	44	III	III	Shoulder	2.54	3.44	12.8	6.79	5981
				Belly	2.10	3.90	14.4	6.62	3239
				Thigh	2.40	3.60	13.6	7.62	5595
E	18	III	III	Shoulder	2.70	3.60	14.0	6.75	4877
				Belly	2.40	4.04	14.8	6.33	5137
				Thigh	2.40	3.44	14.8	6.65	4653
E	445	III	III	Shoulder	2.83	4.03	14.8	5.26	9772
				Belly	2.40	3.70	14.0	6.10	6334
				Thigh	2.28	3.48	9.6	6.28	5482
E	116	III	II	Shoulder	2.62	3.48	12.8	5.75	8400
				Belly	2.17	3.26	12.8	6.79	6874
				Thigh	2.17	3.37	11.6	6.41	5820
E	235	III	III	Shoulder	2.62	3.80	14.8	6.07	8929
				Belly	1.85	3.48	12.4	6.80	3877
				Thigh	2.17	3.80	13.2	7.76	4007

Table I (continued)

R	9043	III	I	Shoulder	3.43	4.48	14.0	6.65	6575
				Belly	2.80	4.08	12.8	7.11	6756
				Thigh	2.80	4.08	15.2	6.79	7108
E	449	III	II	Shoulder	2.62	4.14	13.6	5.48	5677
				Belly	2.06	3.26	10.4	6.59	5765
				Thigh	2.28	3.37	13.2	5.97	3981
E	448	III	I	Shoulder	2.51	4.46	14.4	4.97	6132
				Belly	2.17	3.59	12.8	6.03	4165
				Thigh	2.06	3.59	12.4	5.67	4283
R	29	IV	IV	Shoulder	2.40	2.84	15.2	6.46	4529
				Belly	2.24	3.14	12.0	6.24	3900
				Thigh	2.40	3.44	14.4	7.56	4112
E	217	IV	IV	Shoulder	2.24	3.44	12.8	6.20	4480
				Belly	1.94	3.30	14.4	6.84	2563
				Thigh	2.70	3.74	14.0	8.48	5516
E	508	IV	II	Shoulder	2.51	3.80	14.0	6.52	4823
				Belly	1.74	3.59	12.4	6.63	3135
				Thigh	2.62	3.80	10.8	8.69	5239
E	454	IV	III	Shoulder	2.94	4.14	16.0	5.54	6384
				Belly	2.06	3.59	12.0	6.56	4610
				Thigh	2.72	4.46	10.8	6.45	6429
R	X	IV	IV	Shoulder	2.40	3.60	13.2	5.24	6436
				Belly	2.16	2.88	13.6	6.79	5020
				Thigh	2.16	2.88	13.2	7.12	3662
R	269	IV	III	Shoulder	3.60	4.56	14.0	6.48	6008
				Belly	2.88	4.32	9.8	6.26	3709
				Thigh	3.12	4.56	12.4	6.89	8676
R	Z	IV	IV	Shoulder	2.76	3.36	14.0	5.09	5179
				Belly	2.64	3.84	12.8	5.87	5828
				Thigh	2.28	3.72	12.0	7.52	4134

Staple Length. As stated above, all measurements of staple length were corrected to twelve months' growth for purposes of comparison and the following discussion is upon that basis.

The shoulder samples showed a variation of 1.9 inches to 3.5 inches in length of staple, the belly samples of 1.3 inches to 3.0 inches, and the thigh samples of 1.6 to 3.1 inches.

Table II gives an average of the staple length measurements grouped according to ranking.

Table II

Average Staple Length in Inches

Fleece Rank	No. of Sheep	Shoulders	Bellies	Thighs	Average
I	4	2.39	2.01	2.08	2.16
II	13	2.68	2.10	2.39	2.39
III	16	2.54	2.23	2.33	2.36
IV	7	2.69	2.23	2.57	2.49

There is a small correlation between staple length and rank, $(.233 \pm .084)$, but this may be due to the fact that the difference in staple length between ranks is small. The widest average difference in length between samples from any one body locality is less than half an inch and occurs in the thigh sample averages. Longer staple will result in greater weight and more financial return per fleece, other fleece characteristics being equal. The reason differences in staple length are not given greater consideration by the judge here may be because the minimum lengths represented by the measurements were sufficient so that no particular class was penalized for being too short-stapled, and the maximum lengths were not sufficiently longer to cause the judge to offer much reward to a particular class for extra length.

