RESEARCH BULLETIN 763 JANUARY, 1961

UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION

ELMER R. KIEHL, *Director*

Studies on Calcium Requirements Of Ewes

STANLEY F. ERWIN, G. B. THOMPSON, W. H. PFANDER

(Publication authorized January 23, 1961)

COLUMBIA, MISSOURI

TABLE OF CONTENTS

Studies on Calcium Requirements Of Ewes

STANLEY F. ERWIN, G. B. THOMPSON, W. H. PFANDER

INTRODUCTION

Missouri is one of the leading sheep producing states. The efficient production and feeding of sheep is important to the livestock industry of the state.

Calcium has long been recognized as one of the essential elements in diets of humans and animals. As early as 1842, Chossat demonstrated that poor bone developed on a diet low in calcium. After that time, not much experimental work was conducted with calcium until the beginning of the present century. Since then, it has been determined that 99 percent of the calcium in the body is present in the bones and teeth. This element is also an essential part of blood serum and plays an important role in muscles.

Legumes are an excellent source of calcium but considerable land is not well adapted to legumes and farmers depend upon grass hays which are relatively low in calcium. Very little long term experimental work has been conducted on the calcium requirement of sheep; therefore, part of project 248 has been concerned with this problem.

This bulletin reports the results of experiments to determine the calcium requirements of ewes throughout the year with special attention to their performance during pregnancy, parturition, and lactation.

REVIEW OF LITERATURE

Effects of Feeding Calcium-Deficient Rations

General Effects

Fraser et al. (1933) reported that the feeding of calcium deficient rations to pregnant ewes resulted in the lowering of blood calcium levels, appearance of pregnancy disease, and finally death to the ewes. Ewes that were examined after death had inflammation of the gastrointestinal tract, fatty degeneration of the liver, and uterine death of lambs.

Bell and Kick (1935) reported that lambs fed for eight to twelve weeks on a ration composed of yellow corn, ¼ pound of protein supplement, and timothy

hay *ad lib* had no gains in weight, low blood serum calcium levels which became lower with time, and their cannon bone breaking strength was low. Vitamin D levels in the ration appeared to be adequate when calcium was added to the basal ration.

Bell and Kick (1936) ran another experiment to check on the previous one. They divided forty lambs into four lots of ten each. Two lots were fed the basal ration and the other two lots were fed the basal ration plus 0.5 ounce of limestone flour per lamb per day. These tests were conducted for 182 days during which time one lamb from each of the lots fed the basal ration died after exhibiting signs of tetany. The lambs given the calcium supplement had: (1) keener appetites, (2) 20 percent greater gain in body weight (3) more nearly normal calcium and phosphorus blood serum levels, (4) 36 percent stronger metacarpal bones, (5) a higher percent of bone ash, (6) a greater degree of calcification as determined by histological studies, and (7) no deaths from tetany. These results confirmed the results of the previous test that the basal ration was incapable of furnishing enough calcium.

Bruman and Delachauk (1937) reported that feeding sheep a diet deficient in calcium but adequate in starch and digestable protein did not affect the digestion of organic constituents over periods of 4 to 6 months. There was a general tendency for blood serum calcium to fall with a rise in serum phosphorus and magnesium. The composition of milk did not change nor did the composition of bones alter greatly, but the ewes did not lamb normally, had a lower lambing percentage, and lambs did not survive as well as the controls.

Bone

Kruger and Bechdel (1928) slaughtered seven male holstein calves, one each at the age of 60 days, 90 days, 120 days, 150 days, and three at 180 days of age. They reported that the percent of calcium and phosphorus in bone ash remained nearly constant but the percent of ash and organic matter increased with age.

Fraser (1932) reported that as the serum calcium levels of the blood fall, inorganic phosphorus levels rise. He stated that the calcium x phosphorus concentration product remains nearly constant at all times. This worker suggested that when calcium was mobilized from the bone on low calcium rations, phosphorus would be mobilized also causing a rise in blood phosphorus. The calcium and phosphorus relationship in bone remains relatively constant.

Benzie *et al.* (1955) studied the effects of different levels of dietary calcium during pregnancy and lactation on individual bones of ewes. Three groups of ewes were fed during lactation and pregnancy with mean daily intakes of 1.4 grams, 4.5 grams, and 7.4 grams of calcium. Approximately 100 days after parturition the ewes were slaughtered and individual bones analyzed. They observed that the levels of calcium they used had no effect on the number of lambs born, their birth weight, or their growth weight. Blood calcium was significantly lower in the group with the daily intake of 1.4 grams of calcium.

