THE EFFECT OF THE LEVEL OF NUTRITION ON REPRODUCTION AND LACTATION OF EWES

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By

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INTRODUCTION

Excessive cattle losses have been reported in various parts of eastern Oklahoma during the past few years. In 1947 Ross and Gallup obtained preliminary data that the losses occurred during the late winter and early spring months and were confined mainly to pregnant and lactating cows. The disturbance was manifested in reproductive failures, thin and emaciated animals, and actual death losses in many instances. Red blood cell and hemoglobin values of afflicted animals were consistently low, indicating an anemic condition. The blood values for calcium, phosphorus, vitamin A and carotene were normal, even in the most seriously affected animals.

In 1948 Whitehair, Ross, and Gallup reported that they could not incriminate parasites or any contagious disease as a primary cause of these losses. They also found that the losses seemed to be associated mainly with the type of roughage being fed. Cattle fed good quality legume hays were not affected with this disturbance while trouble was encountered when the cattle were fed poor quality native prairie hay.

In 1949 Whitehair, Gallup, and Ross, using sheep as experimental animals, demonstrated that they could produce symptoms in both the ewes and their lambs that were very similar to the symptoms reported by eastern Oklahoma cattle raisers. These symptoms were produced by feeding ewes during pregnancy a ration consisting almost entirely of native prairie hay from eastern Oklahoma. On this ration the ewes became weak and anemic at lambing time. Rations with added protein supplement in the form of corn gluten meal gave a reproduction-lactation performance that was almost normal. Some additional benefit was obtained when a complete trace mineral mixture was added as a supplement to a lot receiving the protein supplement and prairie hay.

The research reported in this thesis was essentially a continuation of the study to obtain additional information as to the nutritive requirement of cattle in eastern Oklahoma. Sheep were used as experimental subjects in that they could be used with greater economy and ease of handling and they have a nutritive requirement somewhat similar to cattle—both species being ruminating animals. The experiment was designed primarily to find out what nutrients were needed to supplement a basal ration of hay from eastern Oklahoma to provide for normal reproduction and lactation in ruminants. Special emphasis was given to the value of increasing the protein and energy content of the basal hay ration. Since an anemia was one of the clinical symptoms observed in the cattle losses in eastern Oklahoma, the role of trace minerals in this disorder was also to be evaluated.

LITERATURE REVIEW

Very few studies have been reported on the specific effects of the level of nutrition on reproduction and lactation of sheep. Undoubtedly many factors will affect reproduction and lactation in sheep, but this review of literature is limited to the more specific studies on this problem. Most of the literature pertaining to this work was reported after this study was initiated.

Wallace (1949) made a detail three-year study in New Zealand of this problem using Suffolk and Border-Leicester x Cheviot crossed ewes. The purpose of his experiments was to establish feed requirements of the ewes for the purpose of maintenance, live-weight gain, and milk production and to study the growth of lambs receiving different amounts of milk and concentrates. He also investigated the effect of different levels of nutrition during pregnancy on the birth weights of the lambs and milk yield during lactation. Border-Leicester x Cheviot ewes were used in the experiments in 1943 and 1944. They were fed a concentrate mixture consisting of crushed oats 30 per cent, bran 20 per cent, dried brewers grains 20 per cent, linseed cake (crushed) 10 per cent, white fish meal 10 per cent, sugar-beet pulp (dried) 8 per cent, and mineral mixture 2 per cent.

In 1943 the ewes were divided into three groups and fed different levels of nutrients during the last six weeks of pregnancy. One group received a super-maintenance ration of 1.2 to 1.9 pounds of sanfoin hay and from 2 to 2.9 pounds of concentrates daily for each ewe. The maintenance group was given enough sanfoin hay (approximately 2 pounds per day each) to prevent a gain or loss of live-weight. The ewes of the sub-maintenance group, which were fed so as to lose body weight, were given barley straw only, in the amounts of 1 to 1.5 pounds each daily.

In 1944 the ewes were all fed sanfoin hay during the first 15 weeks of pregnancy and in some cases small amounts of concentrates in order to maintain a constant body weight. At the end of this period the ewes were divided into two groups. The high-plane group was fed 0.5 pound concentrates per day and sanfoin hay *ad libitum*, with the average daily consumption of hay from 3.7 to 5.2 pounds. The low-plane ewes were fed sanfoin hay only in amounts adjusted so that they would lose weight; they consumed about 1.3 pounds per day.

In 1943 the ewes in the super-maintenance group gained 30.7 pounds, the maintenance group lost 1.2 pounds and the sub-maintenance group lost 13.9 pounds. In 1944 the high-plane ewes gained 40 pounds whereas the low-plane ewes lost 10.4 pounds.

The results of this three-year study showed that the birth weights of lambs were affected by the plane of nutrition during the last six weeks of pregnancy. In 1943 the birth weights of lambs of the super-maintenance group were 13.7 pounds for singles and 10.9 pounds for twins; the maintenance group lambs average weights were 8.8 pounds and 7.7 pounds for single and twin lambs, respectively; the sub-maintenance group lambs average weights were 8.9 pounds for singles and 5.7 pounds for twins. In 1944 the average weights of lambs of the high-plane group were 12.2 pounds for singles and 10.4 pounds for twins. The low-plane group lambs average weights were 7.9 and 6.7 pounds for single and twins, respectively. The single lambs seemed to be less affected than the twins by the level of the prenatal diet.

Since the same ewes were used in 1943 and 1944, a study was made using some of the same ewes on different levels of nutrition each year. The ewes that were fed a low-level during 1943 produced light lambs whereas in 1944 the same ewes on a higher-level produced much heavier lambs. Likewise, ewes on the super-maintenance ration produced much heavier lambs than they did when fed the low-plane ration the second year.

Wallace found that the addition of each 0.5 pound of gross digestible energy fed in the daily ration for the last month of pregnancy resulted in an average increase of approximately 1 pound in the mean birth weight of twin lambs.

The results of 22 complete lactations each of 16 weeks duration showed that the milk production of ewes is not only affected by the level of nutrition but also by the live-weight and the number of lambs suckled. In 1943 the super-maintenance ewes nursing twins produced an average total of 583 pounds of milk and those nursing singles only 307 pounds. The maintenance ewes produced a total of 376 pounds and 255 pounds of milk for twin and single lambs, respectively. Only one single lamb was raised in the sub-maintenance group and this ewe produced only 132 pounds of milk. In 1944 the total milk yield of the high-plane ewes, which had a slightly lower nutrient intake than the super-maintenance group, was 444 pounds for those nursing twin lambs and 308 pounds for those nursing single lambs. The low-plane group which was intermediate between the maintenance and sub-maintenance groups of the previous year produced an average of 292 pounds of milk when nursing twin lambs. No single lambs were raised in this group. Ewes fed approximately the same ration but suckling single and twin lambs in different years had higher total milk production when nursing twin lambs. Also, ewes on different planes of nutrition each year produced milk yields in accordance with the nutritive plane.

Wallace postulated that the reason for the difference in total milk production for ewes nursing single and twin lambs may be due to the total amount of milk removed by the lamb during the early part of the lactation period. The small or weak lambs that are unable to remove the large quantities of milk during the early part of the lactation period will contribute to a lower total yield of milk. It was calculated that approximately 38 per cent of the total milk yield of the 16 week period is produced in the first month, 30 per cent and 21 per cent in the second and third, respectively, and only about 11 per cent in the last month. These total milk yields were determined by weights of the lambs taken before and after nursing at designated intervals over a 24 hour period. The milk yield was measured every seven days.

Wallace found that the live-weight of the ewe and the amount of milk produced were both important factors in determining the total gross digestible energy requirements for a lactating ewe. Also, the efficiency of the individual to convert nutrients to milk was a varying factor. Approximately 1.27 pounds to 1.34 pounds of gross digestible energy per day were necessary to maintain each 100 pounds of live-weight. This is in close agreement with Brody's (1945) figure of 1.26 pounds of total digestible nutrients required to maintain 100 pounds of body weight.

Wallace found a positive correlation of 0.92 between the pounds of milk consumed and the live-weight of the lamb during the first month. Also, that there was a positive correlation between milk consumed and the live-weight throughout the four-month lactation period with a gradual decline toward the latter part.

Ninety-six per cent of the variation in the gains made by individual lambs between birth and 112 days was accounted for by the difference between lambs in respect to their consumption of milk and supplement.

