WOOL FINENESS AS INFLUENCED BY RATE OF GROWTH [1]

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INTRODUCTION

A study of the variations in the fineness of individual wool fibers as they grow has revealed facts that are of practical significance to the flockowner and the wool trade. According to Roberts [2] "fineness is one of the most important properties of wool." Fleeces with good, sound, uniform fibers bring a better return to the woolgrower and are more desired by the wool manufacturer than those showing undesirable irregularities in diameter along their length. Such well-grown, uniform fleeces make possible the production of cloth of better quality than is possible with similar fleeces produced under poor growing conditions.

Close examination of a large number of fleeces under varying conditions of sheep management has led to the belief that the fineness of wool fibers throughout the growing period of a fleece is affected by the conditions of feeding, breeding, and management under which the wool has been grown. Testing for strength of staple with the fingers has indicated that there is considerable difference in fleeces that appear to be of the same fineness. One often finds wool at shearing time that is weak at some point in the staple and will break under a slight strain. This condition of the wool may have been caused by sickness or other adverse conditions, which in many cases might have been avoided by better management of the sheep.

Roberts [3] refers to the "rise" or thinning of fibers which takes place just before shearing as an intermediate condition of shedding. When this condition occurs it may be caused by hereditary factors. A wool merchant may buy a considerable quantity of staple wool and find many fleeces in the lot that are weak, a condition referred to by the trade as "tender." When these wools are tested for staple strength they yield quickly at one well-defined line across the staple. A small staple is often so weak in one place that, when held horizontally, it will bend over from its own weight. The wool from these tender fleeces is not suitable for combing and the fleeces are, therefore, usually put in with the clothing grades. Sometimes this weak or tender place in the wool occurs a short time before shearing and at a point so near the end of the wool fibers that there is still sufficient length of wool to comb into tops. However, there is a smaller yield of long fibers from these fleeces and they are, therefore, not so profitable to the manufacturer.

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[1] Received for publication Oct. 5, 1929; issued March, 1930.

[2] ROBERTS, J. A. F. WOOL RESEARCH AND THE FARMER. Brit. Research Assoc. for Woollen and Worsted Indus. Pub. 103, 16 p. 1928.

[3] ROBERTS, J. A. F. Op. cit., p. 10.

PRELIMINARY OBSERVATIONS

In the fall of 1924 the senior writer visited a number of wool houses in Boston and obtained samples of tender wool in order to secure information that would help to overcome this defect. In a study of these samples a thinning out of the fibers was readily observed, but there was difficulty in finding a tender place in a fiber that was entirely within the field of the microscope when it was magnified about 150 diameters. A sample of wool obtained from a very tender Australian fleece had an abrupt change in the diameter of the fibers. Figure 1 illustrates such a weak place or "break" in the sample, and

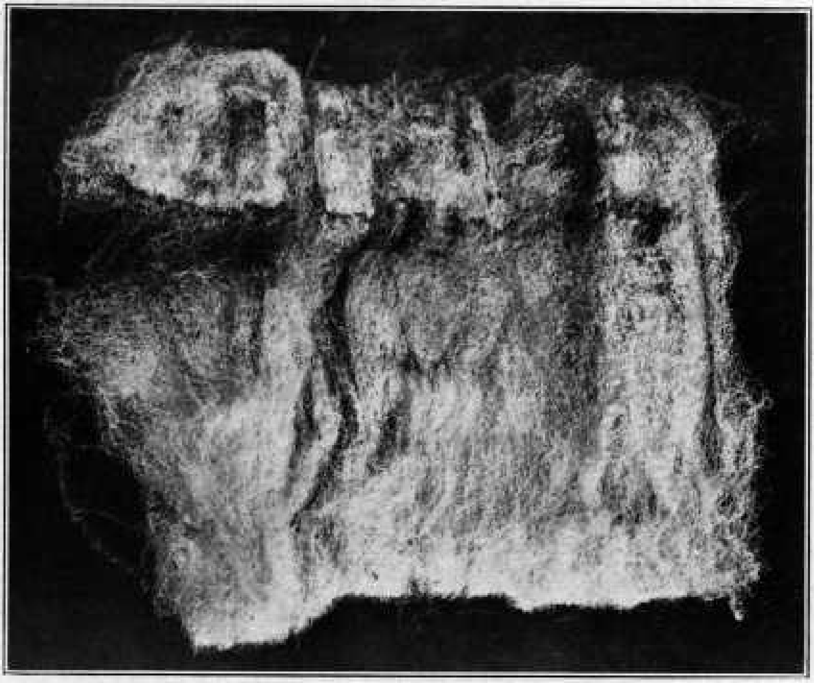

FIGURE 1.—A "break" in a staple. The wool is partially pulled apart to show the location of the weak spot. Approximately natural size