They reported greater resorption of bone in group one than in groups two and three but the severity of resorption varies between bones and regions within certain bones. Resorption of the bone calcium was accompanied by reduction in the percentage of ash in the bones.

Benzie *et al.* (1956) divided 60 Cheviot ewes into six groups to study the relationship between calcium intake and resorption and repair of the skelton during pregnancy and lactation. The basal ration contained 1.6 to 2.3 grams of calcium and 3 to 5.1 grams of phosphorus daily. Group one was fed the basal ration and slaughtered in mid lactation. Groups two and three were fed the basal ration plus 2.9 grams of calcium daily and then slaughtered at parturition plus 60 days and parturition plus 180 days respectively. Groups four and five were fed the basal ration and slaughtered at parturition plus 60 days and 180 days respectively. The sixth group was fed the basal ration to mid lactation at which time 2.9 grams of calcium was added to the ration daily. They reported that when Cheviot ewes were given a ration containing 5 grams of calcium daily during pregnancy and lactation, there was a loss of 6.5 percent of skeletal mineral by mid lactation; but two months after the end of lactation, the loss was fully replaced. When the daily calcium allowance was about 2 grams per ewe per day, there was a loss of 18.2 percent of skeletal mineral by mid lactation and it was not fully recovered two months after the end of lactation. However, if the calcium level was raised to 5 grams by mid lactation, the skeletal mineral was fully recovered within two months after the end of lactation. They also observed that if the sheep are on a low intake of calcium, serum calcium increased in early lactation and then decreased until the end of lactation; but if calcium is added to the ration in mid lactation, the serum calcium levels quickly returned to normal.

Blood

Greaver *et al.* (1934) observed little or no effect upon the blood calcium of forty head of steers which were divided into five groups and fed a basal ration of pressed beet pulp, molasses, alfalfa hay, and salt. Four of the groups had supplements of cottonseed cake, steamed bone meal, mill run bran, and ground barley added respectively. Before the beginning of the trial, 100 cubic centimeters of the blood serum contained 12.25 to 13.13 milligrams of calcium and 2.41 to 3.01 milligrams of phosphorus.

Payne *et al.* (1946) sampled 560 animals out of a large Hereford herd that subsisted on range pasture seven to twelve months of the year. They found blood serum calcium levels of $10.46 \pm .238$, $13.03 \pm .256$, $9.13 \pm .158$, and $9.52 \pm .249$ mgm. percent and serum inorganic phosphorus levels of $7.3 \pm .103$, $4.76 \pm .09$, $5.07 \pm .063$, $4.89 \pm .1$ mgm. percent for yearling bulls, herd bulls, two year old heifers, and aged cows respectively.

Pearson *et al.* (1949) fed six mature ewes a liberal amount of alfalfa and limited grain. Potassium bicarbonate was mixed with the grain to provide five percent potassium in the ration. They took monthly blood samples for four

months and compared these with samples from twelve stock ewes. They found no significant difference in the levels of calcium, magnesium, or potassium in the blood serum of the two groups.

Franklin *et al.* (1951) reported that a ration containing 0.16 percent calcium and 0.39 percent phosphorus could reduce serum calcium to 2.7 mgm. percent. By adding 1 to 1.25 percent of finely ground limestone to the ration, they could prevent the fall of serum calcium or return it to normal if the level had already fallen. Lactating ewes were most affected. Ewes with a low serum calcium which were not exhibiting any clinical disturbances became sluggish and could not stand after moderate exercise.

March and Swingle (1955) collected blood samples from twelve groups consisting of 30 to 32 range sheep over a four year period. Eleven of the collections were made in the winter and one in the summer. They reported an average of 9.2 ± 1 mgm. of calcium and $4.3 \pm .9$ mgm. of phosphorus on 100 ml. of plasma. These workers observed a significant difference between the ewes wintered on the range and ewes fed some concentrate or hay during the winter.

Milk Production

Becker *et al.* (1933) at the Florida station found that cows which were fed silage grown on sandy soil as their only roughage increased their average milk production from 4227.8 pounds to 6667.2 pounds during the lactation period when two percent bonemeal or limestone was added to the concentrate part of the ration. This also caused an increase in the breaking strength of their bones.