Thomson and Fraser (1939) studied the relation of pregnancy disease to nutrition by regulating the diets of three groups of 14 Grayface ewes. One group fed *ad libitum* gained 50 pounds. The second group was maintained on a restricted diet until the last month of pregnancy and then changed to *ad libitum* feeding and they made an average gain in weight of 20 pounds. The diet of the third group was restricted so that they gained only 8 pounds during gestation. The birth weights and vitality of the lambs in the first two groups were comparable but those delivered by ewes on the restricted diet were more than 2.2 pounds lighter and were also lacking in vitality. Many of the lambs in the restricted group were so weak at birth that they required assistance in suckling their mothers. Some of the ewes in this group had very little milk. Higher levels of feeding reduced the incidence of pregnancy disease.

Thomson and Thomson (1949) extended the above work with special emphasis on the problems of lambing and subsequent growth of the lamb in relation to the nutritive plane of the ewe. They used 81 one-year old Sutherlandshire Cheviot ewes that varied considerably in size, build, and fatness. The flock was randomly divided into two experimental groups. During the first ten weeks of gestation all the ewes in both groups were fed so as to bring them to a uniform level of fatness. It was found this was not too successful since some ewes gained more rapidly than others. One group received a liberal high-protein diet, while the other received a restricted low-protein ration. The high-plane group was given hay, swedes, and a concentrate mixture of maize (8 parts), oats (2 parts), bran (2 parts), linseed-cake meal (1 part), fish meal (1 part) and fed in the proportion of 1 part hay, 3 parts swedes and 1.5 parts of the concentrate mixture. The low-plane ewes received the same feeds in the proportion of 1 part hay, 3 parts swedes and 0.25 part of the concentrate mixture. Water, salt, and minerals were fed ad libitum and 5 ml. of cod-liver oil was fed to all ewes daily. These rations were fed in such amounts as to increase the body weights about 30 per cent in the high-plane group and to produce a loss of about 5 per cent in the weights of the low-plane ewes. The feed given low-plane ewes was about one-third of that received by the higher-plane ewes and had relatively higher fiber and lower protein content.

The average birth weights of lambs was 10.5 pounds for the high-plane singles and 8.1 pounds for single lambs from the low-plane group. Twin lambs from the high-plane ewes weighed 7.7 pounds while the low-plane twins weighed only 5.0 pounds.

The single lambs of the high plane ewes had a high vitality at birth, while the twins of this group and the singles of the low-plane group had about equal vitality which was considered adequate. In the low-plane group 32 per cent of the lambs were dead at birth. There was high neonatal mortality, frequent constitutional weakness, and the lambs were seriously devitalized as a result of the severe nutritional strain on the mothers.

These workers believe the most important effect of underfeeding of the ewe is on her udder development and milk supply, which may be so impaired that even a lively lamb will starve to death. They noted that many of the low-plane ewes failed to claim their lambs and even prevented the lambs from obtaining milk, although milk was present in sufficient quantities.

Seven cases of pregnancy toxemia were noted in the low-plane ewes toward the latter part of pregnancy. In six of the cases the ewes were carrying twins. Some of the symptoms observed were blindness, inco-ordination, acetone odor, ketonuria, and inappetence.

Weights of the ewes taken at the 70th day of pregnancy, at time of lambing, and after lambing showed that ewes in the high-plane group that produced single lambs were 8.8 pounds heavier after lambing than at the 70th day of pregnancy. Ewes in this group with twin lambs were 4.4 pounds heavier after lambing than at the 70th day of pregnancy. During this period of pregnancy the ewes with single lambs in the low-plane group lost 22 pounds and those with twins lost 26.4 pounds. Weights of the ewes just before lambing and after lambing showed that high-plane ewes with single lambs lost 19.3 pounds in fluids and tissue due to lambing and those with twin lambs lost 27 pounds. The low-plane ewes with single lambs lost 15.8 pounds and those with twin lambs lost 20.6 pounds.

Wilson and co-workers (1948) conducted a five-year study of the effect of nutrition on reproduction, lactation, and lamb birth weights and growth. The experiment was designed to study feeds for wintering bred ewes in South Dakota. They found that rations producing gains of 30 to 40 pounds during pregnancy gave satisfactory results whereas ewes gaining less than 20 pounds during gestation were actually losing weight. They found a significant difference in the weight, strength, and body width of lambs at birth and in the rate of gain of lambs from ewes fed different rations. The type of ration did not seem to affect the skeletal structure of the lambs, however, the muscles and fat measurements were affected by the rations.

Underwood and Shier (1942) made a preliminary study of the effects of the plane of nutrition of the ewe during late pregnancy on the birth weights, growth rate, and quality of the lamb under Western Australia management. An experiment with 300 Border Leicester x Merino ewes was carried on under field conditions in which the ewes were grazed on clover and annual grass pastures and supplemented with 1 pound of oaten silage per head daily during the early part of gestation. The ewes were divided into two groups during the last four to six weeks of pregnancy. Each group was grazed separately and received 1.5 pounds of oaten silage per ewe per day. An additional 0.5 pound of wheaten grain per ewe was given to the control group daily. In this investigation no difference was found in the birth weight, growth rate, or quality of either the single or twin lambs, but the grain supplement significantly reduced the losses of ewes from pregnancy toxemia. Grain supplementation also reduced the loss of lambs at lambing time.

In 1943 Underwood et al reported two similar studies with higher levels of prenatal feeding. In the first study the fed group was grazed on young green barley and made gains of about 30 pounds. In the second experiment the fed group was grazed on geranium and barley grass and supplemented with 0.5 pound of wheat and 0.5 pound of linseed nuts per ewe daily, during the last seven to nine weeks of pregnancy, and made gains of about 20 pounds. The control groups were grazed on a restricted area so that the ewes would just maintain their weight.

The high levels of prenatal feeding brought about a highly significant increase in birth weights and growth rate of the lambs as compared to those from the restricted group. There was also a significant reduction in losses of ewes from pregnancy toxemia and of lambs at or near lambing time. The heavier lambs at birth grew significantly faster than the lighter lambs. The required time to reach 65 pounds live-weight was reduced 4.5 to 5 days for each 1 pound increase in birth weights. They attributed the increased growth rate of the lambs from the fed groups wholly to the increase in birth weights.

Williams and co-workers (1950) studied the value of legume and non-legume hays and vitamin A as supplemental feeds for pregnant ewes. They also studied the effects of supplemental feeding during the last half of pregnancy. The work was conducted at five separate Canadian stations. The ewes were allotted on the bases of breed, age, weight, and condition. Lot 1 received legume hay plus a complete mineral mixture. Lot 2 was given non-legume hay plus a complete mineral mixture. In lot 3 a non-legume hay plus minerals were fed for the first 100 days after the breeding period, after which legume hay, the mineral mixture, and a supplementary allowance of grain was fed to produce a steady gain in the live-weight and condition of the ewes.

Results obtained with 396 ewes showed that ewes fed a liberal ration during the last half of pregnancy produced lambs equal to those from ewes given legume hay the entire period. Ewes receiving legume hay maintained their body weight and produced heavier and more vigorous lambs than the non-legume hay groups.

The work cited in this literature review indicates that the level of nutrition during the latter part of pregnancy and early lactation of the ewe has a marked effect on her reproduction and lactating ability. The most noticeable effects are on the birth weight, vigor, and growth of the lamb.

EXPERIMENTAL

Thirty head of uniform four-and five-year-old western Texas ewes were used in this experiment. The ewes were purchased from the Oklahoma National Stockyards in Oklahoma City, Oklahoma and delivered to the Animal Husbandry Experimental Barn September 1, 1949.

Management:

The ewes were housed in a closed barn and had access to an exercise lot at all times except in extremely severe weather. A registered Hampshire ram was purchased from a local breeder and placed with the ewes September 15, 1949. During the breeding season the ram was kept separate during the day and allowed to run with the ewes at night. The ewes were all fed the same ration during the breeding period.

November 1, 1949, the ewes were divided into five equal lots of six ewes each on the bases of weight, age, and general health. The beginning weight of the ewes was determined by the average of three consecutive daily weights. The ewes were weighed thereafter approximately each month during pregnancy, at lambing time, after lambing, and at two week intervals during the first six weeks of lactation.

The ewes were separated each evening into their respective lots and fed the concentrate part of the ration. The concentrates were placed in troughs located in the separate pens and the troughs were kept covered when not in use. The ewes had free access to hay, salt, and water at all times.

Blood samples were collected from the ewes at selected times for determinations of hemoglobin, plasma proteins, hematocrit, calcium, phosphorus, and vitamin A values.

The lamb weights were taken as soon as the fleece was dry after birth and at seven-day intervals during the first six weeks. Records were kept at the barn on the vitality and condition of the lambs and on the condition of the udder and of the ewes at lambing time. The lambs were not given any feed other than hay during the first six weeks in order to obtain a better measure of the milk production of the ewes.