Fiber Length. The same individual sheep that showed the longest staple had the longest fiber. The shortest staple produced the shortest fiber. Since the fiber measurement was recorded with the fiber stretched sufficiently to remove the crimp, this indicates that in removing the crimp

a fiber stretches in proportion to its length in the staple. There are a few exceptions to the above, but a comparison of average staple lengths with average fiber lengths for all the sheep in each rank (Tables II and III) indicates this tendency. Figure I presents further evidence of the positive correlation between fiber length and staple length.

Table III

Average Fiber Length in Inches

Fleece Rank	No. of Sheep	Shoulders	Bellies	Thighs	Average
I	4	3.28	3.80	2.83	3.30
II	15	3.64	3.41	3.79	3.61
III	18	3.61	3.56	3.52	3.53
IV	7	3.67	3.52	3.80	3.66

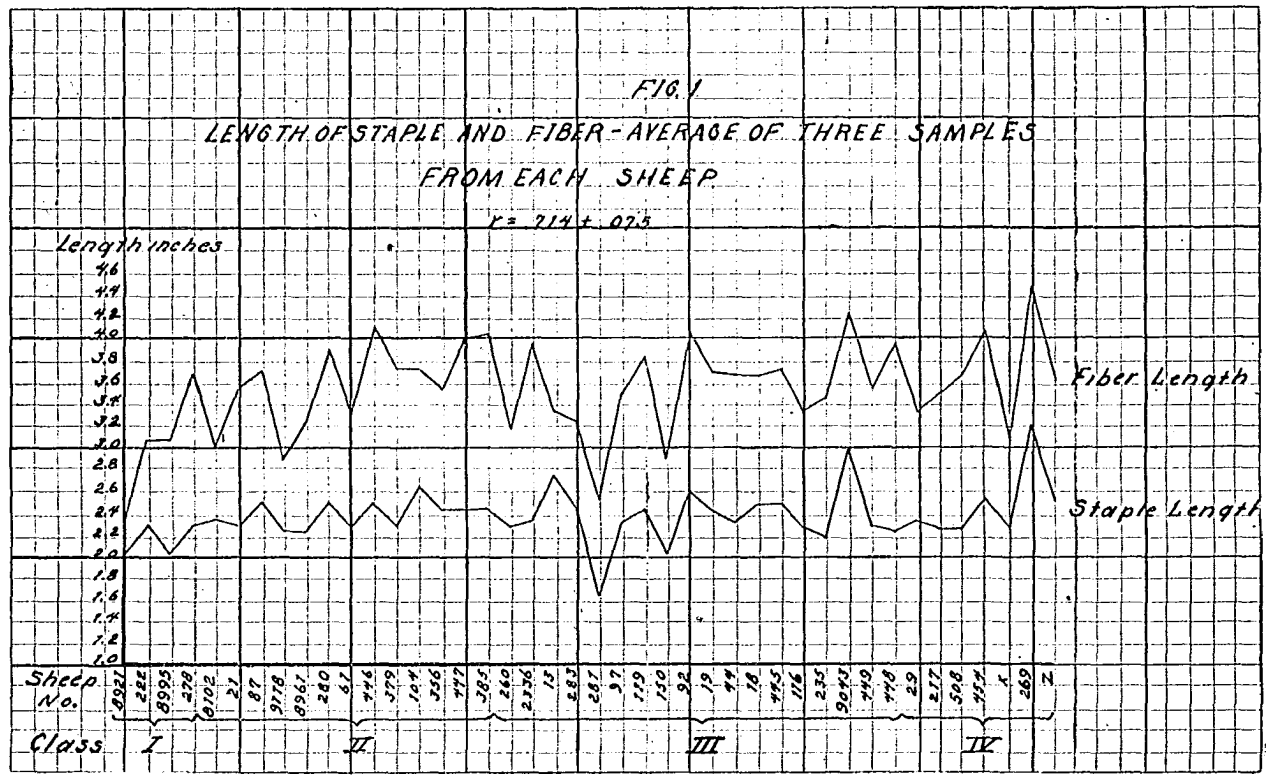
FIG. 1
LENGTH OF STAPLE AND FIBER - AVERAGE OF THREE SAMPLES FROM EACH SHEEP
r = .714 ± .075
Length inches
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
Fiber Length
Staple Length
Sheep No.
8921 222 8995 278 8702 21 87 9218 8961 280 81 446 379 104 356 447 385 260 2336 13 283 281 37 129 130 92 19 44 18 445 116 235 9044 249 448 29 277 568 454 x 269 z
Class I II III IV

Diameter of Fiber. Table IV shows an average diameter of wool fibers for each rank of the sheep in this experiment.