Milk Production Studies With Ewes

Barnicoat *et al.* (1949) reported that the plane of nutrition was the most important factor affecting milk production of ewes. They observed that milk production of the ewes reached its peak in four to six weeks at which time the lambs are big enough to take all of the milk. It was determined that the ewes milk contained approximately .27 percent calcium and 0.16 percent phosphorus.

Barnicoat *et al.* (1956) ran milk production tests from the third to the ninth week of lactation with two groups of Romney ewes on a low and a high plane of nutrition. The average milk production on the low plane of nutrition was 28 ounces per day for ewes with singles and 35 ounces per day for ewes with twins. On the high plane of nutrition the milk yield was 45 ounces per day for singles and 57 ounces per day for twins. They stated that milk yields varied widely and that milk production was the major factor influencing the rate of live weight gain of lambs.

Response to Calcium Supplements and Sources

The national Research Council states that forage containing 0.24 to 0.32 percent calcium is adequate for sheep.

Fraser *et al.* (1933) found that adding cod-liver oil to a basal ration low in calcium increased the serum calcium of sheep. The addition of 2.2 pounds of

chalk per 100 pounds of concentrate did not improve the basal ration, but the addition of chalk plus cod-liver oil increased the weight and improved the condition of the sheep.

Jones and Stangel (1938) found that supplementing sorghum silage and fodder rations with 0.2 to 0.47 ounces of crushed limestone or oystershell per lamb per day increased the consumption of these roughages resulting in greater gains in weight. They determined that 0.4 ounce of limestone per lamb per day fed with sorghum silage or fodder was equal to using alfalfa hay as the roughage.

Lewis *et al.* (1951) stated that steer calves reduced their total feed intake when excess calcium was added to rations that were either borderline or deficient in phosphorus.

Hansard *et al.* (1957) added calcium from 15 different organic sources to the ration of young and mature steers that were being pair fed on 109 individual balance studies. This experiment indicated that age and not the source of calcium caused the difference in digestability. True digestability was greater in the young animals.

Dowe *et al.* (1957) ran a 140 day feeding trial with Hereford steer calves that were approximately eight months old and 475 pounds in weight. The calves were fed 4 pounds of ground shelled corn and one pound of soybean oil meal daily with free access to prairie hay. The calcium of the ration was varied by adding varying amounts of limestone. The calves were divided into four lots and given calcium:phosphorus ratios of 1.3:1, 4.3:1, 9.1:1, and 13.7:1 respectively. Lots one and two gained approximately the same, but there was a great difference between the lower two levels and higher two levels of calcium. These workers suggested that if gains in weight could be used as a criteria, there appeared to be a critical calcium phosphorus ratio somewhere between 4.3:1 and 9.1:1.

Use of Ca^{45}

Hansard *et al.* (1952) maintained Hereford cattle under similar conditions from weaning until they were placed on experiment. At the beginning of the experiment the cattle were placed on a low calcium ration using oat straw as the roughage. After being conditioned to the crates, the cattle were given Ca^{45} both intravenously and orally. They observed that in general the accumulation and turn-over of calcium in the various bones paralleled the metabolic activity and that calcium is continuously removed and replaced in the blood.

Hansard *et al.* (1954) fed 34 selected Hereford cattle ranging in age from 10 days to 190 months, and found that as animals get older they utilize calcium less efficiently. The animals were given a single oral or intravenous injection of Ca^{45} after which seven day radioisotope and balance studies began. The results indicated that absorption and true digestability was greatest in the young animals. Maintenance requirements per 100 pounds of body weight ranged from 0.5 gram for ten day old calves to 2 grams for six-month old calves and remained constant from this point on. Hansard *et al.* (1954) found a threefold increase in

the rate of excretion of unabsorbed calcium in aged animals. This work confirmed the previous experiment.

Effects of Other Factors in the Ration on Calcium Requirements

In four experiments run by Eaton *et al.* (1953) lambs were fed rations in which the roughages were normal alfalfa, normal alfalfa containing 2.73 percent potassium plus potassium chloride to bring the potassium level to four percent, high potassium hay, and high potassium hay containing 3.23 potassium plus enough potassium chloride to bring the potassium level up to four percent. They observed that the natural or high potassium hay had no effect upon calcium retention but the addition of potassium chloride to either one increased the excretion and decreased retention of calcium.