Rations Used:

During the breeding season the ewes had free access to the hay to be fed during the experiment and a small amount of pasture. They were each fed about 1 pound daily of a ration containing corn, oats, and corn gluten meal.

When it was reasonably certain that the ewes were bred they were started on experiment. The composition of the various feeds used in the experiment is given in Table 1. The hay used to make up the major portion of the ration for the ewes was of good quality native eastern Oklahoma hay from unfertilized land. It was cut, baled, and stored in good condition during the latter part of June 1949.

The ration fed during the first part of gestation is shown in Table 2. All lots were allowed free access to hay, salt, and water at all times. Lot 1 served as a negative control lot and received all the hay the ewes would eat. For lot 2 starch was added to the hay to provide additional energy. The lot 3 ewes were given corn and corn gluten meal. The amount of corn fed was equal in energy to the amount of starch supplied to lot 2; the corn gluten meal served to determine the effect of the addition of protein to the ration. Lot 4 received the same ration as lot 3 with the addition of dicalcium phosphate. The ewes in lot 5 which were considered the positive controls were given, in addition to the ration fed lot 4, the trace minerals iron, copper,

Table 1. Chemical Composition of Hay, Corn and Corn Gluten Meal

Feed	Dry Matter %	Composition of Dry Matter								
		Ash %	Protein %	Ether Extract %	Crude Fiber %	N-free Extract %	Calcium %	Phosphorus %	Carotene	
									Crude p.p.m.	True p.p.m.
Prairie hay (Sallisaw)	93.98	7.58	5.66	1.95	34.02	50.79	.429	.083	10.4	6.5
Corn (white)	92.78	1.51	12.26	4.48	1.25	80.50	.021	.383	00.0	0.0
Corn gluten meal	94.38	1.46	44.24	1.43	3.37	49.50	.027	.297	00.0	0.0

Table 2. Daily Feed Allowance in Pounds for Each Ewe Previous to the Last Four Weeks of Pregnancy

Feed	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
Prairie hay	Free Choice	Free Choice	Free Choice	Free Choice	Free Choice
Starch	---	.5	---	---	---
Corn (white)	---	---	.25	.25	.25
Corn gluten meal	---	---	.25	.25	.25
Dicalcium phosphate	---	---	---	.031	.031
Trace minerals	---	---	---	---	Fe, Cu, Co, Mn
Cod liver oil	---	---	---	---	Trace

Table 3. Daily Feed Allowance in Pounds for Each Ewe During Last Four Weeks of Pregnancy

Feed	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
Prairie hay	Free Choice	Free Choice	Free Choice	Free Choice	Free Choice
Starch	---	.75	---	---	---
Corn (white)	---	---	.50	.50	.50
Corn gluten meal	---	---	.25	.25	.25
Dicalcium phosphate	---	---	---	.031	.031
Trace minerals	---	---	---	---	Fe, Cu, Co, Mn
Cod liver oil	---	---	---	---	Trace

Table 4. Daily Feed Allowance in Pounds for Each Ewe During Lactation

Feed	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
Prairie hay	Free Choice	Free Choice	Free Choice	Free Choice	Free Choice
Starch	.75	.75	---	---	---
Corn (white)	.50	.50	1.00	1.00	1.00
Corn gluten meal	---	---	.25	.25	.25
Dicalcium phosphate	---	---	---	.031	.031
Trace minerals	---	---	---	---	Fe, Cu, Co, Mn
Cod liver oil	---	---	---	---	Trace

manganese, cobalt and also cod liver oil.

Since it is known that the last four to six weeks is the most crucial period of pregnancy, the rations were increased for this period as shown in Table 3. The increase of 0.25 pound of starch for lot 2 and of corn for lots 3, 4, and 5 was to provide additional energy.

After lambing the rations for all lots were increased as shown in Table 4. Due to the condition of the ewes in lot 1 at lambing time, starch and corn in amounts equal to that fed in lot 2 were added to their ration. For lots 3, 4, and 5 the corn was increased to 1 pound to help meet the additional feed requirement during lactation. Because of the low palatability of the starch, it was mixed with an equal part of finely ground prairie hay.

Blood Analysis:

Blood samples were collected at selected times from each animal for chemical analysis. These samples were taken by puncture of the jugular vein using either Heller and Pauls' sodium and potassium oxlate mixture as described by Phillips et al (1945) or lithium citrate in the collection tubes as anticoagulants.

Determinations were made of hemoglobin, plasma protein, hematocrit, calcium, phosphorus, and vitamin A.

The percentage of hemoglobin was determined by a method published by Rubican Company (manufacturers of the Eveyln Photoelectric Colorimeter). However, a correction factor based on the method of Wong as described by Hawk (1947) was applied to these values. The plasma protein values were determined by the copper sulfate-specific gravity method as described by Hawk (1947). The Wintrobe and Landsberg method as described by Levinson (1946) was used for the hematocrit determination. The method of Clark and Collip (1925) was employed for the determination of calcium. Inorganic phosphorus was determined by the method of Fiske and SubbaRow (1925). The method of Kimble (1939) was used for the determination of vitamin A.

RESULTS AND DISCUSSION

Weight Changes During Pregnancy and Lactation

The weight changes of the ewes fed the experimental rations during pregnancy and lactation are summarized in Table 5. The ewes in lot 1 lost an average of 8.3 pounds and those in lot 2 lost 3 pounds from the beginning of the experiment until lambing time. The ewes in lots 3, 4, and 5 made average gains of 15.8, 18.8, and 17.8 pounds, respectively, during this same period.

Table 5 also gives the average per cent weight change during pregnancy (from start of experiment until after lambing). During this period lots 1 and 2 had a 25.7 and an 18 per cent weight loss, respectively. Lots 3, 4, and 5 ended gestation at approximately the same weight as at the start of the experiment. Very little weight change occurred in the different lots during the first six weeks of lactation.

The difference in the development and general condition of an average ewe in each lot near the end of gestation is shown in Figure 2, Plate 1. Figure 1, Plate 1 shows a ewe from each lot six weeks after lambing. A comparison of ewe 58 in lot 1 and ewe 68 in lot 5 near the end of pregnancy is shown in Figure 4, Plate 2.

There was some variation in weight changes (gain or loss) within lots. These variations may partially be accounted for by the number of fetuses carried; also, there may have been a difference in the individual maintenance requirements and efficiency in utilizing feeds, as shown by Wallace (1949).

Some indication of the prolonged after-effect of the rations fed lots 1

Table 5. Ewe Weight Changes During Pregnancy and Lactation

Ewe No.	Beginning Weight	Weight Before Lambing	Weight After Lambing	Gain or Loss During Pregnancy	% Body Weight Change	Weight Six Weeks After Lambing
	Lbs.	Lbs.	Lbs.	Lbs.	%	Lbs.
			Lot 1			
47	85	73	67	-12	-21.2	68
53	100	93	73	- 7	-27.0	68
57	121	115	86	- 6	-29.0	---
58	101	107	83	+ 6	-18.0	83
67	110	85	71	-25	-35.5	---
70	110	104	85	- 6	-23.8	87
Average	104.5	96.1	77.5	- 8.3	-25.7	76.5
			Lot 2			
34	89	83	71	- 6	-20.3	65
50	115	116	98	+ 1	-14.8	104
52	110	102	81	- 8	-26.4	---
54	97	99	82	+ 2	-15.5	79
60	108	106	94	- 2	-13.0	79
64	104	99	85	- 5	-18.3	69
Average	103.8	100.8	85.1	- 3.0	-18.0	79.2
			Lot 3			
32	107	121	107	+14	0.0	114
42	92	108	91	+16	- 1.1	92
43	111	131	94	+20	-15.4	108
46	103	115	98	+12	- 4.9	94
61	97	115	99	+18	+ 2.0	114
63	115	130	108	+15	- 6.1	110
Average	104.1	120.0	99.5	+15.8	- 4.2	105.3
			Lot 4			
31	103	109	91	+ 6	-11.7	85
40	92	124	105	+32	+14.0	95
55	107	121	109	+14	+ 1.8	106
62	114	133	117	+19	+ 2.6	121
66	111	137	102	+26	- 8.2	110
69	96	112	98	+16	+ 2.0	96
Average	103.8	122.6	103.6	+18.8	+ 0.2	102.1
			Lot 5			
33	114	129	113	+15	- 0.9	109
45	95	116	90	+21	- 5.3	90
49	94	106	89	+12	- 5.4	91
51	106	129	106	+23	0.0	112
59	114	131	110	+17	- 3.6	106
68	102	121	110	+19	+ 7.8	111
Average	104.1	122.0	103.0	+17.8	- 1.2	103.1

Figure 1. A representative ewe in each lot six weeks after lambing.

Figure 2. A representative ewe in each lot near the end of pregnancy.