Figure 2 is a microphotograph of fibers from the same fleece. These fibers, which are tender and have a very small diameter at one point, show no indications of having ceased to grow.

Weak places in staple wool may be evident in varying degrees according to the reduction in the diameter of the fibers during the period the weak portion of the fiber was growing. Sometimes a sheep may be subjected to such severe conditions that the wool appears to stop growing for a short time. Later, when the sheep becomes thrifty, new fibers apparently are formed in the wool follicle. As these new fibers grow they become embedded in the old ones. This condition is shown in Figure 3. The old fiber will separate from the new fiber under the slightest strain. The sample from which this fiber was taken was obtained from a Southdown sheep seriously infested with internal parasites. All the samples mentioned above, except the last, were warehouse samples of which the previous history was not available, hence there was no direct information on the cause of formation of the tender wool.

EXPERIMENTAL PROCEDURE

METHOD OF OBTAINING SAMPLES

In order to study wool fineness as influenced by the wool's rate of growth, the writers selected five healthy Corriedale ewes all of which

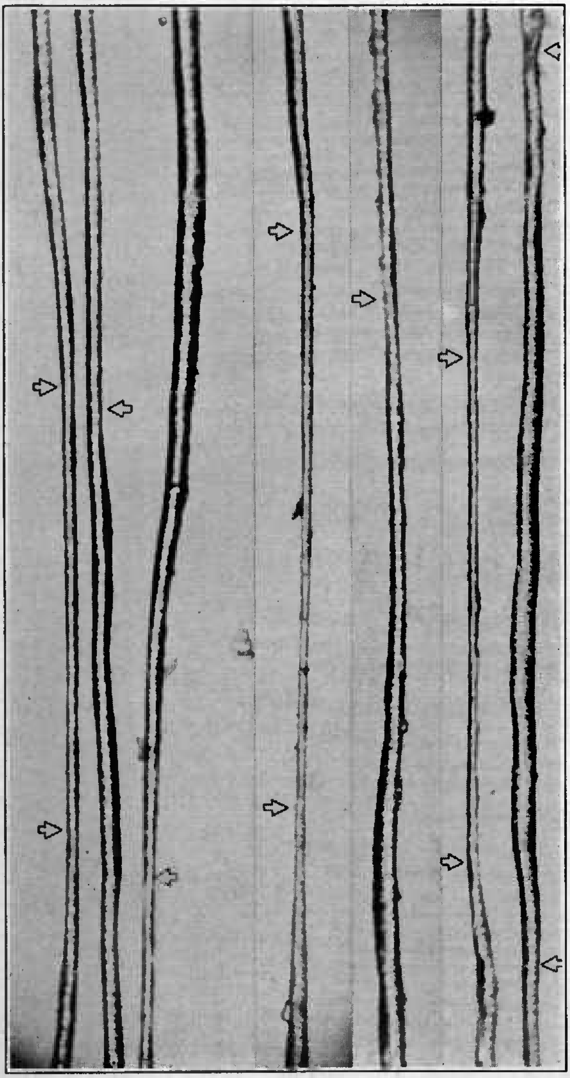

FIGURE 2.—Photomicrograph of fibers taken from lock of wool shown in Figure 1. The weak places in the fibers which have noticeably reduced diameters are indicated by arrows. ×140

produced lambs each year with the exception of sheep 1125 in 1928. The ages of these sheep varied from 1 to 4 years at the beginning of this experiment. Under the supervision of C. G. Potts, of the bureau, these sheep were weighed individually every two weeks and an accurate record was kept of their breeding and feeding.

