OKLAHOMA
AGRICULTURAL AND MECHANICAL COLLEGE
AGRICULTURAL EXPERIMENT STATION
C. P. BLACKWELL, Director
Stillwater, Oklahoma

The Effect of the Ration on Wool Growth and on Certain Wool Characteristics

A. E. DARLOW
Associate Professor of Animal Husbandry
Oklahoma A. & M. College

V. G. HELLER
Head, Department of Agricultural Chemistry Research
Oklahoma A. & M. College

W. R. FELTON
M. S., Oklahoma A. & M. College, 1932

Experiment Station Bulletin No. 220 September, 1934

CONTENTS

THE EFFECT OF THE RATION ON WOOL GROWTH AND ON CERTAIN WOOL CHARACTERISTICS

A. E. Darlow, V. G. Heller, and W. R. Felton*

With the exception of the tropics, the world is wholly or partly dependent on wool for its clothing. The sheep was among the first animals domesticated by man, and has always been one of his most valuable beasts. Continuous efforts have been made to improve both wool and mutton, in order to give the greatest financial return to the sheep grower.

The chief value of wool lies in its ability to be spun into yarn. Other animals—camel, goat and alpaca—produce valuable textile fibers, but for general purposes the fiber is not nearly so useful as the wool of the sheep because the character of fiber produced in most cases is not adapted to as many uses as is wool. Furthermore, the number of animals producing such fibers is inadequate for the world's demands, only a small portion of the world is adapted to the successful raising of these animals. It must be remembered that sheep are found in practically every inhabitable portion of the world.

Because wool is the most valuable animal fiber, the efforts of flockmasters have for centuries been devoted to the search for methods of improving the quality and increasing the quantity produced. The early Spanish flockmasters, desiring to produce the finest staple possible, drove their sheep from southern to northern pastures in the spring and returned them in the fall. When Spanish laws prohibited this seasonal migration, the Spanish shepherd blanketed his sheep through the colder months, his object being to keep an equable temperature and thus increase the fineness of the wool.

REVIEW OF PREVIOUS INVESTIGATIONS

Effect of Feed on Quantity and Quality of Fleece

In recent years, the flockmasters and investigators have turned their attention to the effects of feeding and management on quality and quantity of wool.

Roberts and Wing (1889) found that two lambs fed a ration with a nutritive ratio of 1:4.2 for 160 days produced 7.31 lbs. of raw wool as compared to 4.25 lbs. of raw wool produced by two lambs, of similar breeding, fed a ration with a nutritive ratio of 1:10.9 for the same period.

Cooke and Jones (1890) noticed in working with Merino ewes that when the ewes were sick or not doing well the wool fibers shrunk in diameter.

Craig (1891) fed two lots of grade Shropshires on high protein and high carbohydrates rations for 12 weeks and found very little difference in staple length and amount of clean wool produced. The sheep in the lot receiving the high protein feed produced .4 pound more raw wool than those in the carbohydrate lot, but the difference was due mostly to grease in the wool.

Hill (1914) found that environment had no effect on the amount or strength of wool produced when 10 native wethers of Wyoming and 10 native wethers of Ohio were exchanged. This same investigator observed that Rambouillet wethers tended to give greater wool production when fed a

*Part of this material was prepared by W. R. Felton as a thesis in partial fulfillment of the requirements for the degree of master of science with a major in animal husbandry.

narrow ration of hay and oil meal than when fed a medium ration of the same feed or a wide ration of hay alone. He also noted that there was no advantage in strength of wool grown during the feeding of any one of the three rations.

Skinner and Smith (1910) reported that .8 pound more wool was produced by ewes fed a dry ration than by those fed a succulent ration (corn silage). They did not, however, credit this increase to the difference in the rations.

Investigations by Hill (1921) show that absence of succulent feed has no detrimental effect on wool production. Thirty Rambouillet wethers, age two and three years, were taken off the range with a full year's fleece and sheared. Then they were divided into three groups, put into a dry lot, and fed wide, medium, and narrow rations alternately for three years. The mean fleece weight (clean wool) for the one year on the range was 4.09 ± .07 lbs. as compared to a mean fleece weight of 5.19 ± .08 lbs. the three subsequent years in a dry lot. This seems to indicate that range feed alone does not bring out fully the sheep's inherent capacity for wool production.

Joseph (1926), in working with fine wool sheep, reports that if the sheep remains normal in health the organs which are concerned with the secretion of the wool fiber are not easily affected by changes in the level of feeding, especially when the feding is continued for a period not exceeding five or six months. He concludes that quality of fiber is not affected at all and that quantity of fiber may be modified only slightly.

Wilson (1931) fed three Romney wethers a fattening ration for six months, followed by a maintenance ration for a like period and a sub-maintenance ration for a third period of six months. The fleeces grown on the fattening ration, when compared with the fleeces grown later by the same animals on a sub-maintenance ration, were:

(a) About 343% heavier in grease weight.

(b) About 319% heavier in scoured weight.

(c) Loftier and fuller in texture.

(d) Superior in crimp.

(e) 172% longer in staple.

(f) About 206% stronger as indicated by the mean breaking stress at the basal portion of the fibers.

(g) Coarser, especially at the base of the fiber.

Wilson does not credit all the differences in scoured weights of fleeces to difference in length and diameter.

Weber (1931), in experimenting with Shropshires at the Nebraska Station, found that when sheep on full feed were subjected to a low plane of nutrition, "they produced less scoured wool, doubtless because the wool fibers did not grow normally either in diameter or length." Continued full feeding, however, resulted in normal wool growth. He also reports that, when the method of feeding was reversed, those changed from a low to a high plane of nutrition produced 100% more scoured wool than during the previous period and their wool fibers were 15% larger in diameter and 14% longer. The change from a high to a low plane of nutrition caused the sheep to produce only 50% as much scoured wool as during the previous period and their wool fibers were 30% smaller in diameter and 23% shorter.

Riches (1931) reports that Merino wethers receiving a ration with a nutritive ratio of 1:16.2 produced a much finer wool fiber than wethers of similar breeding that received a ration with a nutritive ratio of 1:10.3.

Cooke (1901) states that when the ration is insufficient for maintenance the growth of wool is but slightly reduced. Hardy and Tennyson (1930) observed that the rate of wool growth was associated with the general thriftness of the sheep. They report a very close relationship between thriftness and quality and quantity of wool produced. Wilson (1927) reports that if sheep are poorly nourished the wool fiber may be weak throughout most of its length.

Effect of Feed on the Cystine Content of Wool

Since wool is known to contain a large amount of sulphur, several studies have been made to determine the effect of sulphur in the ration on the sulphur content of wool. Hart (1912) fed sulphur at different levels to four lots of sheep and reported that neither the average weight of fleeces, nor the proportion of pure wool fiber to the total weight, was greater on the high-sulphur than on the low-sulphur rations. He concluded that normal dry rations of grain and hay contain ample sulphur for wool production and that additional sulphur seems to have no influence upon the proportion of pure wool fiber produced. The sulphur in wool is largely in the form of cystine.

Gebhard (1914) suggests that wool contains an amino acid and a collodial substance loosely attached to the amino groups of the acid. Lightbody and Lewis (1929) report that the amount of hair produced by the white rat is related to the protein (and cystine) content of the diet, but that the demand for cystine for growth of hair appears to be secondary in importance to the demands for body growth. These investigators state that retardation of growth alone did not produce a hair low in cystine, since a diet deficient in some other factor than cystine, e. g. lysine, did not result in the production of a hair with a low cystine content.

In a study on the relation of cystine yield to total sulphur in the wool, Barritt (1927) reports that the maximum yield of cystine corresponds to 66% of the total sulphur present in wool, whereas from black human hair 70% of the total sulphur is recoverable as cystine.