Figure 3. Ewe 67 during the latter stage of pregnancy disease.

Figure 4. Comparison of ewe 5[illegible] in lot 1 and ewe 6[illegible] in lot [illegible] near the end of pregnancy. These ewes started the experiment with approximately the same weight.

and 2 during pregnancy is shown by the live-weight of the ewes six weeks after lambing. Five ewes not nursing lambs in lots 1 and 2 continued to lose weight even though the energy part of the ration had been increased to equal that given lots 3, 4, and 5. Ewe 61 of lot 3 which was the only ewe in any of the other three lots that did not nurse a lamb gained 15 pounds during this same period. In general the ewes in lots 3, 4, and 5, fed a protein supplement (corn gluten meal), had a satisfactory weight gain during pregnancy and lactation.

Lambing Results

At lambing time the ewes in lots 1 and 2 were emaciated and weak and showed little maternal instinct. The udder development and milk supply of the ewes in these lots was very poor.

Miscellaneous difficulties were encountered during the lambing period in lots 1 and 2 that resulted in the loss of ewes and many of the lambs. Ewe 67 of lot 1 developed symptoms, (Figure 3, Plate 2), of pregnancy disease about two weeks before the calculated lambing date. She was weak, lacked co-ordination, and refused to eat. No response to treatment was obtained so the ewe was disposed of in order to obtain tissues for chemical analysis. This ewe was carrying twin lambs and she had lost 35.5 per cent of her original body weight.

Ewe 57 in lot 1 gave birth to twin lambs that were dead. She was in such a weakened condition following parturition that she was unable to stand and died three days later. She had lost 29 per cent of her body weight.

Ewe 52 in lot 2 gave birth to twin lambs. She became very weak and nervous but continued to eat. Five days later she refused to eat grain but continued to nibble at hay. Treatment with appetizers as well as repeated injections of glucose failed to improve her condition. She died 29 days after lambing. During this time the only food she consumed was a small amount of hay. She had lost 26.4 per cent of her original body weight at lambing and 53.7 per cent at the time of death. The results of tissue studies on the last three ewes will be presented later.

One ewe, (47 of lot 1), aborted twin fetuses which were in an aplastic condition. These disturbances in the ewes are very similar to the troubles reported by Wallace (1949) for ewes fed a low-plane of nutrition.

Eighty-two per cent of the lambs in lot 1 and 75 per cent in lot 2 were either born dead or died shortly thereafter. Some of the lambs in these lots had adequate vitality even though they were small at birth, but since most of the ewes in lots 1 and 2 had very little milk, some of the lambs actually starved to death. The lambs of lots 1 and 2 were small in muscular development and skeletal size. This is in agreement with the report of Thomson and Thomson (1949). Wallace (1949) reported that the skeletal structure was least affected by the prenatal feeding of the ewes. Only four lambs were raised of the 17 lambs born in lots 1 and 2 in spite of the extra special care and attention given them. The lack of maternal instinct and an inadequate milk supply probably contributed to the death of these lambs.

There was some variation in the condition of the ewes in lots 3, 4 and 5, but the ewes were all strong, showed interest in their lambs, and had good appetites during parturition. The udder development of the ewes was normal and there was adequate milk for the lambs. A summary of the birth weights and condition of the lambs and ewes at lambing time is presented in Table 6.

In general the lambing results were very poor in lots 1 and 2 where the

Table 6. Birth Weights and Condition of Ewes and Lambs at Parturition

Lot No.	Lamb No.	Birth Weights Singles	Birth Weights Twins	Condition of Lamb	Vitality of Lamb	Condition of Ewe	Udder Development
		lbs.	lbs.				
1	47	—	Aborted	Aplastic	—	Very thin	Very poor
	53	—	4.75	Thin	*Poor	Very thin	Very poor
		—	5.00	Thin	Dead	—	—
	57	—	4.50	Thin	Dead	Very thin	Very poor
		—	6.00	Thin	Dead	—	—
	58	—	5.00	Thin	Adequate	Thin	Very poor
		—	5.00	Thin	*Adequate	—	Poor
	67	—	5.00	Thin	Dead	Very thin	Very poor
		—	5.00	Thin	Dead	—	—
	70	8.25	—	Fair	Adequate	Very thin	Poor
	Average	8.25	5.03				
2	34	7.75	—	Fair	*Adequate	Very thin	Very poor
	50	7.50	—	Fair	Adequate	Thin	Poor
	52	—	4.25	Thin	*Poor	Very thin	Very poor
		—	4.50	Thin	*Poor	—	—
	54	—	4.50	Thin	Dead	Very thin	Very poor
		—	5.00	Thin	Dead	—	—
	60	8.50	—	Fair	Adequate	Very thin	Poor
	64	7.25	—	Fair	*Adequate	Very thin	Poor
	Average	7.75	4.56				
3	32	9.75	—	Good	High	Good	Good
	42	9.75	—	Good	High	Good	Good
	43	—	10.00	Good	**High	Good	Good
		—	7.00	Good	High	—	—
	46	10.00	—	Good	High	Good	Good
	61	11.75	—	Good	**High	Good	Good
	63	—	7.50	Fair	Adequate	Good	Good
		—	6.50	Fair	Adequate	—	—
	Average	10.31	7.75				
4	31	10.00	—	Good	High	Fair	Good
	40	10.25	—	Good	High	Good	Good
	55	11.00	—	Good	High	Good	Good
	62	11.50	—	Good	High	Good	Good
	66	—	8.00	Fair	High	Fair	Good
		—	7.00	Fair	High	—	—
	69	10.75	—	Good	High	Good	Good
	Average	10.70	7.50				
5	33	12.75	—	Good	High	Good	Good
	45	13.75	—	Good	High	Fair	Good
	49	10.00	—	Good	High	Good	Good
	51	10.75	—	Good	High	Good	Good
	59	11.50	—	Good	High	Good	Good
	68	11.25	—	Good	High	Good	Good
	Average	11.66	—				

*Died
**Died of Accidental Causes

ewes were fed hay and hay plus additional energy, respectively. A marked improvement was noted in lot 3 as soon as additional protein was supplied. The slight improvement in the size and general condition of the lambs in lots 4 and 5 over those in lot 3 would suggest that phosphorus, trace minerals, and vitamin A were of secondary importance to the protein supplement. Two lambs died of accidental injuries in lot 3. They were the only lambs not raised in lots 3, 4, and 5.

The Growth Rate of Lambs

The lambs were not given a grain supplement during the first six weeks of lactation in order to obtain a measurement of the milk production of the ewes. The growth rates of the lambs for the first six weeks of lactation are presented in Table 7. In summarizing the data for the growth rate of the lambs, if one lamb of a pair of twins died at or near birth the remaining lamb was treated as a single lamb.

The single lambs in lots 3, 4, and 5 made faster gains than those of lots 1 and 2. The average weight of the lambs in lot 1 was 15.5 pounds at six weeks of age. The single lambs in lot 2 had an average weight of 20.12 pounds. The average weights for the single lambs of lots 3, 4, and 5 were 28.06, 27.85, and 31.37 pounds, respectively, for the same period.

A comparison of a representative lamb in the different lots at six weeks of age is shown on Plate 3. Plate 4 shows a comparison of representative lambs with their mothers in lots 1, 2, 3, and 5 at approximately ten weeks of age. Plate 5 shows a comparison of the ewes and lambs in lots 1, 2, 4, and 5 at approximately ten weeks of age.