Wool-growth clippings were obtained from these sheep at 28-day intervals, in the following manner: All the fibers were removed from an area about one-half inch square, located about 3 inches to the rear of the point of the shoulder and midway between back and belly. This area was selected since previous study had shown wool from this portion to be fairly typical of the entire fleece. Twenty-eight days later two small samples of wool, representing the growth during that period, were taken from the same area. The remaining fibers on the area were removed with sharp scissors that cut very close to the skin. The operation was repeated every 28 days. On the same dates that fiber clippings were taken, two small locks of wool were tied with dental floss close to the skin on the right and left side of the same

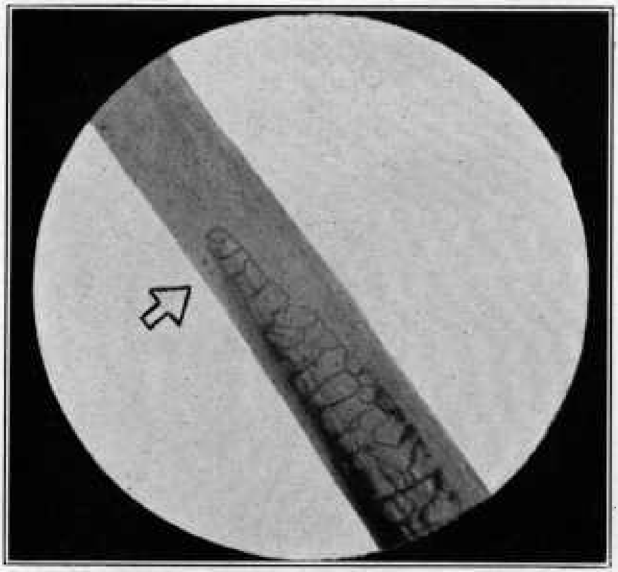

FIGURE 3.—Photomicrograph of the juncture between new and old growths in a wool fiber; the fiber is very weak at such places. × about 500

sheep. Figure 4 illustrates the appearance of the tied locks. These locks made it possible to study the growth of individual wool fibers during successive 28-day periods.

LABORATORY METHODS OF MEASUREMENT

The lengths of the wool clippings were measured with a binocular microscope magnifying 7.5 diameters. This was accomplished by first placing a few of the fibers on a piece of thin glass beneath which was a sheet of cross-section paper of the same size, ruled in millimeters. A microscope slide was then placed across the fibers even with one of the lines of the cross-section paper. The fibers were then pulled slowly out from beneath this slide with small tweezers. When a fiber was just free from the microscope slide, the movement of the tweezers was stopped and the length of the fiber was read to the nearest millimeter. Five fibers were measured from the left and five from the right side of each sheep. The diameter of the wool fibers was measured with a micrometer caliper having a ratchet stop and graduated to one four-hundredth of a millimeter.

FIGURE 4.—Tied locks showing one year's growth of wool from Corriedale sheep by 28-day intervals. Actual size

Fifty fibers were used for diameter measurements from clippings and tied locks from the left side of each sheep, and 50 from the right. This number was considered sufficiently large to furnish a representative average of the samples. Portions representing the same growth period of 25 fibers from the left and from the right side samples of each sheep were measured both with the micrometer caliper and with a microprojector in order to compare the results by these two methods. Under the conditions, this number was considered sufficient to show an accurate comparison between the two methods. By means of the microprojector, the fibers were projected with a 1,000-diameter magnification on an aluminum-coated screen. The measurements on the screen were made with a scale graduated in millimeters. With this magnification each millimeter of the image, as projected on the screen, represented 1 micron of actual wool fiber.

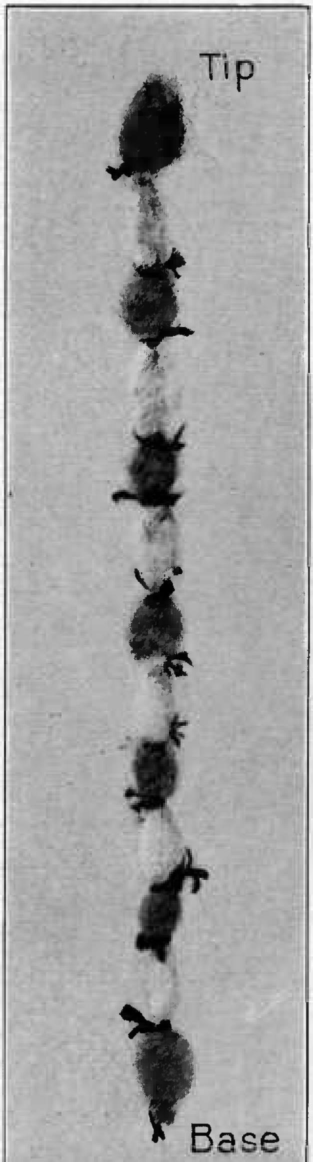

FIGURE 5.—Tied lock of wool with alternate portions dyed to show the different growth periods. Actual size.