Table IV

Average Diameter of Fibers
(in ten-thousandths of an inch)

Fleece Rank	No. of Sheep	Shoulders	Bellies	Thighs	Average
I	4	5.83	6.22	6.17	6.07
II	13	5.58	6.27	6.48	6.11
III	18	6.22	6.65	6.86	6.57
IV	7	6.21	6.45	7.52	6.72

It will be noticed that with two exceptions (belly samples, Rank IV, and shoulder samples, Rank II), the fibers average progressively as coarse or more coarse in diameter as the rank is lower. These differences are, however, in every instance less than one ten-thousandth of an inch. For the human eye to distinguish accurately one ten-thousandth of an inch difference in the diameter of wool fibers requires constant practice in handling wool. Diameter may, however, be correlated with some other more easily distinguishable characteristic which will permit of sorting sheep on the basis of diameter of fiber without actually being able to distinguish between such fine measurements.

Another distinction observed between samples when measuring the diameter of fiber was variation in the range of measurement. For example, all of the shoulder fibers measured from sheep No. 13 fell within a range of 5 to 8, inclusive, while those from sheep No. 2336 extended from 5 to 15, inclusive.

The belly fibers varied from a range of 3 to 8, inclusive, for sheep No. Z to a range of 4 to 16, inclusive, for sheep No. 281. The thigh fibers varied from a range of 4 to 8, inclusive, for sheep No. 150 to a range of 3 to 17, inclusive, for sheep No. 446. The examples given above are the maximum and minimum ranges for the samples from each body location.

The standard deviation is used here as a measure of the variability of the samples with respect to diameter of fiber. The standard deviations of the maximum and minimum samples mentioned above are given in Table V.

Table V

Maximum and Minimum Range of Diameter Measurements

Sheep No.	Location of Sample	Range (ten-thousandths of an inch)	Standard Deviation
13	Shoulder	5 - 8	.848
2336	Shoulder	5 - 15	2.017
Z	Belly	3 - 8	.742
281	Belly	4 - 16	2.441
150	Thigh	4 - 8	.943
446	Thigh	3 - 17	2.700

The increasing of the standard deviation as a result of a widened range of fiber diameter is readily apparent.

Table VI gives the standard deviations of the combined samples from all of the sheep in each class.

Table VI

Standard Deviation of Fleece Rank

Fleece Rank	No. of Sheep Included	Standard Deviation of Rank	Coef. of Variation
I	4	1.241	.204
II	13	1.549	.253
III	18	1.543	.235
IV	7	1.764	.264

The standard deviation for rank II is 24.8% and for rank III is 24.3% greater than for rank I, while the standard deviation for rank IV is 42.1% greater than for rank I. From this we may assume that standard deviation is a fairly reliable expression of the difference in range of diameter existing between the samples. A coefficient of variation obtained by dividing the standard deviation by an average for the class might be considered a more desirable measure. The coefficients of variation show the same tendency as the standard deviations, only in a somewhat less degree in the case of class III.

Crimps per Inch. The number of crimps or curls in a given length of of fiber have generally been thought to be greater with finer fibers. The range of crimp and an average number of crimps for each fleece rank and body location are shown in Table VII.

Table VII

Range and Average Number of Crimps per Inch

Fleece Rank	No. of Sheep	Shoulder		Belly		Thigh		Aver. No. of Crimps All Samples
		Range	Aver.	Range	Aver.	Range	Aver.	
I	4	12-17	14.8	13-16	15.1	12-14	13.7	14.5
II	13	13-16	14.6	10-15	13.8	11-16	13.0	13.8
III	18	10-15	13.5	10-15	13.2	9-14	12.6	13.1
IV	7	12-16	14.1	9-14	12.5	10-14	12.4	13.0

Although the range of crimp appears at first inspection to lack definite order, it will be noticed that the greater number of crimps are in the higher rankings and the lesser number of crimps are in the lower rankings. The average crimps per inch for each fleece rank emphasizes the progressive lessening of crimps per inch as the rank becomes lower.