Table 7. Weight of Lambs in Pounds During the First Six Weeks of Lactation

Lot No.	Lamb No.	1st Week		2nd Week		3rd Week		4th Week		5th Week		6th Week	
		Singles	Twins	Singles	Twins	Singles	Twins	Singles	Twins	Singles	Twins	Singles	Twins
1	53	5.25	---	6.25	---	5.00	---	---	---	---	---	---	---
	58	---	9.00	---	7.50	---	8.00	10.50	---	13.50	---	16.00	---
		---	8.75	---	6.75	---	6.00	---	---	---	---	---	---
	70	9.00	---	9.75	---	10.25	---	11.50	---	12.50	---	15.00	---
	Average	7.12	8.87	8.00	7.12	7.62	7.00	11.00	---	13.00	---	15.50	---
2	50	9.50	---	11.00	---	12.75	---	14.25	---	16.75	---	18.75	---
	60	12.00	---	13.75	---	15.25	---	16.50	---	19.50	---	21.50	---
	Average	10.75	---	12.37	---	14.00	---	15.37	---	18.12	---	20.12	---
3	32	12.50	---	16.75	---	20.75	---	24.25	---	27.75	---	31.75	---
	42	14.00	---	17.75	---	21.50	---	25.00	---	27.50	---	30.50	---
	43	9.75	---	13.00	---	16.75	---	20.00	---	23.00	---	26.25	---
	46	12.25	---	15.00	---	18.50	---	20.75	---	22.00	---	23.75	---
	63	---	10.75	---	12.75	---	14.25	---	15.25	---	17.00	---	18.25
		---	8.50	---	10.25	---	11.75	---	12.75	---	15.25	---	16.75
	Average	12.12	9.62	15.62	11.50	19.37	13.00	22.50	14.00	25.06	16.12	28.06	17.50
4	31	13.00	---	16.25	---	18.00	---	18.75	---	20.50	---	21.00	---
	40	13.50	---	16.00	---	18.50	---	21.25	---	23.00	---	25.00	---
	55	15.00	---	19.00	---	23.00	---	27.00	---	30.00	---	33.25	---
	62	15.25	---	19.25	---	23.00	---	26.50	---	28.50	---	31.25	---
	66	---	10.00	---	11.25	---	13.25	---	14.75	---	16.75	---	18.50
		---	9.25	---	10.50	---	12.25	---	13.25	---	14.00	---	16.00
	69	13.25	---	16.00	---	19.75	---	23.00	---	26.00	---	28.75	---
	Average	14.00	9.62	17.30	10.87	20.45	12.75	23.30	14.00	25.60	15.37	27.85	17.25
5	33	16.25	---	20.00	---	23.25	---	26.00	---	28.75	---	32.25	---
	45	17.75	---	20.50	---	24.00	---	27.75	---	31.50	---	35.00	---
	49	13.75	---	16.50	---	20.00	---	23.75	---	27.75	---	30.00	---
	51	14.75	---	18.25	---	21.50	---	24.50	---	26.50	---	30.50	---
	59	14.50	---	17.00	---	21.50	---	24.75	---	27.75	---	31.75	---
	68	14.50	---	17.50	---	18.00	---	22.25	---	25.50	---	28.75	---
	Average	15.25	---	18.29	---	21.37	---	24.83	---	27.95	---	31.37	---

PLATE 3

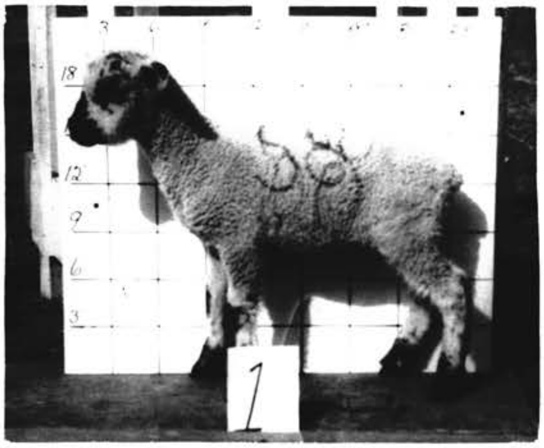

Figure 5. Lamb 58
Age - 42 Days Weight - 16 Pounds

Figure 6. Lamb 60
Age - 41 Days Weight - [illegible] Pounds

Figure 7. Lamb 42
Age - 44 days Weight - 30.50 Pounds

Figure 8. Lamb 62
Age - 44 Days Weight - 31.[illegible]5 Pounds

Figure 9. Lamb 33
Age - 43 Days Weight - 3[illegible] Pounds

A representative lamb in each lot [illegible] weight.

PLATE 4

Figure 10. Ewe and lamb 58
Age of lamb - 70 days Weight - 28 pounds

Figure 11. Ewe and lamb 60
Age of lamb - 69 days Weight - 38 pounds

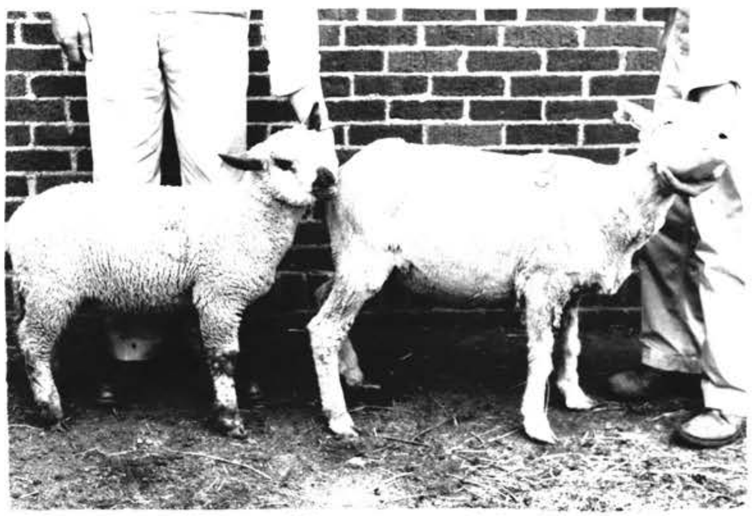

Figure 12. [illegible] lamb [illegible]
[illegible] lamb - 72 days [illegible] - 5[illegible]

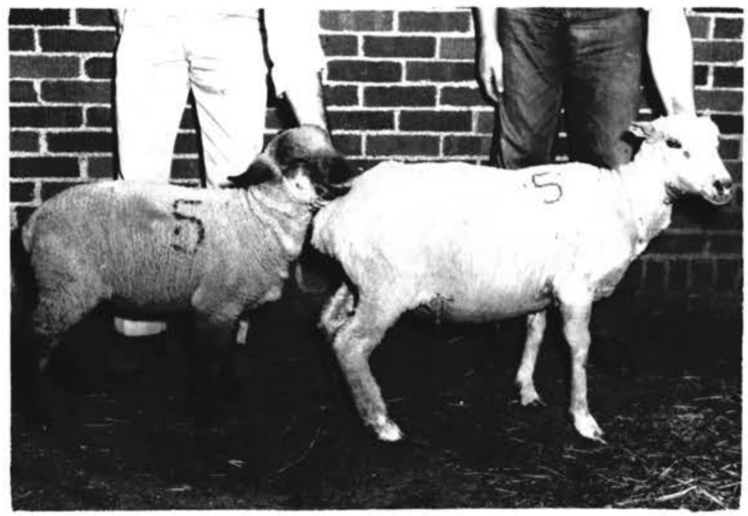

Figure [illegible] [illegible] lamb 33
[illegible] lamb [illegible] Weight - 49 pounds

[illegible] representative [illegible] 5 [illegible] weeks after [illegible]

PLATE 5

Figure 14. Lot 1

Figure 15. Lot 2

Figure 16. Lot 3

Figure 17. Lot 4

[illegible] and [illegible] ing.

The variation in the growth rate of the lambs within the same lots may have been due to the variability between the individual ewes in their efficiency to convert feed to milk as was shown by Wallace (1949), rather than the increased growth rate being wholly from the increase in birth weights as postulated by Underwood and co-workers (1943). The growth rate of the twin lambs of ewe 58 may be an example of insufficient milk in that both lambs lost weight in the second week and one lamb continued to lose weight and died during the third week. The remaining lamb was able to survive and make greater gains than the single lamb of the same lot. The death of lamb 53 appeared to be due to starvation.

Tissue Analysis

Hemoglobin Values:

The hemoglobin values for the ewes during the latter part of pregnancy and early lactation are presented in Table 8. Values for the ewes of lots 1 and 2 were consistently lower than the values for the ewes in lots 3, 4, and 5. There was a gradual decline in the hemoglobin values for all lots near lambing time and during the early part of lactation. Some variation can be noted in the hemoglobin values for the different bleedings and between the individuals of the same lot. There was no indication that the addition of trace minerals in lot 5 increased the hemoglobin values of the ewes. These data would suggest that the anemic condition of the ewes in lots 1 and 2 could be due to the low intake of nutrients—especially protein. Care was taken to prevent any parasitic infection from complicating these results.