Beadles, Braman, and Mitchell (1930) report that the addition of cystine to a diet in which this amino acid is deficient, and in which the protein content is so low as to be the limiting factor in growth, increases its value in the promotion of hair growth in the albino rat. The coat of hair produced on such rations is not only heavier in total, as compared with that produced on the same amount of unsupplemented ration, but is heavier per unit of surface area. Hence it appears that the growth of hair has been stimulated by the cystine supplement to a greater extent than has the growth of all of the tissues as measured by the increase in body surface. This study shows that the demands for cystine by the more vital tissues do not take precedence over the demands of the hair follicles.

Australian investigators (1931) fed cystine-rich protein concentrates to groups of lambs and found that the wool growth was stimulated about 30%. Further studies showed that after the lambs were older, and were relieved of the extra strain of rapid body growth, they produced slightly over 30% more wool than did sheep of the same breeding fed an unsupplemented ration.

Hill (1931) states that the wool fiber is chemically very much like other appendages of the animal skin. The substance of which they are composed is keratin, a proteid substance that is closely related to the true proteins. He suggests that the protein-like nature of the wool is important as indicating that it is derived from the proteins in the feed obtained by the sheep. This fact has caused many investigators to study the optimum protein consumption for sheep.

Crowther and Woodman (1922) found that the optimum retention of protein was 17 grams of nitrogen (106 grams protein). The nutritive ratio in this case was 1:6. Stewart (1931) reports that immature sheep have a more constant retention of nitrogen than mature sheep due to body building. In his work he found that mature sheep show a high fluctuation in nitrogen balance in a relatively short time. Mitchell, Kammlade and Hamilton (1926) fed western lambs a fattening ration and found that the daily wool growth contained only .015 lbs. of protein for a sheep weighing 100 lbs.

Armsby (1917) reports that sheep require more protein for growth of wool than cattle do for growth of hair, the sheep requiring 13.5 lbs. protein per day per 1,000 lbs. liveweight. This same investigator states that the minimum protein requirement for mature sheep is .41 lbs. for body maintenance and .14 lbs. for wool growth per 1,000 lbs. liveweight. Thus a mature sheep weighing 100 lbs. would require .055 lb. of digestible protein for maintenance.

Effect of Environment and Advancing Age on Wool Production

Many other evnironmental factors that influence the wool fiber have been investigated. Davenport and Ritzman (1926) report that age and feed level have a modifying influence on fleece weight of individuals. They found that the advancing age, state of health, level of subsistence, and exposure to changing weather conditions affect growth of wool to such an extent that an unfavorable combination of these factors may vary the fleece weight from the same individual by as much as 50%.

Lush and Jones (1923) found when studying 132 grade Rambouillet wethers that individuality was the cause of variation in fleece weights 38.6% of the time. They found that ewes produce the heaviest fleece at two years of age but that wethers may produce heavier fleeces at three years of age. Hill (1914) reports that age up to five or six years causes no falling off in the wool production of purebred Rambouillet wethers. Joseph (1926) observed that, in sheep of fine wool breeding, advancing age after the third or fourth year caused a decrease in staple length. This same investigator found that 28 ewes of fine wool breeding weighing 100 lbs. or less produced a fleece averaging 8.4 lbs., as compared to 9.4 lbs. for ewes of similar breeding weighing from 131 to 161 lbs. and 10.3 lbs. for 23 ewes weighing 146 to 165 lbs. Joseph (1930) also reports that the clip from two-year-olds was the heaviest and that age up to eight years had no detrimental effect on wool production. Hardy and Tennyson (1930) report that the greatest growth of wool occurs in summer or fall and the least in midwinter. They found that the period of least growth in ewes was during lambing and 45 days preceding.

Spencer, Hardy, and Brandon (1928) report that age of sheep has a most important influence on length of staple and that fleeces from three year olds are heaviest.

Interrelation of Different Wool Characters

Numerous studies have been made to determine the relationship existing between certain wool characteristics such as crimp, tensile strength, diameter, etc.

Hardy (1920), in studying the influence of humidity upon the breaking strength and elasticity of the wool fiber, concluded that:

(a) Tensile strength of wool increases with the decrease in diameter of wool fiber.

(b) Fine wool has a breaking strength varying more closely with the first than with the second power of the diameter.

(c) Coarse wool has a breaking strength varying with a figure which lies somewhere between the first and second powers of the diameter.

(d) The breaking strength and tensile strength of both scoured and unscoured wool decrease with an increase in humidity from 40 to 60% and show a tendency to increase from this point to that of saturation.

(e) The elasticity of both scoured and unscoured wool increases with an increase in humidity from 40 to 80% and decreases from this point to the point of saturation.

Barker, as reported by Hill (1931), found that the wool fiber increases in size with absorption of moisture. However the increase from perfect dryness up to 63% relative humidity was only 3.4%.

Hultz (1927) found in studying the wool fibers of Ramboillet sheep that the stretch of fiber is generally related to staple length and that diameter of fiber is correlated with density and with crimp. He found that fibers from the more desirable fleeces average between .00055 and .00065 of an inch in diameter and that 34,000 fibers per square inch is an average for the better sheep studied. He reports a correlation of $-.321 \pm .081$ between crimp and fineness. In a later investigation, Hultz and Paschal (1930) found a correlation of $-.28 \pm .03$ between diameter and density of shoulder samples, and a certain of $-.23 \pm .02$ between crimp and diameter of shoulder samples. No correlation existed between density and staple length. They found a density of 27.936 per square inch in the shoulder samples and 22,492 in the thigh samples. Female fleeces were superior to male fleeces in fineness and crimp, but inferior in density and fiber length.

Reimers and Swart (1931) used samples containing 500 fibers from 100 different Merino sheep and found a correlation of $-.401 \pm .084$ between crimp and diameter. Hardy and Tennyson (1930) report that the greatest growth in length of fiber appears to be correlated with the largest diameter of fiber and vice versa, and that the weight of fibers increases as the length and diameter increase and vice versa.

Davenport and Ritzman (1926) found a correlation of $-.216 \pm .094$ between crimp and diameter in the fleece of Rambouillet sheep.

Hultz (1927) states that, in determining the relative merit of a fleece, range of diameter in fibers is probably more important than the ranges of staple length, fiber length, number of crimps, or density.

EXPERIMENTAL RESULTS

Experiment I: The Effect of the Ration on Wool Growth and on Certain Wool Characteristics

The 28 wethers used in this experiment were purchased through a commission firm from a rancher in Reagan county, Texas. They were approximately 18 months of age at the time of their purchase, October 1, 1930. They showed a preponderance of fine wool breeding.

Upon their arrival at the Station farm they were put in a dry lot and fed oats and a good grade of alfalfa hay. No record of feed consumption was kept during the period between arrival of the wethers and the beginning of the experiment. They were all sheared Novmber 1 and the fleeces were weighed individually. The exact date of the previous shearing is not known, but it is assumed that this represents approximately a 7-month fleece growth.

The exact conditions under which these fleeces were grown are not known, but it is assumed that all fleeces were produced under the same conditions, i. e., 6 months on the range and 1 month in the feed lot. This clip shall be referred to hereafter as Series A.

This experiment was started December 13, at which time the wethers were divided into seven lots of four animals each. An effort was made to have the groups as uniform as possible. Lot I averaged 67 lbs. in weight; Lot II, 69.1 lbs.; and the remaining five lots 67.1 lbs. each. The wethers were kept in a dry lot and fed individually in stanchions, under the same shelter. They were fed from individual containers and a weekly record was made of the feed consumed. Salt and water were kept before them at all times.

Lot I reecived a ration of four parts native hay, four parts yellow corn, and one part linseed oil meal. The nutritive ratio was approximately 1:7.00.

Lot II was fed a high protein ration consisting of four parts native hay, two parts yellow corn and two parts linseed oil meal. The nutritive ratio in this case was about 1:4.6.