Since the fibers are coarser in the lower ranks and are also less crimped, we would expect to find a negative correlation between diameter of fiber and crimps per inch. The coefficient of correlation between crimps and diameter, using the three samples from each sheep, is $-.321 \pm .081$. Davenport and Ritzman found a correlation of $-.216 \pm .094$ between crimp and diameter in Rambouillets (5).

Density. The density studies show a very definite association between density and rank of fleece. Degree of density is probably more easily recognized by a judge than is diameter of fiber or crimp, but is more difficult for the judge to determine than staple length. It appears from this study

that Mr. King was readily able to determine the density of a fleece and that he placed considerable emphasis upon density in his rankings. An average density of the samples by ranks is given in Table VIII.

Table VIII

Average Calculated Density of the Samples by Fleece Ranks

Fleece Rank	No. of Sheep	Shoulders	Bellies	Thighs	Average
I	4	11,958	6,462	7,590	8,670
II	13	8,248	5,272	5,924	6,481
III	18	7,120	4,797	5,010	5,643
IV	7	5,333	4,491	5,135	4,980

The four sheep represented by rank I have been placed as champions, firsts, and seconds at the International Livestock Exposition and at the Kansas City Royal, in the individual show classes. The average density of fleece for the three samples from the four sheep in rank I was 8,670 fibers for a half inch square, or 34,680 fibers per square inch. Rank I averaged 74% more fibers for a given area than rank IV.

Density is negatively correlated with diameter of fiber ($-.330 \pm .079$). Density is also correlated with crimp ($.255 \pm .083$). It will be recalled that crimp is correlated with diameter of fiber ($-.321 \pm .081$). We would expect these simple correlation coefficients to be of similar magnitude. Purebred Rambouillets of the quality used for this research should all tend to show a considerable degree of density, of fineness and of crimp and therefore a relationship similar to that indicated by the above correlation coefficients.

Uniformity. In the selection of breeding sheep, uniformity of fleece

over different parts of the body may be a factor. Manufacturing processes with wool require uniformity of diameter in the raw product (14). A variable raw product requires a greater amount of sorting, entailing an expense to the manufacturer which is no doubt reflected in the price received by the producer of the wool. Aside from the excellence of the sheep in each wool characteristic, then, we should know how uniform the appearance of each essential characteristic is in the body localities studied.

A table of points (Table IX) has been prepared which includes all of the wool factors studied in this research. A value of 0 has been assigned to the sheep showing the least range for each fleece factor and a value of 10 to the sheep showing the widest range for each factor as measured in this experiment. The inter-grades between 0 and 10 are whole or decimal numbers as required. Table IX is compiled on the assumption that each of the characteristics studied (range of staple length, fiber length, crimp, fineness, and density) carries equal weight as a factor in uniformity. That is, uniformity of staple length is considered equal in importance with uniformity of diameter or any of the other characters.