Table 8. Hemoglobin Values
(Grams/100 ml. Blood)

Ewe No.	12-30-49	2-2-50	2-28-50	3-17-50	4-4-50	4-22-50	4-28-50	5-4-50
				Lot 1				
47	8.0	9.0	9.2	10.2	10.1	9.3	9.4	9.4
53	6.6	7.3	7.6	7.0	7.6	6.9	9.4	8.2
57	10.0	9.0	Dead	—	—	—	—	—
58	11.1	10.1	10.6	8.4	6.4	6.1	6.4	6.4
67	10.5	Dead	—	—	—	—	—	—
70	11.4	5.8	9.3	8.4	9.1	7.7	7.7	8.1
Average	9.6	8.2	9.1	8.5	8.3	7.5	8.2	8.0
				Lot 2				
50	11.8	9.4	9.9	8.7	7.8	7.3	6.6	7.0
52	9.5	7.8	7.2	Dead	—	—	—	—
54	11.3	10.1	7.8	8.0	8.3	3.0	4.2	5.7
60	11.7	10.7	10.3	9.4	5.9	6.0	6.0	6.5
64	10.4	8.3	7.8	10.1	8.6	6.6	5.9	4.2
34	9.8	8.3	8.6	8.0	5.6	7.1	8.3	7.9
Average	10.7	9.1	8.6	8.8	7.2	6.0	6.3	6.2
				Lot 3				
42	12.4	12.4	14.0	8.0	10.6	9.0	7.5	6.9
43	11.3	10.9	8.9	9.4	9.6	9.3	10.9	10.1
46	12.2	12.7	10.5	9.2	10.9	10.5	11.0	10.5
32	13.7	12.7	14.0	13.2	13.4	13.8	12.7	12.3
61	12.4	12.4	13.8	12.3	11.2	11.6	9.6	8.7
63	10.1	10.6	12.7	10.4	9.3	9.9	9.6	9.6
Average	12.0	11.9	12.3	10.4	10.8	10.6	10.2	9.6
				Lot 4				
40	10.9	12.0	11.7	10.8	11.7	11.6	11.7	12.1
31	10.3	10.4	11.4	11.2	10.7	9.6	8.9	9.0
55	13.1	11.5	11.8	11.2	10.7	10.1	9.9	11.0
62	9.6	12.2	11.7	9.9	10.6	7.7	8.6	8.3
66	10.6	8.7	8.1	6.8	7.7	8.1	9.9	9.3
69	12.5	10.7	11.8	10.9	9.3	8.6	9.3	9.1
Average	11.1	10.9	11.0	10.1	10.1	9.2	9.7	9.8
				Lot 5				
33	11.4	11.5	6.9	6.6	7.4	7.7	9.4	7.7
45	12.0	10.6	10.6	10.6	9.0	9.0	9.0	10.0
49	11.8	13.1	15.6	13.8	11.4	12.8	12.5	11.2
51	12.4	10.9	11.8	10.4	10.1	10.1	10.7	10.7
59	11.3	11.4	12.0	6.9	9.7	10.2	9.9	11.8
68	11.2	10.7	12.3	12.6	10.7	10.1	10.6	10.4
Average	11.6	11.3	11.5	10.1	9.7	9.9	10.3	10.3

Hematocrit Values:

The hematocrit values of the ewes in lots 1 and 2 were lower than those of lots 3, 4, and 5. These are summarized in Table 9. There was a slight drop in hematocrit values around lambing time for all lots. The low hematocrit values of the ewes in lots 1 and 2 are an additional indication of the anemic condition of the ewes. The trace minerals fed to lot 5 ewes did not increase their hematocrit values over those of lots 3 and 4.

Plasma Protein:

The plasma protein values for the ewes during the latter part of pregnancy and early lactation are given in Table 10. The plasma protein values of the ewes in lots 3, 4, and 5, which received a protein supplement, were consistently higher than those for the ewes of lots 1 and 2. The plasma protein values were lower in all lots near lambing time and there was a gradual increase in the values during the second month of lactation. The values for lots 3, 4, and 5 agree with the normal values recently reported by Klosterman et al (1950). These findings are in agreement with those of Dalgarno and co-workers (1950) in that pregnant ewes fed on a high-plane of nutrition had a higher total serum protein content than the ewes fed on a low-plane of nutrition.

Phosphorus:

The inorganic blood phosphorus values of the ewes are given in Table 11. There was considerable variation between individuals--even in the same lot. There was also individual differences in the values from one sampling period to the next. The ewes in lots 4 and 5, which received dicalcium phosphate, had no higher values than the other three lots. This would suggest that a lack of phosphorus was not the primary cause of the poor results obtained in lots 1 and 2.

Table 9. Hematocrit Values

Ewe No.	2-2-50	2-28-50	3-17-50	4-4-50	4-20-50	4-28-50	5-4-50
				Lot 1			
47	31.0	26.0	32.0	35.0	30.0	29.2	33.0
53	27.0	26.7	25.0	27.0	23.7	25.0	28.7
57	30.0	Dead	—	—	—	—	—
58	37.0	32.0	30.0	15.7	20.0	22.0	23.5
67	Dead	—	—	—	—	—	—
70	41.0	27.5	29.7	26.0	28.0	24.4	27.0
Average	33.2	28.1	29.1	25.9	25.4	25.1	28.0
				Lot 2			
50	34.0	33.0	29.7	26.7	24.0	22.0	22.7
52	25.0	20.0	Dead	—	—	—	—
54	35.0	25.0	24.7	32.6	10.2	14.0	19.8
60	35.0	34.0	33.0	21.0	24.0	19.8	21.7
64	29.0	23.4	24.7	26.0	23.2	24.0	12.8
34	28.0	24.0	25.7	20.0	24.0	24.2	27.0
Average	31.0	26.5	27.5	25.2	21.0	20.8	20.8
				Lot 3			
42	44.0	40.6	29.0	25.0	32.6	26.5	22.7
43	40.0	32.7	35.6	34.6	33.0	33.3	36.6
46	49.0	34.0	32.0	28.0	33.0	33.0	35.6
32	45.0	47.0	46.0	46.5	42.0	38.0	44.0
61	43.0	40.5	40.0	39.0	39.0	31.0	28.7
63	42.0	37.2	37.0	32.0	29.7	32.6	35.2
Average	43.8	38.6	36.6	34.1	34.8	32.4	33.8
				Lot 4			
40	41.0	38.5	39.6	29.2	46.0	37.0	44.0
31	39.0	35.0	39.0	36.3	30.0	27.2	28.7
55	47.0	39.0	41.5	40.0	36.0	32.3	35.6
62	40.0	37.4	37.0	36.6	24.0	24.0	27.4
66	30.0	27.3	27.0	28.0	23.0	32.0	30.6
69	38.0	30.5	34.3	32.6	31.0	26.4	28.7
Average	39.2	34.6	36.4	33.7	31.6	29.8	32.5
				Lot 5			
33	43.0	26.8	24.7	29.0	29.0	27.2	27.0
45	39.0	33.3	32.0	33.6	31.0	27.7	33.6
49	50.0	45.5	50.0	44.0	39.6	37.7	37.6
51	46.0	35.5	37.0	39.0	33.6	32.6	39.6
59	42.0	46.5	27.0	37.0	29.7	32.0	40.0
68	42.0	36.0	32.3	37.0	33.0	31.0	34.3
Average	43.6	37.2	33.8	36.6	32.6	31.3	35.3

Table 10. Plasma Protein Values
(Grams/100 ml. Plasma)

Ewe No.	2-2-50	2-28-50	3-17-50	4-4-50	4-20-50	5-4-50
			Lot 1			
47	7.052	5.500	5.112	5.500	5.112	5.112
53	6.664	5.888	5.112	5.500	5.500	5.500
57	5.690	Dead	——	——	——	——
58	6.276	6.664	5.888	5.888	5.500	6.664
67	Dead	——	——	——	——	——
70	5.690	6.664	6.664	5.888	6.276	6.664
Average	6.274	6.179	5.694	5.694	5.597	5.985
			Lot 2			
50	5.500	6.276	5.500	6.276	5.888	6.276
52	5.112	5.112	Dead	——	——	——
54	5.300	5.500	5.888	5.888	7.052	7.052
60	5.500	5.888	5.500	5.112	5.500	5.112
64	5.500	6.664	6.276	6.276	5.888	6.664
34	5.112	5.500	5.500	5.500	5.888	6.276
Average	5.370	5.823	5.732	5.810	6.043	6.276
			Lot 3			
42	5.888	6.276	6.664	7.052	7.052	7.052
43	6.664	6.664	6.664	7.440	6.664	7.052
46	7.240	7.052	7.052	7.052	7.440	7.440
32	6.470	7.052	7.052	6.664	7.052	7.052
61	6.664	6.664	7.052	7.440	7.440	7.828
63	7.440	7.440	6.922	7.052	7.440	7.440
Average	6.727	6.858	6.901	7.117	7.181	7.310
			Lot 4			
40	6.664	7.052	7.052	7.052	7.052	7.440
31	5.690	7.052	5.500	5.112	5.888	6.276
55	7.440	7.052	7.052	7.440	7.440	7.828
62	7.052	6.664	6.664	7.052	7.052	7.440
66	5.500	6.664	7.052	7.440	7.052	7.052
69	6.664	6.664	6.664	7.052	6.664	7.052
Average	6.501	6.858	6.664	6.858	6.858	7.181
			Lot 5			
33	6.664	6.664	6.664	7.440	7.440	7.440
45	5.690	5.500	6.664	6.664	6.664	7.052
49	7.052	7.052	6.276	6.664	7.052	7.052
51	6.470	6.664	6.276	7.052	7.052	7.440
59	6.664	7.440	6.664	7.440	7.052	7.440
68	6.664	7.440	7.440	7.440	7.440	7.440
Average	6.534	6.793	6.664	7.116	7.116	7.310