The length and diameter of clippings from the greatest, least, and last growth periods of the year 1927–28 were again measured in order to study the relationship of length and diameter to weight. For this purpose 100 fiber clippings were taken from the left and right sides of each sheep. This larger number of fibers was used in order to have a quantity that could be weighed with accuracy. After the length of each fiber was determined, its diameter also was immediately measured with a micrometer caliper. The weights of each of these groups of 100 fibers were taken on a microbalance and the fibers were then placed in small gelatine capsules for safe keeping and future reference.

All measurements were made under controlled conditions of temperature and humidity with the exception of those taken by means of the microprojector. Owing to the heat caused by the operation of the microprojector, it was impossible to maintain a constant temperature while making these measurements. For all other measurements the temperature was maintained at 70° F. and the relative humidity was kept at 65 per cent.

The various growth periods on the tied locks were shown more clearly by dyeing alternate growth periods as illustrated in Figure 5. This was accomplished by wrapping a thread saturated in crude wool grease around the growth of alternate 28-day periods so that it covered the entire growth of such periods; the greased thread excluded the dye from the covered portions of the lock. The entire lock was then dyed in an alcoholic solution of malachite green dye just long enough to stain all the fibers of the unprotected growth periods.

After the wool-growth clippings and tied locks were measured for length, tabulations were made of the data on the basis of average length growth for the five sheep from the periods in which the wool grew the greatest length, the least length, and also for the last growth period before shearing. These measurements, from samples obtained from each of the five animals for four successive years, are presented in Table 1. The average diameter of the growth clippings for the same periods is also given. In four cases the greatest and least growth periods for individuals are not the same as that for the average of the group. These variations were largely due to differences in the dates of lambing and other factors influencing the physical condition of the sheep. The coarsest fibers were produced each year during the periods of greatest growth and the finest during those of least growth.

TABLE 1.—*Average length and diameter of 100 wool fibers, for the greatest, least, and last growth periods, for five Corriedale sheep during four successive years*

Sheep No.	For greatest growth period, 28 days ended Aug. 28, 1925		For least growth period, 28 days ended Jan. 12, 1926		For period just before shearing, 28 days ended May 4, 1926		For greatest growth period, 28 days ended Oct. 20, 1926	
	Length	Diameter	Length	Diameter	Length	Diameter	Length	Diameter
	Cm.	*Microns*	*Cm.*	*Microns*	*Cm.*	*Microns*	*Cm.*	*Microns*
977	1.27	22.75	1.06	21.78	1.12	16.90	1.40	25.00
979	1.47	22.98	1.08	21.95	1.24	20.33	1.48	23.83
982	1.21	22.80	.92	19.78	1.18	20.98	1.19	26.18
1125	1.50	20.08	.90	17.70	1.50	19.98	1.49	22.95
2B	1.55	28.00	1.01	24.38	1.16	24.33	1.56	28.70
Average	1.40	23.32	.99	21.12	1.24	20.50	1.42	25.33

Sheep No.	For least growth period, 28 days ended Jan. 12, 1927		For period just before shearing, 28 days ended Apr. 6, 1927		For greatest growth period, 28 days ended June 29, 1927		For least growth period, 28 days ended Feb. 8, 1928	
	Length	Diameter	Length	Diameter	Length	Diameter	Length	Diameter
	Cm.	*Microns*	*Cm.*	*Microns*	*Cm.*	*Microns*	*Cm.*	*Microns*
977	1.18	23.95	1.12	21.48	1.46	25.58	1.10	18.13
979	1.14	23.90	1.20	23.68	1.37	26.68	.98	21.58
982	1.05	25.00	1.23	25.03	1.22	27.08	1.05	21.05
1125	1.24	22.08	1.27	22.88	1.35	26.28	1.15	20.25
2B	1.30	27.58	1.13	23.25	1.37	30.05	1.02	26.70
Average	1.18	24.50	1.19	23.26	1.35	27.13	1.06	21.54