White *et al.* (1958) reported that fat added to a ration as corn oil decreased cellulose digestion. Two lots of eighty pound wethers were fed this basal ration supplemented with 4.4 grams of calcium and 4.4 grams of calcium plus 0.86 grams of phosphorus. The calcium or the calcium plus phosphorus restored the digestion of cellulose to normal. These workers also reported that 4.4 grams of calcium was equal to 30 grams of alfalfa ash added to the ration.

Thompson *et al.* (1959) divided 12 lambs into three groups and fed them the basal ration, basal plus 1 percent aluminum, and basal plus 1 percent zinc. The basal ration contained 0.18 percent calcium and 0.21 percent phosphorus. The results of this experiment indicates that zinc decreased the absorption and retention of calcium and phosphorus while aluminum has no effect on these two minerals.

This review of literature indicates that a ration containing less than four to five grams of calcium daily will result in reduced breaking strength of bone, lower milk production, and lower blood serum calcium, especially during the lactation period. These effects have resulted in a smaller lamb crop and less efficient lamb gains.

MATERIALS AND METHODS

Effects of Feeding a Low Calcium Ration to Ewes

November 1955 to November 1958

Twelve 60-pound Colorado ewe lambs were placed on a low calcium ration containing timothy hay, shelled corn, and cottonseed meal in November of 1955 to study "stiff lambs" disease. In 1938 Dr. Hogan of the University of Missouri observed stiffness in ewe lambs fed this same ration. The present experiment was continued for three years with the ewes being bred to lamb in the spring of the second and third years of the trial.

In February of 1956 one ewe died and the experiment was continued with eleven ewes. During the lambing season in 1957 three more ewes died and the

following fall four Texas ewes that were on a similar ration were added to this trial to bring the number of ewes to the original number of twelve.

The ration in Table 1 was used all three years of the trial and the amounts of feed fed to the ewes was varied according to their condition and need. By

TABLE 1-RATION USED IN TRIAL I

45% Timothy Hay
45% Shelled Corn
10% Cottonseed Meal

chemical analysis the ration contained from 0.13 to 0.18 percent calcium. Salt was fed free choice and the water was supplied by automatic heated waterers.

In general good management practices were carried out during the experiment with the animals being kept free of parasites and diseases. The records that were kept are:

1. Weekly weights of ewes and lambs
2. Feed records
3. Breeding dates
4. Lambing dates and birth weight of lambs
5. Wool weights
6. Complete production records

Effects of Feeding Ewes on Low Calcium and High Calcium Rations

December 1958 to November 1959

In order to more carefully evaluate the adequacy of the ration for reproduction, the ten ewes on the low calcium ration were divided into two equal groups using weight, production records, and condition for criteria.

One group of the ewes was continued on the same low calcium ration. The other group of ewes was placed on the basal ration plus 1 percent ground limestone.

In general, good management practices were carried out. The ewes were crotched out a month prior to lambing and their feet were trimmed as needed. The lambs were docked and castrated between two and seven days of age. In June the ewes and lambs were vaccinated for enterotoxemia. The ewes were fed twice daily in one large feeder in each lot. The daily allowance was varied according to the condition and need of the ewes. Salt was fed free choice and the water was furnished by automatic electrically heated waterers. The records that were kept were the same as previously mentioned in this paper with the addition of milk production records.

The composition of the rations used is shown in Table 2 and analysis for ash, calcium, and phosphorus is shown in Table 3. The first two months of this trial the ewes were fed a ration of lespedeza, shelled corn, and cottonseed meal with the high calcium ewes receiving added limestone. From February 1 to No-

TABLE 2-RATIONS USED IN TRIALS

Year	Nov. 1, 1958 to Feb. 1, 1959		Feb. 1, 1959 to Mar. 6, 1960		Mar. 6, 1960 to June 30, 1960	
Treatment	L[1] %	H[1] %	L %	H %	L %	H %
Lespedeza Hay	60	60				
Grass Hay			50	50		
Corn Cobs					50	50
Shelled Yellow Corn	37	37	47	47	47	47
Cottonseed Meal	3	3	3	3		
Soybean Meal (Solvent 44% Crude Protein)					3	3
Ground Limestone		1		1		1

[1]The following abbreviations are used: L, is low calcium ration; H, is high calcium ration.