Table 11. Inorganic Phosphorus Values
(Mg/100 ml. Plasma)

Ewe No.	2-2-50	2-28-50	3-31-50	4-13-50	4-28-50
			Lot 1		
47	5.20	3.84	4.88	3.52	4.68
53	4.28	3.68	4.24	3.96	4.08
57	6.92	Dead	——	——	——
58	4.88	4.56	5.32	3.84	4.48
67	Dead	——	——	——	——
70	5.68	5.28	4.76	5.12	4.40
Average	5.39	4.34	4.80	4.11	4.41
			Lot 2		
50	4.96	4.96	7.40	6.36	8.40
52	4.52	1.36	Dead	——	——
54	3.48	3.76	6.08	5.60	5.00
60	5.20	5.12	3.20	5.64	7.16
64	5.96	5.88	7.92	9.12	5.80
34	4.40	5.12	5.20	7.56	4.48
Average	4.75	4.36	5.96	6.85	6.16
			Lot 3		
42	4.76	3.32	3.28	3.64	4.60
43	4.84	3.96	4.92	3.60	4.48
46	4.40	3.80	6.00	4.48	6.72
32	3.80	6.64	2.44	3.60	3.44
61	4.96	5.40	6.72	5.04	5.20
63	4.40	3.48	4.84	3.28	4.36
Average	4.52	4.43	4.70	3.94	4.80
			Lot 4		
40	5.72	4.60	5.42	5.36	3.60
31	7.04	5.40	7.04	3.24	6.56
55	6.16	5.00	5.80	4.60	4.04
62	6.20	6.36	6.36	5.04	5.80
66	5.04	4.60	4.28	2.24	2.88
69	5.52	5.72	4.16	2.52	4.08
Average	5.94	5.28	5.51	3.83	4.49
			Lot 5		
33	4.76	4.60	5.24	5.20	6.36
45	5.20	4.56	4.56	3.24	3.44
49	3.84	3.68	3.28	2.72	3.60
51	5.56	6.04	4.76	4.40	5.88
59	5.32	5.88	5.04	5.20	5.24
68	4.04	5.72	4.56	3.56	3.68
Average	4.78	5.08	4.57	4.05	4.70

Calcium:

An analysis for blood calcium was made at the end of the lambing period. The results are shown in Table 12. There was very little difference among either individuals or lots; therefore, further determinations were not made.

Table 12. Calcium Values 3-31-50
(Mg/100 ml. Plasma)

Lot 1		Lot 2		Lot 3		Lot 4		Lot 5	
Ewe No.		Ewe No.		Ewe No.		Ewe No.		Ewe No.	
47	10.0	50	11.0	42	11.0	40	11.8	33	11.0
53	11.6	54	9.4	43	12.0	31	9.2	45	10.4
58	10.6	60	10.0	46	10.0	55	11.0	49	12.0
70	10.2	64	10.2	32	12.0	62	10.6	51	12.0
		34	11.6	61	10.6	66	12.0	59	10.8
				63	10.4	69	12.0	68	11.0
Ave.	10.6		10.4		11.0		11.1		11.2

Vitamin A:

Blood vitamin A determinations were made toward the latter part of the experiment in an effort to determine if a vitamin A deficiency was present. The blood vitamin A values are given in Table 13. There was a considerable variation in vitamin A values between individuals. The lot 5 ewes, which were supplemented with cod liver oil, had only slightly higher values than ewes in the other lots.

The condition, weight, and vitamin A content of the livers taken from the ewes at the termination of the experiment are presented in Table 14. There was some variation in the condition of the liver of ewes within lots but in general considerable atrophy was present in the livers of the ewes from lots 1 and 2. The average liver weights of the ewes were over

Table 13. Vitamin A Values
(Mcg/100 ml. Plasma)

Ewe No.	3-1-50	3-31-50	4-13-50	4-28-50
		Lot 1		
47	9.2	29.8	26.3	28.9
53	13.8	13.1	16.6	19.2
57	Dead	----	----	----
58	13.8	20.8	26.9	33.5
67	Dead	----	----	----
70	18.0	15.1	14.6	13.6
Average	13.7	19.7	21.1	23.8
		Lot 2		
50	19.9	24.1	26.3	26.9
52	13.3	Dead	----	----
54	22.9	25.2	26.3	16.4
60	17.6	13.1	23.0	19.7
64	15.2	21.9	24.1	17.7
34	10.6	13.1	19.2	7.1
Average	16.5	19.4	23.7	17.5
		Lot 3		
42	20.9	33.5	28.7	27.5
43	19.9	23.0	21.9	23.2
46	14.3	18.7	17.7	22.1
32	18.5	17.7	17.7	15.6
61	19.5	26.9	22.4	18.7
63	20.9	27.5	23.0	22.1
Average	19.0	24.5	21.9	21.5
		Lot 4		
40	16.1	15.6	18.2	15.3
31	13.8	25.2	26.9	27.5
55	24.3	34.8	29.8	29.8
62	16.1	24.1	21.1	20.8
66	11.5	18.2	18.7	13.6
69	13.3	16.6	13.6	13.1
Average	15.9	22.4	21.3	20.0
		Lot 5		
33	25.8	34.1	29.8	25.5
45	23.8	25.8	21.9	22.4
49	17.3	17.9	18.7	17.1
51	21.4	28.1	26.9	23.2
59	22.9	25.2	21.9	18.7
68	21.9	28.7	25.8	28.7
Average	22.1	26.6	24.1	22.6

Table 14. Liver Analysis at Termination of Experiment

Ewe No.	Condition of Liver	Liver Weight Grams	Gamma Vitamin A/gm.	Gamma Vitamin A/Liver
		Lot 1		
47	Atrophy	409	233.7	95,583
53	Atrophy	320	290.5	92,960
58	Good	559	215.6	120,520
70	Atrophy & Fatty	445	243.4	108,313
Average		433	245.8	104,344
		Lot 2		
34	Atrophy & Fatty	271	581.1	157,478
50	Fair	464	206.0	95,584
54	Atrophy & Fatty	376	363.6	136,714
60	Atrophy & Fatty	435	147.9	64,337
64	Good	470	108.9	51,183
Average		403	281.5	101,059
		Lot 3		
32	Good	565	185.4	104,751
42	Fair	616	99.8	61,477
43	Good	690	215.6	148,764
46	Good	543	99.8	54,191
61	Atrophy	582	60.8	35,386
63	Good	548	107.3	58,800
Average		590	128.1	77,228
		Lot 4		
31	Fatty	527	73.8	38,893
40	Good	543	182.6	99,152
55	Good	781	56.4	44,048
62	Good	669	139.8	93,526
66	Fair	610	141.9	86,559
69	Good	507	235.9	119,601
Average		606	138.4	80,296
		Lot 5		
33	Good	711	340.1	241,811
45	Fair	510	156.3	79,713
49	Good	524	104.2	54,601
51	Good	590	237.8	140,302
59	Good	581	126.9	73,729
68	Good	697	83.5	58,200
Average		602	174.8	108,059

150 grams lighter for lots 1 and 2 than for the other lots. Wallace (1949) found that ewes fed on a low-plane of nutrition had livers of lighter weights and of a higher percentage of fat than ewes fed on a high-plane of nutrition.

Vitamin A in the liver was determined by the method of Gallup and Hoefer (1946). Lots 1 and 2 had a higher storage of vitamin A per gram of liver than lots 3, 4, and 5. There was considerable variation between individuals of the same lot. In all cases it would appear there was adequate storage of vitamin A in the liver by comparison with normal storage values reported by Moore (1942). These results indicate that sheep have the ability to store vitamin A for long periods of time. Weir et al (1949) were also unable to produce a vitamin A deficiency in ewes during reproduction and lactation using an oat straw and concentrate basal ration. It would appear that a vitamin A deficiency was not the cause of the trouble encountered at lambing time even though some of the symptoms noted were similar to a vitamin A deficiency.

Liver Tissue Studies:

The only gross tissue changes noted on autopsy of ewes 52, 57, and 67 (died at lambing time) were those of the liver. The livers were very fragile and yellow in color. Chemical analysis of the fresh livers were made by the method of Jaffe et al (1949). The results which are presented in Table 15 indicate that the liver glycogen stores were low and that a pathological change had taken place as indicated by a marked increase in the fat content of the liver. Wallace (1949) reported 4.09 to 5.16 per cent of fat in livers of pregnant ewes fed on a high plane of nutrition.