Table IX

Points Showing Uniformity of Wool

Sheep No.	Rank of Fleece	Range of Staple Length	Range of Fiber Length	Range of Crimp	Range of Diameter	Range of Density	Total Points
8921	I	10.000	4.292	2.500	.516	1.798	18.906
222	I	6.250	3.875	9.167	4.993	5.318	29.603
8995	I	2.579	1.709	0.000	1.337	10.000	15.625
278	I	1.250	10.000	2.500	1.705	4.968	20.423
8102	II	2.969	1.459	3.334	3.424	3.593	14.779
21	II	3.594	3.167	2.500	1.442	3.378	14.081
87	II	3.594	0.000	0.000	2.606	2.725	8.925
9118	II	3.985	1.334	2.500	2.748	1.268	11.835
8961	II	4.532	5.709	7.500	1.269	3.553	22.563
280	II	5.157	5.375	6.667	1.705	3.925	22.829
61	II	.157	2.500	4.167	2.516	1.458	10.798
446	II	5.782	6.834	6.667	7.223	3.852	30.358
379	II	9.141	5.000	5.334	5.819	1.694	24.988
104	II	1.250	3.167	4.167	4.415	.626	13.625
356	II	2.422	1.792	4.167	5.976	1.608	15.965
447	II	4.922	1.875	5.834	5.729	7.077	25.437
385	II	4.844	7.750	7.500	4.437	4.242	28.773
260	III	.235	2.292	2.500	4.785	4.614	14.424
2336	III	2.344	3.750	3.750	4.708	2.697	17.249
13	III	0.000	1.917	4.167	0.000	1.087	7.171
283	III	8.282	6.917	1.667	1.802	.748	19.416
281	III	3.594	1.250	3.334	10.000	.290	18.468
97	III	5.938	5.584	3.334	1.269	5.015	21.140
119	III	1.250	.584	3.334	1.097	3.717	9.982
150	III	.157	5.000	0.000	.436	0.000	5.593
92	III	1.250	3.750	5.000	5.976	4.621	20.591
19	III	0.000	1.917	3.334	6.082	3.312	14.645
44	III	2.344	1.917	2.500	2.305	2.279	11.345
18	III	1.250	2.500	.834	2.838	.212	7.634
445	III	3.204	2.292	10.000	5.301	3.696	24.493
116	III	2.422	.917	1.667	2.088	2.131	9.225
235	III	6.329	1.334	4.167	2.981	4.393	19.204
9043	III	3.829	1.667	1.667	3.694	.257	11.114
449	III	3.282	3.667	5.834	6.322	1.402	20.507
448	III	2.422	3.625	3.334	3.176	1.569	14.126
29	IV	.157	2.500	5.834	4.513	.162	13.166
217	IV	4.844	1.834	2.500	6.382	2.472	18.032
508	IV	5.782	.875	5.834	9.407	1.695	23.593
454	IV	5.782	3.625	10.000	5.158	1.434	25.999
X	IV	.782	3.000	0.000	7.193	2.308	13.283
269	IV	4.532	1.000	7.917	3.094	4.316	20.859
Z	IV	2.657	2.000	3.334	3.672	1.320	12.983

Table IX shows that the most uniform sheep, as determined by this method, was No. 150, which was in rank III. Sheep No. 150 showed the minimum range for crimp and density, a range of less than one-tenth of the maximum for staple length and fineness of fiber, a range half way between the minimum and maximum for length of fiber and total points of 5.593. The second most uniform sheep was No. 13, also in rank III, and the third most uniform was No. 87 from rank II.

An average score for all factors in uniformity of all the sheep in each rank shows:

Rank I 21.389

Rank II 18.842

Rank III 14.795

Rank IV 18.273

This ranking is almost in inverse relationship to the rankings of the fleeces according to their excellence by Mr. King. Mr. King has frequently remarked upon the importance of uniformity of fleecing or evenness of covering. For example, in the National Wool Grower (15) Mr. King is quoted as saying: "Candland's ewe which stood second could have been placed first without criticism, but the finer fiber, crimp, evenness of covering, and feminine type of the Madsen ewe appealed to my judgment." Some of the wool characteristics must be of more importance than others in deciding the evaluation of uniformity. Table X gives an average of the points for each rank and range as shown in Table IX.

Table X

Averages of Ranks from Table IX

Fleece Rank	Range of Staple Length	Range of Fiber Length	Range of Crimp	Range of Diameter	Range of Density	Total
I	5.019	4.969	3.542	2.088	5.521	21.389
II	4.027	3.535	4.487	3.793	2.999	18.842
III	2.674	2.827	3.357	3.603	2.336	14.795
IV	3.219	2.119	5.060	5.060	1.958	18.273

As shown by Table X, the only characteristic with a range value which nearly follows Mr. King's ranking is that of diameter of fiber. The range of diameter in rank IV is two and one-half times as great as in rank I and the intermediate ranks are between ranks I and IV. Here is evidence that range in diameter of fiber is a very important, if not the important, characteristic considered by Mr. King under uniformity in judging Rambouillet fleeces.*

There are reasons why an efficient judge might not place much emphasis on uniformity of staple length, fiber length, or density. The length of staple and fiber are so tampered with in fitting show sheep that a judge

*The method used above for determining range does not take into account relative differences in the basic measurements for each characteristic. There was found to be, however, only a small difference between an average of the ranks for a given factor by the two methods. The above method was therefore selected because of its greater simplicity. The actual average difference in range for fiber diameter by the two methods is shown below.