TABLE 3-CALCIUM AND PHOSPHORUS CONTENT OF RATIONS

		Ash %	Calcium %	Phosphorus %
Nov. 1958[1]	L[2]	5.41	.27	.25
	H[2]	4.64	.55	.27
Feb. 1959	L	5.14	.25	.11
	H	5.74	.35	.11
Dec. 1959	L	4.93	.26	.21
	H	5.85	.59	.23
Feb. 1960	L	5.19	.24	.20
	H	5.48	.53	.21
Mar. 1960[3]	L	1.58	.07	.15
	H	2.64	.50	.18
May 1960	L	2.88	.31	.21
	H	3.68	.53	.18
May 1960	L	2.73	.18	.21
	H	3.61	.39	.17
Average	L	4.00	.24	.15
	H	4.54	.49	.16

[1]These are the dates when new rations were mixed and samples were taken.
[2]The following abbreviations are used: L, is low; H is high.
[3]The roughage was changed from grass hay to corn cobs.

vember the basal ration consisted of poor quality grass hay, shelled corn, and cottonseed meal. One to two tons of the complete rations were ground and mixed at a time. The calcium content of the low calcium ration ranged from 0.25 to 0.27 percent and the calcium content of the high calcium ration ranged from 0.35 to 0.59 percent.

The difference in the composition of the low calcium and the high calcium rations varied more than was expected. The ration was mixed in a 1000-pound mixer and there was some difficulty in obtaining a uniform mixture. Therefore, there may have been some variation due to the mixing. The amount of calcium in the ground limestone may have varied also.

The ewes were kept in open lots with sheds to go into at night or in bad weather. During lambing the ewes were penned up until the lambs were two days old. Heat lamps were used to keep the lambs warm.

Breeding dates of the ewes were determined by observing the ewes twice daily for paint marks on the rump. Sheep marking fluid mixed in 30-weight motor oil was applied to the brisket of the ram daily. The color of the paint was changed every fifteen days.

Weekly weights of the ewes were obtained. The lambs were weighed at birth and each week after birth until weaning.

The ewes were shorn on April 1. Individual wool weights were recorded.

Blood samples were drawn from the ewes in late pregnancy and again in lactation. These were analyzed for blood calcium to determine the blood calcium levels of the ewes before and after lambing.

Weekly milk yields of the ewes for a 12-hour period were obtained from the first or second week of lactation for an eight week period. The lambs were separated from the ewes at 7:00 a.m. and then allowed to nurse at four hour intervals for the next 12 hours. The milk production was determined by weighing the lambs immediately before and after nursing and obtaining the difference in weights. The lambs were placed on their backs in a V-shaped trough on a Howe Weight-O-Graph for milk production weights. (Figure 1.) The Howe