Sheep No.	For period just before shearing, 28 days ended May 1, 1928		For greatest growth period, 28 days ended Oct. 17, 1928		For least growth period, 28 days ended Feb. 6, 1929		For period just before shearing, 28 days ended May 1, 1929	
	Length	Diameter	Length	Diameter	Length	Diameter	Length	Diameter
	Cm.	*Microns*	*Cm.*	*Microns*	*Cm.*	*Microns*	*Cm.*	*Microns*
977	1.16	23.00	1.28	23.80	1.08	22.13	1.25	23.15
979	1.15	23.15	1.26	24.20	1.10	22.68	1.14	21.05
982	1.12	23.33	1.10	24.63	.88	21.33	1.09	23.08
1125	1.27	23.73	1.32	22.03	1.11	22.83	1.13	24.18
2B	1.38	27.88	1.35	29.68	.99	25.70	1.21	27.83
Average	1.22	24.22	1.26	24.87	1.03	22.93	1.16	23.86

TABLE 2.—*Comparison of average diameters of 100 wool fibers from tied locks of five Corriedale sheep, measured with a micrometer caliper and also by a microprojector*

Sheep No.	Average diameter of 100 wool fibers—					
	For greatest growth period, 28 days ended June 29, 1927,[a] when measured with—		For least growth period, 28 days ended Feb. 8, 1928,[b] when measured with—		For period just before shearing, 28 days ended May 1, 1928,[c] when measured with—	
	Micrometer caliper	Microprojector	Micrometer caliper	Microprojector	Micrometer caliper	Microprojector
	Microns	*Microns*	*Microns*	*Microns*	*Microns*	*Microns*
977	25.28	26.66	19.10	20.50	21.83	24.74
979	24.98	28.08	20.35	22.64	21.58	26.20
982	27.23	30.42	20.98	23.68	22.25	24.56
1125	25.80	29.32	17.58	23.12	23.68	28.56
2B	31.03	34.36	26.03	30.04	27.75	30.72
Average	26.86	29.77	20.81	24.00	23.42	26.96

[a] Average length of clippings, 1.35 cm.
[b] Average length of clippings, 1.06 cm.
[c] Average length of clippings, 1.22 cm.

The measurements of diameter which were taken with a micrometer caliper and also with a microprojector are recorded in Table 2 and

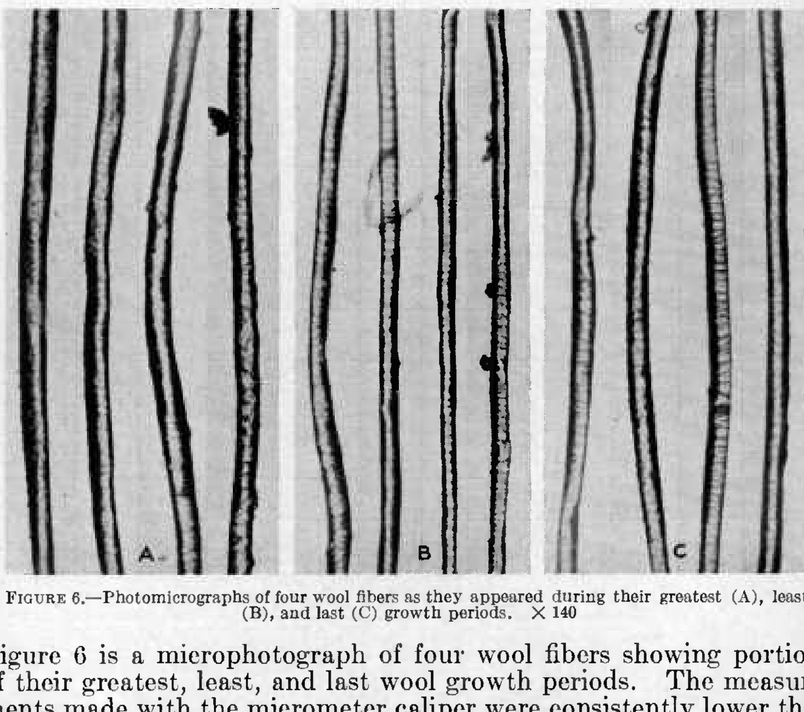

FIGURE 6.—Photomicrographs of four wool fibers as they appeared during their greatest (A), least (B), and last (C) growth periods. × 140