Lot III was fed a ration with approximately the same nutritive ratio as the ration fed Lot II, but it consisted of five parts native hay, two and a half parts yellow corn and two parts cottonseed meal.

Lot IV was fed a ration of four parts native hay, two parts yellow corn and two parts corn gluten meal. The nutritive ratio of this ration was 1:4.80.

Lot V was given a wide ration consisting of equal parts native hay and yellow corn with a nutritive ratio of 1:10.6.

Lot VI reecived the same ration as Lot V but in this case two wethers were given the regular amount of feed and two were kept on a slightly sub-maintenance ration.

Lot VII was given the same ration as Lot I but two wethers were given the normal feed and two were kept on a slightly sub-maintenance ration.

All wethers received approximately 2 lbs. of feed per day except those on the sub-maintenance ration in Lots VI and VII. These were given approximately 1 lb. per day. The corn and hay was finely ground in order to secure a uniform feed mixture and prevent waste.

On April 1, 1931, the wethers were sheared and those in Lots VI and VII that were receiving a sub-maintenance ration were changed to the regular feed and the wethers on regular feed were placed on the sub-maintenance ration. During this phase of the experiment all wethers received the same feed for 43 days and the rations mentioned above for 108 days. This clip shall be known hereafter as Series B.

On October 3 two wethers from each lot were sheared and those in Lots VI and VII were again changed to different planes of nutrition. The two wethers that were sheared were considered representative of the lot and it was assumed that the other wethers in the group would have performed the same as the two that were sheared. This clip shall be referred to hereafter as Series C.

The experiment was closed on April 1, 1932, at which time all wethers were sheared. This clip is known as Series D.

At each shearing the wethers were machine sheared and the fleeces were tied separately. A sample of each fleece was taken from the heart girth midway between the back and belly. Portions of the samples were used for laboratory determination and other portions were taken to the Department of Agricultural Chemistry Research and used in determining the cystine content of the wool. The fleeces were then shipped to the Agricultural and Mechanical College of Texas for scouring.

Effect of the Ration on Weight of Fleece

Since there is a variation of several days in each feeding period, it was thought advisable to get the average amount of wool produced for a 30-day period of each series.

Table I shows the average amount of wool produced by each lot and the percentage increase over the previous period. These figures are based on a 30-day average for each series.

It should be pointed out that all of the weights of fleeces are subject to the error incident to removal of small samples of wool. These samples were taken to furnish material for the measurement of growth, diameter of fiber, breaking strength, and crimps per inch. A small sample was also taken in order to determine the percentage of cystine in the wool. The total weight of the samples removed was quite small, and was practically the same for each fleece.

Table I shows that Lot I made the greatest gain in grease wool produced during the experimental period. The sheep in this lot averaged 19.6% more grease wool for the three periods than they did at the initial clip. The other four lots, which remained on the same plane of nutrition throughout the course of the experiment, show a decrease in average amount of grease wool produced. The greatest decrease was in Lot V. The wethers in this lot produced 13% less grease wool while in the feed lot than they did on the range. This same lot showed the greatest increase in average amount of scoured wool produced during Series B and C as compared to Series A. This increase amounted to 58.6%. During the latter part of this trial the wethers in Lot V were "off feed" and the production of scoured wool in Series D was considerably less than in Series B and C. Lot III, which was receiving cottonseed meal, showed the smallest increase—only 26.5%.

If the initial clip may be taken as a fair measure of the wool producing capacity of the sheep, these figures would indicate that the wide ration had a greater effect on amount of clean wool produced than either the medium or narrow rations, while the narrow ration of cottonseed meal had the least effect.

Lot I produced slightly more grease wool during Series B than during Series A, but they produced a smaller amount of wool at the initial clip than five of the other six lots. The two wethers in Lot VII that were receiving the same ration as those in Lot I also showed a slight increase in amount of grease wool produced during the second period as compared to the first. The only other increase in amount of grease wool produced during Series B was by the two wethers in Lot VI that were receiving 2 lbs. of feed each per day.

During the third period, or Series C, the wethers in Lot I continued to produce more grease wool than they did during either of the first two periods, although the wether in Lot VII receiving the same ration as those in Lot I showed a decrease of 9.7% during Series C as compared to Series A and a decrease of 12.64% during C as compared to B. It must be remembered that this wether had been on a sub-maintenance ration during Series B.

Lots II, III and IV, which were on high protein rations, produced more grease wool at the initial clip than they did at any of the succeeding clips. The same is true of Lot V, which was fed a high carbohydrate ration.

Lot I, which showed an increase in amount of grease wool produced during Series B and C as compared to A, also showed an increase in amount of clean wool produced during these same periods.

Lots II, III, IV and V all produced more clean wool during Series B and C than they did during Series A, even though they show a decrease in

TABLE I.—The Effect of the Ration on Weight of Fleece.

Lot No.	SERIES A		SERIES B				SERIES C				SERIES D			
	Grease weight (lbs.)	Scoured weight (lbs.)	Grease weight (lbs.)	Percent Increase	Scoured weight (lbs.)	Percent Increase over A	Grease weight (lbs.)	Percent Increase	Scoured weight (lbs.)	Percent Increase over B	Grease weight (lbs.)	Scoured weight (lbs.)	Percent increase	Percent Increase over C
I	.648	.253	.701	8.18	.339	34	.810	15.54	.403	18.88	.814	.49	.471	14.39
II	.792	.247	.745	− 5.94	.374	51.42	.766	2.82	.375	.27	.771	.65	.409	9.06
III	.780	.253	.681	−12.69	.324	28.06	.733	7.63	.315	− 2.77	.765	4.36	.372	18.09
IV	.795	.201	.662	−16.73	.228	13.43	.763	15.26	.350	53.50	.732	− 4.06	.334	− 4.57
V	.731	.203	.671	− 8.21	.304	49.75	.677	.9	.340	11.84	.561	−17.13	.275	−19.1
VI	.625	.212	.755	20.8	.320	50.94	.694	− 8.08	.323	.94	.198	−71.47	.367	13.6
*VI	.588	.234	.397	−32.48	.218	− 6.84	.661	66.50	.323	48.16	.417	−36.91	.170	−47.3
VII	.750	.243	.775	3.33	.376	54.73	.677	−12.64	.323	−14.09	.720	6.35	.321	− .6
*VII	.669	.240	.566	−15.40	.306	27.50	.564	.4	.290	− 5.23	.470	−16.66	.227	−21.7

*Sub-maintenance ration.

TABLE IA.—Effect of Plane of Nutrition on Weight of Fleece.

Wether No.	SERIES A			SERIES B			SERIES C			SERIES D		
	Feed consumed daily	Grease wool (lbs.)	Clean wool (lbs.)	Feed consumed daily (lbs.)	Grease wool (lbs.)	Clean wool (lbs.)	Feed consumed daily (lbs.)	Grease wool (lbs.)	Clean wool (lbs.)	Feed consumed daily (lbs.)	Grease wool (lbs.)	Clean wool (lbs.)
145	Range	.588	.239	2	.715	.327	1	.694	.323	1.3	.198	
149	Range	.588	.232	1.10	.397	.219	1.9	.661	.323	1	.417	
142	Range	.750	.243	2.03	.755	.376	1.2	.564	.290	2	.720	
133	Range	.559	.232	1.10	.603	.282	1.93	.677	.323	1.02	.470	

amount of grease wool produced during the same periods. This indicates that the wool produced by these wethers while they were on the range contained more foreign matter or grease than the fleeces grown during the subsequent periods in the feed lot.

Table IA shows the effect of the plane of nutrition on the amount of wool produced by the four wethers in Lots VI and VII that were sheared at the end of each period.

Wethers Nos. 145 and 149 were fed a ration of equal parts corn and hay, while wethers Nos. 133 and 142 were given a ration of four parts hay, four parts corn, and one part linseed oil meal.