	Relative	Method Used
Rank I	1.937	2.088
Rank II	3.568	3.793
Rank III	2.738	3.603
Rank IV	5.200	5.060

might attribute differences in length on different body localities to the shepherd's shears rather than to nature's tendency. From the writer's experience in watching Rambouillet judging, it is doubtful if a judge inspects the fleece for density in more than one place. In this research such indications of density as face, leg, and belly covering are considered under type or ranking of the sheep, and the laboratory density studies do not differentiate between different degrees of completeness of covering on the sheep. The judge's ranking and the range of density tend to move in opposite directions, as is shown in Table X. This is further evidence that density as such, disregarding the characteristics implied by covering of wool, is determined by examining the fleece on only one or two body localities. Range in density is of no importance to the manufacturer.

Range of crimp may have been considered important by the judge. Crimp is related to diameter of fiber in the sheep studied here and the range of crimp may have assisted the judge in determining the range of diameter. Combining range of crimp with range of diameter for the four ranks, the point value of the ranks becomes: Rank I, 5.63; Rank II, 8.28; Rank III, 6.96; Rank IV, 10.12. Ranks II and III do not follow in exact order, but they lie between ranks I and IV.

In a further effort to determine which of the ranges of the characteristics studied had the greatest bearing on fleece uniformity, each different characteristic was correlated with fleece rank. The correlation coefficients obtained are small as compared with their probable errors. Four fleece ranks may be too small a number to permit of reliance on these coefficients. The characteristics with their coefficients are:

Range of diameter	.322 ± .138
Range of crimp	.078 ± .153
Range of staple length	-.128 ± .147
Range of fiber length	-.352 ± .135
Range of density	-.420 ± .127

Neither of the positive coefficients is significant in the light of its probable error. From the information in Table IX, combined with that obtained from the above coefficients, it appears that range of diameter may have been the only characteristic examined for variation as a determiner of uniformity of fleece.

Scouring

Because of the practice of oiling Rambouillet show sheep and because it is believed that feed has an effect upon the quantity of oil secreted by the skin, it was thought expedient to confine the scouring studies to the eleven head of sheep owned by the University. These eleven sheep were fed identically, had never been fitted for showing, and were all shorn during the same week, both in 1925 and 1926. When shorn in 1926, a composite sample of each fleece was secured for the scouring test and the weight of the fleece recorded. The results of the test are given in Table XI.

Table XI

Scouring Record - 12 Months' Growth from Eleven Sheep

Sheep No.	Sex	Rank of Fleece	Pounds Shorn	Wt. of Grease Sample (ounces)	Wt. of Clean Sample (ounces)	Per Cent of Clean Wool	Lbs. Clean Wool in Fleece
446	E	II	16.00	13.75	7.00	50.91	8.1454
447	E	II	16.00	9.50	4.75	50.00	8.0000
445	E	III	16.00	8.50	3.75	44.12	7.0587
379	E	II	14.00	10.75	5.00	46.51	6.5116
448	E	III	15.50	9.25	3.75	40.54	6.2838
454	E	IV	12.25	10.25	4.75	46.34	5.6768
356	E	II	12.50	8.50	3.75	44.12	5.5146
449	E	III	11.00	10.50	5.25	50.00	5.5000
116	E	III	13.50	14.50	5.75	39.66	5.3334
385	E	II	14.50	9.50	3.50	36.84	5.3418
235	E	III	15.50	9.50	3.25	34.21	5.3026

The number of sheep used in the scouring test was necessarily small. On the basis of yield of clean wool an average for the ranks was: Rank II, 6.70 pounds; Rank III, 5.90 pounds; Rank IV, 5.68 pounds. The ranks follow in order. There was, however, a wide variation both in percentage of clean wool yielded and in pounds of wool shorn, by fleeces of the same rank. These meagre figures suggest that a competent judge may be able to balance up the two factors, weight of fleece and scouring percentage, so as to arrive at the third factor, clean wool yielded in pounds.