Figure 6 is a microphotograph of four wool fibers showing portions of their greatest, least, and last wool growth periods. The measurements made with the micrometer caliper were consistently lower than those made with the microprojector. In order to determine the cause of these differences in the diameter measurements, 25 short pieces of fine uniform wire were measured by both methods. The average diameter for the wire with the micrometer caliper was 82.80 microns and with the microprojector was 85.64, a difference of 2.84 microns. The average differences found between the measurements made with the micrometer caliper and the microprojector in the case of the wool fibers was 3.21 microns. Thus with both materials the measurement of fibers by means of the microprojector gave results slightly greater than those obtained with the micrometer caliper. The microprojector generally yields more consistent results, however, than the micrometer caliper, and makes possible the more rapid measurement of growth changes in the diameter of wool fibers. It is impossible to use the micrometer caliper for measuring changes occurring quickly because of the width of its jaws which are too large to measure short-time growth.

TABLE 3.—*Average length, diameter, and weight of 100 wool-growth fiber clippings for the greatest, least, and last growth periods of four Corriedale sheep*

Sheep No.	Item	For greatest growth period, 28 days ended June 29, 1927			For least growth period, 28 days ended Feb. 8, 1928			For period just before shearing, 28 days ended May 1, 1928		
		Length	Diameter	Weight	Length	Diameter	Weight	Length	Diameter	Weight
		Cm.	*Microns*	*Mgm.*	*Cm.*	*Microns*	*Mgm.*	*Cm.*	*Microns*	*Mgm.*
977	Left side	1.248	24.95	1.20	0.914	17.85	0.46	1.036	21.88	0.73
	Right side	1.426	24.75	1.28	.984	16.70	.47	1.137	22.30	.77
	Average	1.337	24.85	1.24	.949	17.28	.465	1.087	22.09	.75
	Average weight of 1 cm. growth			.927			.490			.690
979	Left side	1.088	24.00	.94	.917	19.50	.51	1.040	21.50	.71
	Right side	.958	25.30	.80	.896	20.08	.57	1.090	23.00	.79
	Average	1.023	24.65	.87	.907	19.80	.54	1.065	22.25	.75
	Average weight of 1 cm. growth			.850			.595			.704
982	Left side	1.040	26.25	1.10	.840	18.50	.50	.910	20.00	.67
	Right side	1.090	26.50	1.25	.940	18.50	.54	.990	21.50	.79
	Average	1.065	26.38	1.175	.890	18.50	.52	.950	20.75	.73
	Average weight of 1 cm. growth			1.103			.584			.768
1125	Left side	1.250	25.00	1.170	.980	19.48	.64	1.090	24.85	.95
	Right side	1.300	25.75	1.34	1.040	18.95	.60	1.160	24.60	1.02
	Average	1.275	25.38	1.255	1.010	19.22	.62	1.125	24.73	.985
	Average weight of 1 cm. growth			.984			.614			.876
	Average	1.175	25.32	1.135	.939	18.70	.536	1.057	22.45	.804
	1 cm. growth			.964			.571			.760

The average of the length, diameter, and weight of 100 fibers from clippings taken from the left and right sides of four Corriedale sheep are shown in Table 3. The difference in weight of fiber between the greatest and the least wool growth periods for the four sheep was 52.8 per cent. As has been previously stated, the length of the wool-growth periods was 28 days, or one-thirteenth of a year. Based on a 10-pound fleece shrinking 55 per cent, this would mean a reduction of 0.182 pound of clean wool during a period of 28 days. The reduction in length of the wool from the greatest to the least growth period is 2.36 millimeters. For a reduction of 1 millimeter in length (with-out taking diameter into consideration) there would be a reduction of 0.0771 pound of clean wool. In order to find out what proportion of the decrease in weight of fiber is due to the reduction in diameter, the weights of fiber for each period equivalent to 1 cm. growth were determined. These figures are given in the table opposite the average weight of 1 cm. The reduction in wool diameter from the greatest to the least growth period is 6.62 microns, with a corresponding reduction of 0.393 mgm. of wool fiber. This is equal to 6.11 per cent reduction in weight of wool fiber for each decrease of 1 micron in diameter. With these figures also based on a 10-pound fleece shrinking 55 per cent, there would be a reduction of 0.02 pound of clean wool in 28 days due to reduction in diameter of wool fiber. These data show that there is a reduction in weight of fleece resulting from both the reduced rate of growth and the reduction in fiber diameter.