Wether No. 145 produced more grease and scoured wool during Series B while receiving 2 lbs. of corn and hay than he did on the range the previous period. When he was placed on 1 lb. of this same feed he continued to produce a greater amount of both grease and scoured wool than he had on the range during Series A, but he showed a slight decrease during this period as compared to Series B. During Series D this wether went off feed and refused to eat more than 1.3 lbs. per day. As a result he produced 28.5% as much grease wool as he did the previous period. He was posted at the close of the experiment and was found to be anemic as a result of malnutrition. The heart and kidneys were in an edematous condition and the rumen was full of food although the third and fourth stomachs were empty and edematous.

Wether No. 149 produced a smaller amount of both grease and scoured wool during Series B, while he was receiving one pound of the high carbohydrate ration daily, than he did during Series A, while on the range. When his ration was changed to 1.9 pounds per day the production of both grease and clean wool increased over the two previous periods. During Series D he was given 1 lb. of feed per day and showed a decrease in amount of grease wool produced as compared to the previous period, but an increase over B when he was receiving 1.1 pounds per day of the same ration.

Wether No. 142 showed an increase in amount of grease wool produced and a marked increase in amount of clean wool produced during Series B, while receiving 2.03 pounds of the normal ration of corn, hay and linseed oil meal, as compared to the previous period on the range. When subjected to the lower plane of nutrition during the third period he produced less grease wool than he had during either of the previous periods, and he also showed a decrease in amount of clean wool as compared to Series B, but produced 19.34% more clean wool than during Series A. During Series D this wether received 2 lbs. of feed per day and showed an increase of 27.66% in amount of grease wool produced as compared to the previous period, although he still produced slightly less grease wool than he did during Series A and B.

Wether No. 133 produced more grease wool and clean wool while receiving 1.1 lbs. of the normal ration than he did on the range. The production of wool was further increased when the ration fed was 1.93 lbs. per day. In Series D the ration was 1.02 lbs. per day. The wool produced during this series was considerably less than during Series C.

Effect of the Ration on Length of Staple

Table II shows the average length of staple produced for a 30-day period during each series.

By comparing Tables I and II it is seen that the increase in staple length is not always the same as the increase in amount of scoured wool produced.

TABLE II.—The Effect of the Ration on Length of Staple

	SERIES A	SERIES B		SERIES C		SERIES D	
Lot No.	Length of staple (mm.)	Length of staple (mm.)	Percent increase over A	Length of staple (mm.)	Percent increase over B	Length of staple (mm.)	Percent increase over C
I	4.6	6.2	34.80	5.8	− 6.45	5.7	− 1.70
II	4.8	7.1	47.90	6.1	−14.08	6.0	− 1.60
III	4.5	5.9	31.10	5.2	−11.86	5.7	9.60
IV	4.6	5.9	28.28	6.0	1.69	5.0	−16.60
V	4.6	6.1	32.61	5.9	− 3.27	5.7	− 3.40
VI	3.9	5.6	43.50	5.4	− 3.50	4.1	−24.07
*VI	4.6	5.6	21.70	5.2	− 7.10	4.5	−13.40
VII	4.6	6.8	47.80	5.7	−16.10	5.4	− 5.20
*VII	4.4	6.1	38.63	5.5	− 9.80	5.4	− 1.80

*Sub-maintenance group.

The wethers in Lot I produced 34% more clean wool during Series B than they did during Series A, while the increase in staple length was 34.8%. However, they showed an increase of 18.88% in amount of scoured wool produced during Series C as compared to B, while the length of staple decreased 6.45%. The two wethers in Lot VI that were on the sub-maintenance ration produced 6.84% less scoured wool during Series B than they did during A, yet they showed an increase of 21.7% in staple length. This seems to indicate that factors other than length of staple are involved in determining the amount of clean wool produced. This is in agreement with results reported by Vaughan, Joseph and Vinke (1927).

The longest staple was produced in each series by the wethers in Lot II but in no case did they produce the greatest amount of scoured wool. This raises the question of whether or not the narrow ration containing linseed oil meal is responsible for the greater staple length. Table II shows that this lot produced a longer staple while on the range, therefore their production of a longer staple during the experiment might be attributed to some other factor, such as individuality, rather than to the ration fed.

Effect of the Ration on Diameter of Fiber

The micrometer caliper was used to measure the diameter of the wool fiber. One hundred fibers were measured from each fleece, the samples being taken from the heart girth. Measurements were made approximately midway of the fiber, the same operator making all measurements. Table III shows the average diameter of fiber produced by each lot during each period, with the percentage increase over the previous period.

It has previously been shown that increase in staple length did not account for all the increase in amount of scoured wool produced.* The question arises whether or not this difference can be accounted for by increase in diameter of fiber. By comparing Tables I, II and III it is seen that at least some of this difference may be accounted for by changes in diameter of fiber, but it appears there are factors other than length and diameter that influence the amount of clean wool produced. Table III shows that all lots, except the two wethers in Lot VI that were receiving 2 pounds of feed daily, produced a smaller fiber during Series B than they did during the previous period on the range. All wethers produced a larger fiber during Series C than they did during the previous period, although Lots II and IV and the sub-maintenance wether in Lot VII produced a smaller fiber than they did while on the range.

*See Tables I and II.

TABLE III.—Effect of the Ration on Diameter of Wool Fiber
(Diameters expressed in ten thousands of an inch)

Lot No.	SERIES A	SERIES B		SERIES C		SERIES D	
	Diameter of fiber	Diameter of fiber	Percent increase over A	Diameter of fiber	Percent increase over B	Diameter of fiber	Percent increase over C
I	4.71	4.11	−12.74	5.54	34.79	6.51	17.51
II	5.05	3.95	−21.78	4.65	17.72	5.83	25.37
III	4.87	4.18	−14.17	5.25	25.60	6.10	16.19
IV	4.98	3.95	−20.68	4.39	11.14	6.06	38.04
V	4.68	3.89	−16.87	5.26	35.22	5.41	2.85
VI	3.96	4.03	1.7	4.47	10.91	5.14	15.0
*VI	4.85	4.36	−10.09	4.88	11.92	5.54	13.54
VII	4.09	3.93	− 3.91	4.76	21.12	5.62	18.07
*VII	4.72	3.95	−16.31	4.54	14.93	6.19	36.34

*Sub-maintenance group.

During Series D every lot produced a larger fiber than they did during any of the previous periods. Lot VI showed an increase in each series in spite of the fact that wether No. 145 was off feed and in very poor condition during Series D.

Effect of the Ration on Breaking Strength and Stretch of the Wool Fiber

The McKinzie fiber testing machine was used to determine the breaking strength and stretch of the fibers. One hundred fiber samples were used and all measurements were made by the same operator.

Table IV shows the breaking strength and stretch of the fiber produced by the wethers in each lot during each series. The figures in this table indicate that the ration had a limited influence on breaking strength of the fiber during the first period in the feed lot. The sub-maintenance wethers in Lots VI and VII showing the greatest effect. The two wethers in Lot VII produced a fiber that was 24% weaker than that produced during the previous period. The sub-maintenance wethers in Lot VI produced a fiber that was about 20% weaker than that produced on the range.

TABLE IV.—Effect of Ration on Breaking Strength and Stretch of the Wool Fiber

Lot No.	SERIES A		SERIES B		SERIES C		SERIES D	
	Breaking strength (gm.)	Stretch (mm.)	Breaking strength (gm.)	Stretch (mm.)	Breaking strength (gm.)	Stretch (mm.)	Breaking strength (gm.)	Stretch (mm.)
I	6.699	3.85	6.930	4.32	10.355	4.98	11.244	5.61
II	7.281	3.74	7.181	4.48	8.910	5.05	10.440	5.59
III	6.589	3.69	6.328	4.42	9.288	4.56	10.684	5.49
IV	6.540	3.72	5.597	4.11	7.428	4.92	10.128	5.46
V	6.632	3.88	5.578	4.51	8.718	4.90	9.404	5.39
VI	6.053	3.79	7.015	4.57	7.685	4.88	8.605	5.51
*VI	6.070	3.93	4.848	4.22	8.875	4.83	10.102	5.40
VII	7.020	3.97	7.133	4.47	7.450	4.78	10.658	5.46
*VII	8.838	3.60	6.703	4.39	6.400	4.63	10.913	5.42

*Sub-maintenance group.