Table 15. Chemical Composition of Fresh Liver of Ewes that Died

Lot No.	Ewe No.	Percentage of Fat	Glycogen + Water Soluble Material	Protein Residue	Moisture
1	67	16.3	2.2	17.9	65.1
1	57	14.8	2.3	12.5	70.4
2	52	27.9	1.5	8.0	62.4

Bone Ash:

A cross section of the fore shank from each ewe was analyzed for bone ash. The determinations were made by the method described in the Official and Tentative Methods of Analysis of the Association of Official Agriculture Chemists (1945). The per cent of ash of dry, fat free bone is given in Table 16. There was very little difference in the per cent of bone ash in the different lots. This data would be an additional indication that a calcium or phosphorus deficiency was not present.

Carcass Grades:

At the time of slaughter, the carcasses were graded by Wilson and Company graders and the results are given in Table 17.

Wool:

The condition and weight of the fleeces of the ewes were determined at shearing time and the results are presented in Table 18. The fleeces of the ewes in lots 1 and 2 all had breaks occurring about lambing time. Lots 1 and 2 had lighter fleeces than lots 4 and 5. Ewes 43 and 46 of lot 3 had lost approximately one-half of their wool by shearing time due to an old break in the fleece; therefore, the average fleece weight for lot 3 was unduly light.

Table 16. Per Cent of Ash of Dry Fat Free Bones of Ewes

	Lot 1		Lot 2		Lot 3		Lot 4		Lot 5	
	Ewe No.	% Ash	Ewe No.	% Ash	Ewe No.	% Ash	Ewe No.	% Ash	Ewe No.	% Ash
	47	69.66	34	69.83	32	69.17	31	69.58	33	68.55
	53	70.07	50	69.02	42	69.74	40	69.43	45	70.57
	58	69.94	54	70.44	43	69.95	55	69.63	49	69.23
	70	70.25	60	69.74	46	69.63	62	70.29	51	69.55
			64	69.24	61	69.54	66	69.86	59	69.05
					63	68.72	69	69.55	68	69.37
Average		69.98		69.65		69.45		69.72		69.38

Table 17. Carcass Grades of Ewes

Lot 1		Lot 2		Lot 3		Lot 4		Lot 5	
Ewe No.	Carcass Grade	Ewe No.	Carcass Grade	Ewe No.	Carcass Grade	Ewe No.	Carcass Grade	Ewe No.	Carcass Grade
*47	P	*34	P	32	L	31	P	33	L
*53	P	50	P	42	L	40	L	45	Condemned
58	P	*54	P	43	P	55	P	49	P
70	P	60	P	46	G	62	L	51	L
		*64	L	*61	G	66	P	59	P
				63	P	69	P	68	L

* - Ewes Did Not Raise Lambs
P - Poor
L - Low
G - Good

Table 18. Character and Weight of Wool at Shearing (4/28/50)

Lot 1			Lot 2			Lot 3			Lot 4			Lot 5		
Ewe No.	Character of Wool	Fleece Weight lbs.	Ewe No.	Character of Wool	Fleece Weight lbs.	Ewe No.	Character of Wool	Fleece Weight lbs.	Ewe No.	Character of Wool	Fleece Weight lbs.	Ewe No.	Character of Wool	Fleece Weight lbs.
47	BF-AL	6.5	34	BF-AL	6.0	32	GF	7.1	31	GF	6.5	33	GF	7.2
53	BF-AL	4.4	50	BF-AL	7.3	42	GF	6.5	40	BF-O	6.7	45	GF	6.2
58	BF-AL	5.1	54	BF-AL	5.9	43	BF-O*	3.7	55	GF	7.4	49	GF	7.1
70	BF-AL	6.7	60	BF-AL	5.3	46	BF-O*	3.6	62	GF	8.5	51	GF	8.2
			64	BF-AL	6.8	61	GF	6.0	66	GF	8.8	59	BF-O	6.1
						63	GF	6.4	69	GF	6.6	68	GF	8.8
Average		5.67			6.26			5.55			7.41			7.26

BF - Broken Fleece
GF - Good Fleece
AL - Break at Lambing
O - Old Break (Previous to Lambing)
* - Ewes Had Lost Approximately One-half of Wool at Shearing Time

CONCLUSIONS

The disturbances encountered in the ewes and lambs in lots 1 and 2 during late pregnancy and early lactation were very similar to some of the disorders in cattle in eastern Oklahoma reported by Ross and Gallup (1947). The data presented in this paper indicates that the unsatisfactory results obtained in lots 1 and 2 were due primarily to a protein deficiency.

The primary symptoms of a protein deficiency as reported by Cannon (1948) are a loss of weight, anemia, and low plasma protein values. In this experiment consideration was given to other possible causes of the anemic condition observed. No evidence was found indicating that the experimental animals were parasitized. Routine analysis were made for parasite eggs in the fecal passages and the animals that died in lots 1 and 2 were carefully checked for the presence of worms. Deficiencies of the mineral elements copper, iron, and cobalt are also known to cause an anemia in ruminants. Since the performance of the ewes and lambs in lots 3 and 4 receiving none of these trace minerals was practically equal to lot 5 receiving trace minerals, it would indicate trace minerals have a minor, if any, role in the anemia encountered.

Further evidence that a protein deficiency was encountered in lots 1 and 2 was the lowered plasma protein values. Cannon (1948) has found that small decreases in plasma protein levels are very significant and decreases in values of 10 to 15 per cent are indicative of a protein deficiency or some interference in protein metabolism.

The inappetence, especially for concentrate feeds, observed in the ewes in lots 1 and 2 during the latter part of pregnancy is similar to an observation reported in cattle in eastern Oklahoma during the late winter and early spring months. This symptom might be somewhat misleading in that it would tend to lead one to believe a single deficiency of some nutrient or an infectious or metabolic disease existed rather than a simple deficiency of protein and energy. In this study tissue changes, especially liver degeneration, were noted to occur at about the same time as the symptoms of inappetence appeared. The lack of response to curative measures carried out in three ewes and the slow gain in weight of other ewes in lots 1 and 2 would indicate that tissue changes had occurred that were difficult to restore to normal. Tissue changes, especially those that occur in the liver, would undoubtedly have secondary effects in that the normal functional capacity of these organs is reduced. While calcium, phosphorus, vitamin A, and trace minerals are important requirements in ruminant nutrition, in this study they were of secondary importance to the protein supplement.

This study would suggest that further work is needed on the requirements of ruminating animals during reproduction and lactation. Maynard (1947) stresses that very little is known regarding the nutritive requirements for reproduction and lactation of ruminating animals. He points out that the nutritive requirements are higher during pregnancy and that the last quarter of gestation is the most critical period. He postulates that energy and protein are both important during pregnancy and lactation, but that the protein part of the diet is the more critical.

SUMMARY

An experiment was designed to determine what nutrients were needed to supplement a basal ration of hay from eastern Oklahoma in order to obtain normal reproduction and lactation in sheep. Special emphasis was given to the value of increasing the protein and energy content of the basal (hay) ration. Thirty head of four-and five-year-old western Texas ewes were used to conduct this study. They were equally divided into 5 lots, bred, and started on experiment November 1, 1949.

Lot 1 was fed the basal ration of prairie hay. Lot 2 was given the basal hay plus an energy feed (corn starch). Lot 3 received the basal hay with the addition of a protein feed (corn gluten meal). Lot 4 was given the same ration as lot 3 plus dicalcium phosphate. Lot 5 received the same ration as lot 4 with the addition of the trace minerals (iron, copper, cobalt, and manganese) and vitamins A and D (cod liver oil).

The gain or loss in body weight of the ewes during pregnancy appeared to be in relation to the type and quantity of nutrients fed. The ewes in lot 1 and lot 2 suffered heavy losses of body weight during pregnancy. At lambing time they were emaciated, weak, apparently lacked maternal instinct, and had very poor udder development. Many of the lambs born in lots 1 and 2 were either dead or so weak that they died shortly after birth. The ewes in lots 3, 4, and 5 maintained their body weight during pregnancy and lactation. They gave birth to lambs that were normal in size, vitality, and growth.

The hemoglobin, hematocrit, and plasma protein values were lower for lots 1 and 2 than for the other three lots. The phosphorus, calcium, and vitamin A values were about equal for all lots.

The data suggest that the anemic condition of the ewes in lots 1 and 2 as well as their poor lambing results was due to the low intake of nutrients —especially protein. The slight improvement in the size and general condition of the lambs in lots 4 and 5 indicates that phosphorus, trace minerals, and vitamin A were of secondary importance as compared to the protein supplement.

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