Rank of the Sheep

The rankings of the sheep on type and conformation not taking into account fleece characteristics, do not properly belong to this study. The rankings of the sheep are based upon such characteristics as size, vigor, mutton tendency, sexuality, breed type, and quality. The ranking of the sheep independent of fleece is included in Table I to demonstrate that, although the Rambouillet is known as a wool sheep, characteristics other than the wool play a part in the ranking decisions of the judge. The correlation between rank of sheep and rank of fleece is .544±.108. This indicates a fairly positive relationship between the sheep as individuals and the fleece on those sheep when each is considered separately.

It is quite possible that a competent sheep judge who has carefully examined a group of animals and ranked them in comparative excellence may not know which characteristic, and to what extent each characteristic, influenced his final ranking to the greatest degree. A multiple correlation table was prepared, correlating the six characteristics (staple length, fiber length, crimp, diameter, density, and uniformity) with the rankings of the fleeces. It was hoped that the relative influence which each of the characteristics carried in Mr. King's rankings could be determined from this multiple correlation. The value of the result is doubtful. Four ranks or classes of fleeces may present too small a number for the result of the correlation to be significant. R = .766±.551, and the size of the error confirms a doubt as to the reliability of this method. A point value for each of the Beta coefficients from the multiple correlation gives the following:

Characteristic	Weight
Density	41.55
Crimp	32.64
Uniformity	10.63
Staple length	5.94
Fiber length	4.71
Fineness	4.53
	100.00

In a further effort to determine the relative emphasis placed upon each characteristic, simple correlation coefficients were calculated between each of the characteristics and the fleece ranks. The results of these simple correlations are shown in Figure 2. With either of the above methods density and crimp, in the order named, are the important characteristics examined. It may be possible that crimp is used as an aid by the judge for determining fineness. As pointed out earlier, crimp and fineness are correlated. The difference in crimps per inch between ranks I and IV was one and one-half crimps per inch or 3%, while the difference in fineness between ranks I and IV was .00006 of an inch or .9%. The percentage difference between ranks I and IV is more than three times as great in the case of crimp, and since both of the measurements are visual in nature, the readiness of determination should be similar for each. It is, however, easier for the eye to distinguish a difference of one and one-half crimps per inch of fiber than a difference of .00006 of an inch in fiber diameter. This fact was demonstrated in the wool laboratory in connection with the experiment reported here.

The difference between individual sheep was not large, either in staple length or diameter of fiber. The range in both of these characteristics was so small that probably neither extra credit or fault was entered for them by Mr. King while making the rankings.