During Series C all wethers except the sub-maintenance wethers in Lot VII produced a stronger fiber than they did during either of the previous periods.

All wethers produced a stronger fiber during Series D than they did during Series A, B, or C. The two wethers in Lot VI on regular feed produced a slightly weaker fiber than did the wether which was on a sub-maintenance ration during Series C. It should be remembered that wether No. 145 was in this group and that he was in very poor condition during the final feeding period. Even then these wethers produced a stronger fiber than they did during either Series A or B.

The figures in Table IV indicate that the ration fed had a greater effect on strength of fiber during Series D than during either Series B or Series C. By comparing the fiber produced during this period with the fiber produced during Series A, it is found that Lot I showed the greatest increase in breaking strength. This lot produced a fiber during the final period that was 67.8% stronger than the one produced during Series A. The two wethers in Lot VI that were on a sub-maintenance ration during Series B and D and the regular feed of the wide ration during Series C produced a 66.4% stronger fiber during the final period than they did on the range. Lot V produced a fiber during Series D that was 41.8% stronger than that produced during Series A. This was the smallest percentage of increase shown by any of the lots except the sub-maintenance wethers in Lot VII.

All lots in the experiment produced a more elastic fiber during each series than they did the previous series. Lot II showed the greatest increase in stretch when one considers the average for the three periods in the feed lot as compared to the initial clip produced while on the range. The average fiber produced by this lot during the three series was approximately 35% more elastic than the fiber produced by the same lot during Series A. The two wethers in Lot VI which were fed the sub-maintenance ration during Series B and D and the regular ration during Series C showed the smallest increase when the average of these three periods is compared to A. The fiber produced by these wethers while in the feed lot was approximately 23% more elastic than that produced on the range. Lot V, which received the regular feed of the wide ration during the course of the experiment, showed an increase of only 27%; while the other three lots that were on the regular amount of feed during the experiment, i. e., Lots I, III and IV, showed an increase in stretch of fiber of 29, 30.7 and 30% respectively. It seems reasonable to assume that the effect of the ration should be more pronounced during Series D than during any of the previous series. A comparison of Series D and A, shows that wethers in Lot II produced a fiber during Series D that was 49.5% more elastic than that produced during Series A. The two wethers in Lot VI which were given a sub-maintenance ration during Series B and D and the regular ration during Series C show the smallest increase in stretch of fiber. The difference here between the period on the range and the final period in the feed lot is 37.4% in favor of D. It should be remembered that these same wethers produced a 66.4 stronger fiber during Series D than Series A, being exceeded only by Lot I in this respect.

Correlation Between Crimp and Diameter

Table V shows the crimps per inch as calculated from the average of 100-fiber samples from each fleece.

From a comparison of Tables III and V it appears that there may be a relationship between diameter of fiber and crimps per inch. In order to find whether or not there was a definite correlation between these two characters, the authors determined the correlation coefficient for the ninetynine 100-fiber samples that were measured during this experiment. The coefficient between crimps per inch and diameter of fiber was −.512±.074.

TABLE V.—Average Crimps per Inch of the Wool Fiber

Lot No.	A	B	C	D
I	13.55	13.27	9.29	10.97
II	13.24	12.71	10.97	10.81
III	13.70	13.21	9.43	11.19
IV	13.60	12.95	10.07	10.39
V	13.48	13.15	10.61	11.33
VI	12.85	12.43	10.92	10.95
*VI	13.50	12.68	11.00	11.81
VII	13.59	12.95	10.38	11.28
*VII	13.49	13.19	10.90	10.64

*Sub-maintenance group.

Hultz (1927), working with Rambouillet sheep, both male and female, found a coefficient of −.321±.081 between crimp and fineness of shoulder samples. In a later investigation, Hultz and Paschal (1930) found a coefficient of −.23±.02 between crimp and diameter of shoulder samples. Reimers and Swart (1931) report a coefficient of −.401±.084 between crimp and diameter in Merino wool.

Davenport and Ritzman (1926) report a coefficient of −.216±.094 between crimp and diameter in Rambouillet wool.

Correlation Between Cystine Consumed and Cystine Content of the Wool

Gebhard (1914) suggests that the wool fiber contains an amino acid and a colloidal substance loosely attached to the amino group.

Since wool is known to contain cystine, a number of investigations have been conducted in recent years to determine the effect of cystine-rich feed on the growth and composition of the wool fiber.

TABLE VII.—Comparison of Cystine Consumed and Cystine in Wool

		SERIES A		SERIES B		SERIES C	
Wether No.	Lot No.	Percent of Cystine in Wool	Percent of Cystine in Ration	Total Cystine Consumed (lbs.)	Percent of Cystine in Wool	Cystine Consumed (lbs.)	Percent of Cystine in Wool
135	I	12.000	.0145	4.6363	10.8966	5.7109	12.1827
144	II	9.600	.0214	6.8181	12.1700	7.3986	14.8258
180	II	12.800	.0214	6.7213	11.1021	7.2792	11.8111
147	III	10.6666	.0135	4.4760	11.2009	4.8964	14.6790
140	III	13.1883	.0135	4.5973	11.1914	5.0471	11.7073
148	IV	9.8000	.0553	16.6599	10.0156	20.5205	13.5337
131	IV	11.1111	.0553	16.3380	9.4704	20.1250	12.3116
128	V	9.0745	.0085	2.4899	10.6076	3.0671	8.8883
145	VI	12.4382	.0085	1.7070	9.5683	1.7074	10.6202
149	VI	12.8345	.0085	1.4118	10.0313	2.9039	11.8252
142	VII	9.8891	.0145	4.4446	11.5169	3.3712	9.7567
133	VII	11.5394	.0145	2.4622	10.7865	5.2052	8.6331

The five rations fed in this experiment differed as to percentage of cystine contained. Accurate records were kept of the amount of feed consumed, and the amount of cystine consumed was figured from this

Table VII shows the amount of cystine consumed during each period and the amount stored in the wool. The cystine determinations were made by the Department of Agricultural Chemistry Research. The Sullivan* method was used in making the determinations.

The amount of cystine consumed during Series A is not known, but it is assumed that all wethers received approximately the same amount.

Table VII includes only the figures for the 12 wethers from which cystine determinations were made at each shearing.

TABLE VIIA.—Changes in Percentage of Cystine Content of Wool between Series A and Series D

Lot No.	Percent Cystine in Ration	Average of Series A	Average of Series D	Percentage of Cystine Increase
I	.0145	11.1849	11.8855	6.26
II	.0214	10.1486	11.4695	13.01
III	.0135	11.5172	12.5350	8.8
IV	.0553	10.8091	13.1390	21.5
V	.0085	10.2525	12.0775	17.8
VI	.0085	11.9798	11.0400	– 7.8
VII	.0145	11.4209	11.12125	– 2.7

It would seem from Tables VII and VIIA that there is an optimum of cystine consumption. Cystine fed in excess of this optimum has little or no effect on the cystine content of wool. The figures shown here do not indicate the optimum amount, but it seems safe to assume that any ration that contains ample protein will contain ample cystine.

Table VII shows that wethers Nos. 148 and 131 consumed slightly over 20 pounds of cystine during Series C, yet the percentage of cystine in the fleece was less than that in the fleece of wether No. 147, which received only 4.9 pounds of cystine during the same period.