This group of experimental sheep had better feed and care than most flocks of sheep and did not have to withstand the hardships of range conditions, yet the less favorable conditions in the winter months were reflected directly in their wool production. The wool of these sheep was sound, but not of such good quality as it would have been had it been uniform in diameter throughout its entire length. A reduced rate of growth associated with a reduction of the diameter of wool fiber is the first indication of tender undesirable wool.

DISCUSSION

An analysis of the records for these sheep showed that the greatest wool growth is associated with a thrifty condition of the sheep as indicated by the weight records. The end of the period of least growth of wool was found to be from about 45 days before lambing to about lambing time. After this fact was determined, the data for length of wool grown for the last period before shearing were selected and diameter measurements were made of fibers grown in this period. This was done in order to determine what the diameters of the fibers were during a period as late as possible before shearing.

Probst [4] based a series of measurements on observations of Zorn who stated [5] that wool grows two-thirds of its length in the first six to seven months and one-third of its length in the remaining months of the yearly period between shearings. On this basis, Probst measured a wool sample, from one of his stud bucks, at four different places along its length. He calculated that the measured portion of the tip was produced in August; that of the section next to the tip in October, before breeding time; the measured portion of the third section in December; and that of the base in March or April. He concluded that this decrease probably was due in part to the influence of the winter season and in part to reduced vigor of the buck after breeding time. The decrease, moreover, was more pronounced in 1923 than in 1924; Probst explains this by the fact that in the first instance the buck had run with the flock, while in the second case, hand breeding was practiced.

[4] PROBST, E. DIE FEINHEITSBESTIMMUNG DES WOLLHAARES. Ztschr. Tierzuchtung u. Zuchtungsbiol. 6: [403]-488, illus. 1926.

[5] ZORN, W. HAUT UND HAARE ALS RASSE UND LEISTUNGSMERKMAL IN DER LANDWIRTSCHAFTLICHEN TIERZUCHT. Flugschr. Deut. Gesell. f. Zuchtungsk. 48. 1919. [Original not seen.]

The findings of Duerden and Bosman [6] in their study of wool from seven sheep at three different places along the staple, including the top, middle, and base, show that "the growth of the fleece is less vigorous toward the end of the season than at any other period." It seems quite possible that the end of the season might have been unfavorable for the growth of the fleeces from which those seven samples were taken and that more favorable conditions would have been associated with a larger diameter. It is also possible that the reduced growth, in part, may have been caused by some hereditary factor. The writers' data on the clipping measurements also show that the average diameters for the greatest, least, and last growth periods vary directly with the average rate of growth.

SUMMARY

A study of five healthy Corriedale ewes was undertaken in order to determine, if possible, the effect of the rate of wool growth on fineness and length of fibers. Periodic wool-growth clippings and tied locks were used in this study. It was found that the rate of wool growth and the fineness of the fibers produced varied throughout the year, both growth and coarseness being greatest in summer or fall and least in midwinter. The greatest growth in length of fiber appeared to be correlated with the largest diameter of fiber and vice versa. The period of greatest wool growth was also associated with a generally thrifty condition of the sheep as indicated by their weight. The period of least wool growth occurred, in ewes, usually during lambing time and the 45 preceding days. The weight of the wool fibers increased as the length and diameter increased and vice versa. The indications are that the character of the fleece is probably very largely within the control of the flock owner because the experiments appear to show that there is a rather close relationship between the thriftiness of a sheep and the quality and quantity of wool it produces.

[6] DUERDEN, J. E., and BOSMAN, V. ABSENCE OF UNIFORMITY IN GROWTH OF THE MERINO FLEECE. Jour. Textile Inst. 18: T191–T194, illus. 1927.