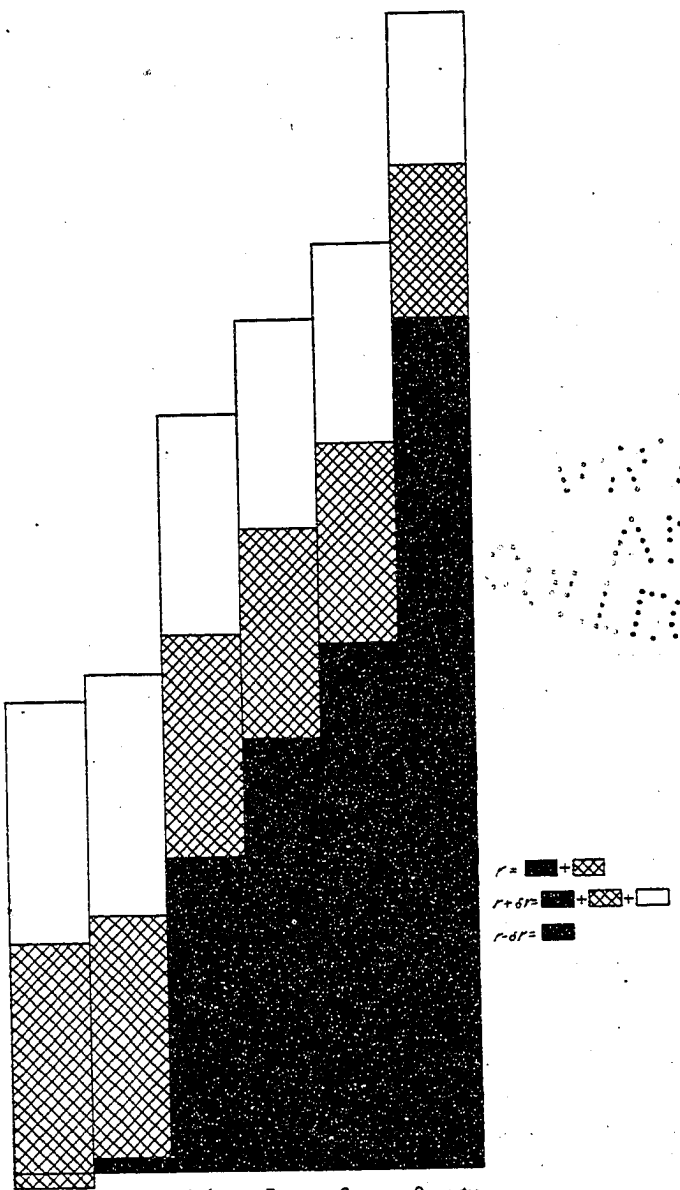

FIG.2. SIMPLE CORRELATION BETWEEN EACH OF THE SIX CHARACTERISTICS AND RANK OF FLEECES

Summary

1. A study has been made of seven factors which affect the quality of, and yield of wool from, purebred Rambouillet fleeces. These factors are length of staple, length of fiber, fineness, density, crimp, uniformity, and scouring characteristics.

2. The fleeces studied were judged on the sheep and placed in one of four ranks. Each sheep was separately placed in one of four ranks on characteristics other than fleece.

3. Length of staple was inverse to the fleece rankings of the judge. An average difference in staple length between the highest and lowest ranks was three-tenths of an inch.

4. The length of the stretched fibers show a direct relationship to the length of staple. On an average the staple lengths were 66.54% of the fiber lengths.

5. The higher ranks of fleeces were finer in fiber than the lower ranks. Shoulder samples were generally finer than belly samples and belly samples finer than thigh samples. An average difference in diameter of fiber between the highest and lowest ranks was .00006 of an inch.

6. The range of diameter of fiber by ranks expressed as standard deviations varied from 1.241 for rank I to 1.765 for rank IV. The narrowest range of diameter was found in the shoulder samples, the widest range in the thigh samples.

7. The finer fibers were more crimped. There was an average of 1.5 more crimps per inch in rank I than in rank IV.

8. The averaged samples from rank I fleeces yielded 74% more fibers

for a given area than the averaged samples from rank IV.

9. The ranking according to uniformity of fleece over the parts of the body studied was dependent mainly upon range of diameter of fiber. Range of crimp may also have had some bearing upon the judge's determination of fleece uniformity.

10. There was a wide variation in the percentage of scoured wool yielded from the different fleece ranks. The rankings of the judge indicate that he was able to determine with some accuracy the yield of clean wool from the eleven fleeces included in this report.

11. In this study there was a correlation between the fleece rank and the sheep rank, although in making the sheep rankings fleece was not considered.

12. Density, crimp, and diameter were apparently given more weight by the judge in making his rankings than were uniformity, staple length, and fiber length. The number of crimps per inch may have been used by the judge as a measure of fineness.

Conclusions

A twelve months' staple length, the thigh and shoulder of which average 2.23 inches, is acceptable in show Rambouillet sheep.

Wool fibers from the sheep in this experiment generally stretched very nearly in relation to their staple length.

Diameter of fiber in Rambouillets is correlated with density and with crimp, both of which are more readily discernible than diameter in wool fibers. Fibers from the more desirable fleeces will average between .00055 and .00065 of an inch in diameter.

There is considerable variation in the diameter of fibers from different parts of the bodies of Rambouillets. Greater variation occurs in the thigh samples than in the shoulder or belly samples. The thigh or breech generally consists of coarser fibers than the shoulder or belly.

In Rambouillets the finer fibers are more crimped. Twelve to seventeen crimps per inch are average limits for shoulder samples from the better sheep studied here.

Density of fleece is an important factor in selecting Rambouillets. The better sheep may show two or three times the density of fiber found in individuals of less excellence. A density of 34,000 fibers per square inch is an average for the better individuals studied here.

Range of diameter in fiber is probably more important in determining the relative merit of a fleece on the sheep than are the ranges of staple length, fiber length, number of crimps, or density.

Density of fiber on the skin area and number of crimps per inch are two characteristics of major importance to be considered in the selection of Rambouillet stud sheep that have a minimum staple length of 2.2 inches.

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