Effect of the Ration on Body Weight

The difference in body weight at the beginning of the experiment is shown in Table VIII. Each wether was weighed at three-week intervals and body measurements were taken. The measurements taken were length of body, length of leg, width of chest, depth of chest, width of loin, and girths of paunch, heart and flank. The wethers were approximately 19 months of age at the time this experiment was started and there was very little difference in changes of the body measurements of the wethers except those maintained on sub-maintenance rations. Therefore this phase of the experiment was considered of little importance.

TABLE VIII.—Effect of the Ration on Body Weight

Lot No.	Weight at Beginning of Experiment (lbs.)	Weight at Close of Experiment (lbs.)	Percent Increase
I	67.0	110.5	64.92
II	69.9	108.0	54.50
III	67.1	97.5	45.31
IV	67.1	110.3	64.38
V	67.1	92.2	37.41

*For a complete discussion of this method see the thesis of J. Long in the library of the Oklahoma A. & M. College, or "Cystine Content of Sheep Wool as Affected by Diet," by J. E. Long, V. G. Heller, and A. E. Darlow, Oklahoma Academy of Science Proceedings, Vol. XIII, p. 12 (1933).

Table VIII shows the change in body weight of the five lots that were continued on the same plane of nutrition throughout the course of the experiment.

This table shows that the wethers in Lot I, which received a ration with a nutritive ratio of 1:7.02, made the greatest gain in body weight during the experiment. The wethers receiving the wide ration of corn and hay made the least gain. These figures do not show the actual gain, since the initial weight was taken 43 days after shearing, while the final weight was taken just previous to shearing. This table, however, serves very well as a basis for comparison.

Table VIIIA shows the effect of the plane of nutrition on the weight of the four wethers that were placed on the sub-maintenance ration during alternate periods. The percentage of increase or decrease in body weight is figured for each series and compared to the series immediately preceding.

TABLE VIIIA.—Effect of Plane of Nutrition on Body Weight

Wether No.	Initial Weight (lbs.)	Weight at Close of Series B (lbs.)	Percent of Increase During Series B	Weight at Close of Series C (lbs.)	Percent of Increase During Series C	Weight at Close of Series D (lbs.)	Percent of Increase During Series D
145	73	83	13.7	79*	– 4.8	57	–27.8
149	58	57*	– 1.7	84	47.4	67*	–20.2
142	72	89	23.6	85*	– 4.5	98	15.3
133	62.5	60*	– 4.0	92	53.3	70*	–23.9

*Indicates sub-maintenance ration.

Wether No. 145 should be considered as one of the sub-maintenance group during Series D, since he refused to eat all of the feed placed before him. He consumed only 1.3 lbs. of feed per day during this period.

A comparison of Tables IA and VIIIA indicates that the plane of nutriton has slightly more influence on the amount of clean wool produced than it does on body weight.

Table VIIIA indicates that the wethers receiving one pound of the wide ration per day did as well as those reciving one pound of the normal ration. When the amount was increased to 2 lbs. per day, however, the wethers on the normal ration made more rapid gains than those receiving the wide ration.

DISCUSSION OF EXPERIMENT I

The entire fleece was scoured to determine the clean weight. It is generally known that small samples of wool from any part of the fleece do not give accurate results in scouring tests.

The results of this experiment indicate that the ration fed to the wethers in Lot I had the greatest effect on amount of grease wool produced and gain in body weight. This agrees with the findings of Wilson (1931) that a fattening ration also acts as a stimulus to the sebaceous glands in the production of yolk.

These results also indicate that the organs which are concerned with the secretion of the wool fiber may be affected by such influences as drastic changes in the level of feeding for a short period. The function of these organs is easily disturbed when the sheep becomes abnormal in health. The growth of wool is reduced when the ration is insufficient for maintenance and the amount of wool fiber produced seems to be affected to a greater extent than body weight.

Samples of 100 fibers each were used for measurement of length, diameter, breaking strength, stretch and crimps per inch. These 100-fiber samples may not represent the absolute average for the entire fleece; but since all samples were taken from the same location, and since in one case the 100-fiber sample was checked against a 1000-fiber sample with approxiate agreement, it was thought advisable to use 100-fiber samples.

Wilson (1931), Joseph (1926), and Burns and Koehler (1925) report results based on 100-fiber samples. Burns (1931) in a later paper suggests that, in studying effect of environment on measureable fleece characters, samples from a tattooed area in the side region should give satisfactory results.

Hill (1930) states that 100-fiber samples are too small a number for accuracy, but he shows further that variations occur even when 1000-fiber samples are used.

There was considerable variation in staple length in lots from series to series; however, during the entire experiment Lots I, II, III, and V show the greatest increase in staple length. Lot IV, which was receiving a high protein ration, the protein being furnished in the form of corn glutten meal, and Lots VI and VII, which include the wethers that were on half ration, show the least increase in this measurement. Measurements of staple length were made by laying a rule alongside of the staple on a dark background.

The McKenzie fiber testing machine was used to determine strength and stretch. This machine has been used by Hill (1912), Joseph (1926), Hardy (1920), and Wilson (1931).

A machinist's micrometer caliper was used for measuring the diameter of fibers. Burns and Koehler (1925) found that the average miscroscopic measurements of any sample were larger than the average caliper measurements. For all practical purposes this difference amounts to .0001 inch.

Hardy (1920) has shown that humidity has an influence upon strength and elasticity of the wool fiber. The measurements for this experiment were not made in a control room, as none was available. The samples were put in a dessicator and allowed to dry at least 24 hours before measurements were made. A check was made by the U. S. D. A. and results indicate that the methods used were satisfactory.*

Cooke and Jones (1890) noticed that the wool fiber shrinks when sheep are in poor health, but this was not true with wether No. 145. He was in a very poor condition during Series D, yet produced a larger fiber than during any of the previous periods. This may be due to the fact that measurements were made midway of fiber and the further possibility that this wether was in such poor physical condition that the wool fibers grew very little or not at all during the period of sickness. Stretch and strength of fiber were decreased, but crimp was not affected.

EXPERIMENT II: FURTHER STUDIES OF THE EFFECT OF RATION ON WOOL GROWTH AND ON CERTAIN WOOL CHARACTERISTICS

The results secured in Experiment I were such that it was thought advisable to check them further and to include a new ration low in cystine. Accordingly, in the spring of 1932, 16 wethers, originally in Lots I, II, III, and IV, were redivided and placed on experimental rations. One wether from each of the four lots in Experiment I composed each lot in this experiment. This was done to equalize any carry-over effect from previous experimental rations.

---

*Unpublished data. A. E. Darlow, Oklahoma A. & M. College.

The original wool clip taken from these wethers in 1930 was used as a basis of comparison with the clip that was grown on the experimental rations during the period of Experiment II. A number of the differences shown by the measurements in Table IX can be accounted for by changes that had taken place between 1930 and the beginning of this experiment. These figures are used, not to represent absolute increases or decreases in the different measurements, but rather from the standpoint of percentage of increase or decrease. As suggested previously,* the original wool clip represents an unknown period of growth; but it was estimated to be 210 days. Fleece weights and staple lengths are subject to whatever error is present in this estimate.

Rations Fed

Lot I received a ration of prairie hay, yellow corn, and corn gluten, with a nutritive ratio of approximately 1:4.80. This is the same ration fed Lot IV in Experiment I. Lot II received prairie hay and yellow corn with a nutritive ratio of 1:10.6. Lot III received prairie hay and soy beans, with a nutritive ratio of 1:6.5. Lot IV received prairie hay, yellow corn, and linseed oil meal, with a nutritive ratio of about 1:7. Lot IV represents what was called in Experiment I the "normal ration." Lot I is high in cystine. Lot II is high in carbohydrate. Lot III is the only new ration included.

Soy beans have been found to be deficient in the amino acid cystine when the protein is fed at a level of 10 or 15 percent in a purified ration. The soy beans in the experiment were fed in amounts sufficient to balance the ration and were fed with prairie hay. It was thought that this ration might be low enough in cystine to show some effect on the cystine content of the wool.

Diameter

Reference to Table IX shows an increase in diameter from 4.8% in Lot IV to 26% in Lot II. As suggested above, part of the change in diameter had come about before the wethers were placed on this experiment, but since all lots are comparable as to previous treatment this should not constitute a major objection to using these figures as they are used here. These results certainly indicate no lack of wool growth on the poorly balanced ration of corn and prairie hay. If, as has been suggested by Hardy and Tennyson (1930), the diameter of the fiber is an indication of thriftiness and well being of the sheep, it follows that this ration is satisfactory for wool production, at least if it is not fed for a period of more than 12 months.

Length

Length of staple increased from 6.8% for the wethers receiving the prairie hay and corn ration to 17.8% for those receiving the prairie hay, corn, and corn gluten ration. Results secured with the other two rations approach closely those secured with the ration containing corn gluten. It has been suggested by Wilson (1927) that the more rapid growing fibers are the largest, but that has not proved to be the case in this experiment. The small number of sheep used and the size of the samples measured may account in part for the lack of agreement of this work with that of Wilson.

Crimp

Wilson (1931) working with Romney sheep has shown that crimp of wool is influenced by the ration fed. Norris and van Rensburg (1930) have suggested that the crimp is a direct result of the element "time" rather than some other factor. In the present experiment the crimps per inch have decreased in every case. A number of workers have suggested the negative

*See page 7.

correlation of crimp and diameter; and therefore Experiment II might be expect to show a decrease in crimps per inch, since these fibers are both larger and longer than the fibers produced in Series A, Experiment 1. However, this decrease in crimps per inch is quite small, varying from .45% in Lot II to 10.4% in Lot III. The crimp of wool is probably of little intrinsic value, but it is certainly of value as an indication of quality and fineness. Hultz (1927) has shown that crimps per inch is more closely associated with judges' ratings of fine wool sheep than is actual diameter. Hence the crimp is an important item in helping establish the value of the fleece, regardless of its actual worth.

Stretch

The increase in stretch ranged from 32.6% for Lot III to 50.3% for Lot II. The other two lots approach Lot III very closely.

Breaking Strength

The breaking strength increase varies from minus 4.8% for Lot II to plus 11.5% for Lot III. Hill (1912) has shown that this measurement, as well as that of stretch, is not dependable, especially on samples as small as those used in this work. Several workers have shown a positive correlation between diameter and breaking strength. Diameter of fiber in Lot II increased 26% and breaking strength decreased 4.8%. All of the other lots show an increase both in diameter and breaking strength; but for the most part diameter increased considerably more than breaking strength.

Weight of Fleece

The increase in weight of clean wool varies from 33.6% for Lot II to 94.5% for Lot III. Lot I, receiving the ration containing corn gluten, increased 71.5%. The indication is that the ration composed of prairie hay and yellow corn does not meet all the requirements for wool production, particularly when the ration is fed over a long period of time. It was shown in Experiment I that after wethers had been on this ration for about 18 months they went off feed and declined in condition rapidly. The low cystine ration shows the greatest increase in clean wool production. This fact would support a statement made previously in this bulletin, namely: that a ration containing sufficient protein will in all probability contain sufficient cystine.

Cystine

The increase in cystine ranges from 8.5% for Lot I to 25.12% for Lot IV, the latter receiving the "normal ration." Lot III, receiving soy beans, showed an increase of 17.97% in cystine content of the wool. As has been suggested previously, the cystine analyses may be subject to considerable error; and the cystine content for the wool produced on experimental rations is probably higher than is the original fleece, partly due to improved technique and more refined methods used in the later determinations. Considered from the standpoint of comparative increase, there is an appreciable difference between Lot I on a high cystine ration and Lot III on a low cystine ration. Lot III, receiving the low cystine ration, showed the greater increase.

SUMMARY

Twenty-eight western wethers were divided into seven lots of four each and fed rations containing different amounts of protein and cystine. They were sheared before they were placed on experiment. This clip was used as a measure of their wool producing capacity.

Expriment I was divided into three phases of approximately six months each. Five lots were kept on an average daily feed of 2 lbs. per head. Two wethers in each of the other two lots were given 1 lb. of feed per day during

TABLE IX.—Comparison of Measurable Characters and Cystine Content of Wool in Series A, Experiment I, and Series E, Experiment II

Lot No.	DIAMETER (.0001 inch)			LENGTH (mm.)			CRIMPS (per inch)			STRETCH (mm.)		
	A	E	Percent increase	A	E	Percent increase	A	E	Percent increase	A	E	Percent increase
I	4.97	5.79	16.5	54.33	64.00	17.8	13.40	12.75	− 4.85	3.80	5.21	37.1
II	4.57	5.76	26.0	56.06	59.90	6.8	13.08	13.02	− .45	3.44	5.17	50.3
III	5.07	6.33	24.8	55.11	63.22	14.7	13.76	12.32	−10.4	3.59	4.76	32.59
IV	5.00	5.24	4.8	52.45	59.58	13.6	13.89	13.49	− 2.8	3.82	5.14	34.5

TABLE IX.—(Continued)

Lot No.	BREAK (gms.)			CLEAN WEIGHT (lbs.)			PERCENTAGE CYSTINE CONTENT OF WOOL		
	A	E	Percent increase	A	E	Percent increase	B	E	Percent increase
I	6.936	7.359	6.1	2.81	4.82	71.5	11.9707	12.99	8.5
II	6.627	6.308	− 4.8	2.62	3.5	33.6	10.5449	13.14	24.7
III	6.831	7.620	11.5	2.38	4.63	94.5	10.8531	12.80	17.97
IV	6.783	6.619	2.4	2.62	3.92	49.6	10.3459	12.95	25.12

RATIONS FED:
Lot I Prairie hay, corn gluten, and corn.
Lot II Prairie hay and corn.
Lot III Soy beans and prairie hay.
Lot IV Prairie hay, corn, and linseed oil meal.

one phase and changed to 2 lbs. during the next phase of the experiment.

All the wethers in this experiment with the exception of some of those on a sub-maintenance ration produced more clean wool during the experimental period than they did during the period they were on the range. Part of this increase may be due to the more advanced age of the wethers but undoubtedly part of it is due to a more satisfactory nutritional regime.

Lot I receiving what was considered a normal ration of corn, native hay and linseed oil meal showed a slightly greater increase in amount of grease wool produced than any of the other lots, and Lot V receiving the wide ration of corn and native hay showed a slightly greater increase in amount of scoured wool produced than any of the other lots.

The wethers subjected to the low plane of nutrition did not produce as much wool when on the sub-maintenance ration as they did when receiving the regular amount of feed.

The results secured in Experiment II do not entirely agree with those secured in Experiment I. The smallest increase in amount of clean wool produced during this period was in the lot receiving prairie hay and corn. The difference between the amount of wool produced in this lot and each of the other lots, but more particularly, the lot receiving soybeans and prairie hay is significant.

In Experiment I, Lot IV, receiving a high protein ration, and Lot VI, receiving corn and prairie hay, showed the smallest increase in length of staple during the experimental period. The incrase in length of staple did not account for all of the increase in weight of scoured wool produced.

The results on legnth of fiber secured in Experiment II agree closely with those of Experiment I; however, the smallest increase in length of fiber was in Lot II, receiving a ration of yellow corn and prairie hay.

In Experiment I the sheep receiving the normal ration produced the strongest fiber; but the wethers that were on a sub-maintenance ration of corn and hay for two of the three periods showed an increase in strength of fiber greater than that shown by any of the other five lots.

In Experiment II, Lot II (receiving a ration of yellow corn and prairie hay) produced wool that showed the greatest increase in stretch, but this was the only lot that produced a weaker fiber than the same sheep produced in Series A. These measurements are the least dependable of the measurements made during these trials and these diffrences may not be significant.

There was an appreciable difference in the change of crimps per inch among the different lots but it is not known whether these differences can be attributed to the difference in the rations.

Results secured in this experiment indicate that there is a rather close relationship between breaking strength and stretch.

The correlation coefficient between crimp and diameter, for the 99 samples measured in this experiment, was $-.512 \pm .074$.

The wethers in Experiment I receiving the normal ration showed the greatest increase in body weight, while those on the wide ration showed the least gain in body weight.

There seems to be an optimum of cystine consumption and the results of these experiments indicate that a normal balanced ration will contain ample cystine for body maintenance and wool growth.

The data secured in these two experiments would indicate that any ordinary balanced ration will allow sheep to produce wool which is normal in both quality and quanity. The amount or character of the wool produced by Rambouillet wethers may be affected by drastic changes in the kind or amount of the ration, but rations ordinarily considered quite unsatisfactory will not greatly influence the amount or quality of the wool unless continued for long periods of time. Wool production in fine wool wethers tends to remain normal as long as the sheep remain in normal health.

The wethers receiving an adequate amount of any ration fed during these two experiments produced more scoured wool than they did while on the range. This agrees with Hill's (1914) findings. The wethers in Lots VI and VII, receiving a sub-maintenance ration, produced less scoured wool than when they were on more liberal feed.

The diameter of fiber produced (by all wethers except those in Lot VI), during Series B shows a decrease when compared to Series A. This may be due to lack of well-being because of adjustment to the new conditions imposed on the wethers. All wethers except those on sub-maintenance ration show a marked increase in diameter of fiber during the subsequent periods of the experiment. This agrees with the findings of Hardy and Tennyson (1930) and Weber (1931). The increase in diameter of fiber during Experiment II was considerably greater in Lot II receiving corn and hay than in Lot IV receiving the "normal" ration.

BIBLIOGRAPHY

Armsby, H. P., The nutrition of farm animals. MacMillan, New York, pp. 327, 328, 711. 1917.

Barritt, John, The relation of the cystine yield to the total sulphur in wool. Jour. Soc. Chem. Ind. **46**:338-341. 1927.

Beadles, J. R., Braman, W. W., and Mitchell, H. H., The relation between cystine deficiency in the diet and growth of hair in the white rat. Jour. Biol. Chem. 88:623-627. 1930.

Burns, R. H., and Koehler, W. B., The micrometer caliper as an instrument for measuring the diameter of wool fibers. Wyoming Agr. Exp. Sta. Bul. No. **141**:15-28. 1925.

Burns, Robert H., Fleece analysis in sheep. Proceedings Amer. Soc. of Animal Production. pp. 246-258. 1931.

Cooke, W. W., and Jones, L. R., Wool and wool measurements. Vermont Agr. Exp. Sta. Rpt. **4**:55-64. 1890.

Cooke, W. W., The maintenance ration for sheep. Rpt. of the Pennsylvania State College, July 1, 1900, to June 30, 1901, p. 287.

Craig, J. A., Sheep feeding trials. II. Influence of different rations on the growth of wool and increase of live weight of fattening sheep. Wisconsin Agr. Exp. Sta. Annual Rpt. **8**:14-39. 1891.

Crowther, C., and Woodman, H. E., Study of nitrogen metabolism in the dairy cow. Jour. of Agr. Sci. **12**:40-41. 1922.

Davenport, C. B., and Ritzman, E. G., Some wool characters and their inheritance. New Hampshire Agr. Exp. Sta. Tech. Bul. 31, p. 9. 1926.

Gebhard, K., The presence of an amino group in wool. Jour. of the Soc. of Chem. Ind. **33**:856. 1914.

Hart, E. B., Influence of sulphur in feeds on wool production. Wisconsin Sta. Bul. No. 228. Report of the Director, 1911-12, pp. 37-38.

Hardy, J. I., and Tennyson, J. B., Wool fineness as influenced by rate of growth. Jour. Agricultural Research **40**: No. 5, p. 467. March, 1930.

Hardy, J. I., Further studies on the influence of humidity upon the strength and elasticity of wool fibers. Jour. Agricultural Research. **19**:55-62. 1920.

Hill, J. A., The value of fiber testing machines for measuring the strength and elasticity of wool. Wyoming Agr. Exp. Sta. Bul. No. 92, pp. 1-23. 1912.

Hill, J. A., Report of the wool specialist. Annual Rpt. of Agr. Exp. Sta., Univ. of Wyoming, 1913-14.

Hill, J. A., Studies in the variation and correlation of fleeces from range sheep. Wyoming Agr. Exp. Sta. Bul. No. 127, pp. 39-52. 1921.

Hultz, F. S., and Hill, J. A., Range sheep and wool. J. Wiley and Sons. 1931.

Hultz, F. S., Wool studies with Rambouillet sheep. Wyoming Agr. Exp. Sta. Bul. No. 154, p. 121. 1927.

Hultz, F. S., and Paschal, L. J., Wool studies with Rambouillet sheep. II. Wyoming Agr. Exp. Sta. Bul. No. 174, pp. 19-21. 1930.

Joseph, W. E., Effect of feeding and management of sheep on tensile strength and elasticity of wool. Jour. Agricultural Research. 33:1073-1089. 1926.

Joseph, W. E., Some important factors in lamb and wool production. National Wool Grower. pp. 21-24. April, 1930.

Lightbody, H. D., and Lewis, H. B., The relation of the protein and cystine content of the diet to the growth of hair in the white rat. Jour. Biol. Chem. 82:496-97. 1929.

Lush, J. L., and Jones, J. M., The influence of individuality, age and season upon the weights of fleece produced by range sheep. Texas Agr. Exp. Sta. Bul. No. 311, pp. 5-6. 1923.

Mitchell, H. H., Kammlade, W. G., and Hamilton, T. S., A technical study of the maintenance and fattening of sheep and their utilization of alfalfa hay. Univ. of Illinois Agr. Exp. Sta. Bul. No. 283, pp. 2-22. 1926.

Norris, M. H., and van Rensburg, P. J. J., Crimp in wool as a periodic function of time. Textile Institute Jour. 21T:481-98. Oct., 1930.

Reimers, J. H., and Swart, J. C., Correlation between crimp and diameter of wool. Reprint from South African Journal of Science. 28:315-322. 1931.

Riches, J. H., Sheep feeding experiments at Muresk Agricultural College. Jour. of Dept. of Agriculture. 8: Second Series, No. 4, pp. 541-47. Dec., 1931.

Roberts, I. P., and Wing, H. H., The effect of different rations on fattening lambs. Cornell Agr. Exp. Sta. Bul. No. 8, pp. 81-83. 1889.

Shrewsbury, Charles L., and Bratzler, John W., Cystine deficiency of soybean protein at various levels, in a purified ration and as a supplement to corn. Jour. Agr. Research. 47: No. 11, pp. 889-893.

Skinner, J. H., and Smith, W. W., Corn silage for winter feeding of ewes and young lambs. Indiana Agr. Exp. Sta. Bul. No. 147, pp. 619. 1910.

Spencer, D. A., Hardy, J. I., and Brandon, M. J., Factors that influence wool production with range Rambouillet sheep. U. S. D. A. Tech. Bul. No. 85. 47-48. 1928.

The Pastoral Review, p. 362. April 16, 1931.

Vaughan, H. W., Joseph, W. E., and Vinke, L., Length of staple in relation to weight of fleece. Montana Sta. Rpt., pp. 49-79. 1927.

Weber, A. D., The effect of the plane of nutrition on wool growth. Proceedings of the Amre. Soc. of Animal Production. Nov. 27-28. pp. 228-30. 1931.

Wilson, J. F., Wool production in California. California Ext. Cir. No. 12, p. 27. 1927.

Wilson, J. F., The influence of the plane of nutrition upon various factors related to wool production. The National Wool Grower, 31:23-28. Dec., 1931.