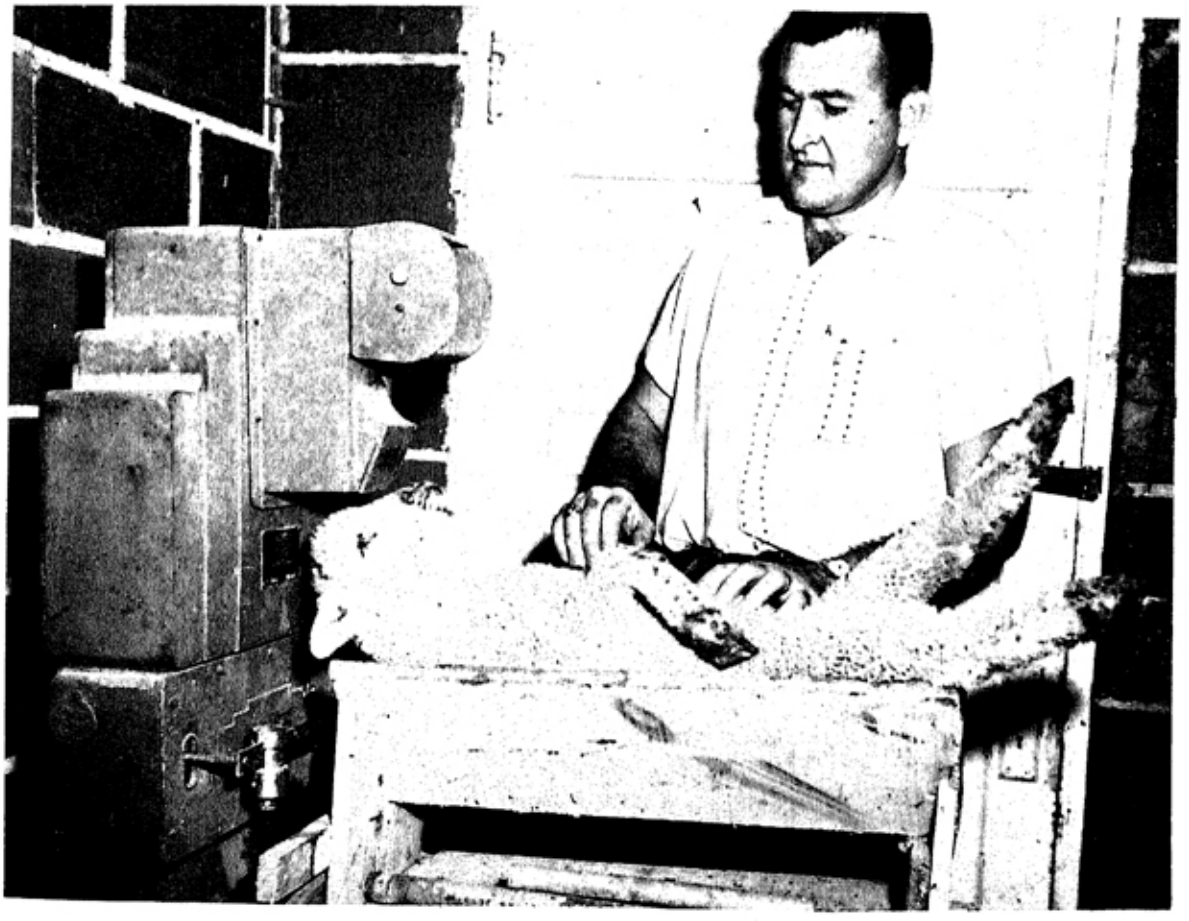


Figure 1.-The Howe Weight-O-Graph used to weigh the lambs for Milk Production Studies.

Weight-O-Graph is accurate to .02 of a pound. If the lamb did not take all of the milk, the ewes were milked by hand and the weight of this milk was added to the difference in weight of the lamb. Twin lambs were weighed and then they nursed simultaneously.

The ewes and lambs that died were taken to the Veterinary Diagnostic Laboratory where a post mortem examination was made. Sick ewes were taken to the clinic for treatment. Blood was analyzed for calcium and phosphorus at the Missouri Agricultural Experimentation Station spectroscopic laboratory, using unpublished procedures of Dr. Pickett. Analysis of the rations, feces, and urine for calcium and phosphorus were accomplished by the Missouri Agricultural Experimentation Station laboratories, using modifications of procedures accepted by the Association of Official Agricultural Chemists.

November 1959 to June 1960

In November of 1959 three yearling Texas ewes were added to each lot. This made a total of eight ewes on the low calcium ration and seven ewes on the high calcium ration as one of the ewes in this lot died while lambing in 1959.

The procedures used during this trial were the same as the preceding trial with the following exceptions.

The roughage of the rations was changed from grass hay to corn cobs, and soybean meal was substituted for the cottonseed meal on March 9, 1960. The composition of these rations is shown in Table 2 and chemical analysis for ash, calcium, and phosphorus is shown in Table 3. After the roughage was changed to corn cobs, 4000 I.U. of vitamin A was added to the ration per ewe per day. The food consumption of the ewes declined when they were placed on the corn cob rations. Corn syrup, and later corn molasses, was mixed with the rations in an attempt to increase their food consumption. This did not increase consumption of the ewes appreciably.

From October, 1959, to May, 1960, the ewes were fed in individual feeders shown in Figure 2. The ewes were not fastened in these feeders but allowed to eat free choice.

The calcium intake from water was determined from December 17, 1959, to December 23, 1959. The water intake of the ewes was measured daily and a 200-ml. sample was taken twice a day. Later a chemical analysis of the water was made to determine the calcium and phosphorus content.

A calcium phosphorus balance trial was conducted six weeks prior to the average lambing date. The ewes were individually fed constant amounts of the ration thirty days prior to the start of the balance trial. They were placed in the collection crates shown in Figures 3 and 4 for a three-day adjustment period and then feces and urine collections were made for seven days. These were analyzed and the calcium and phosphorus balances determined. Feed samples were taken daily during the collection period and analyzed also.

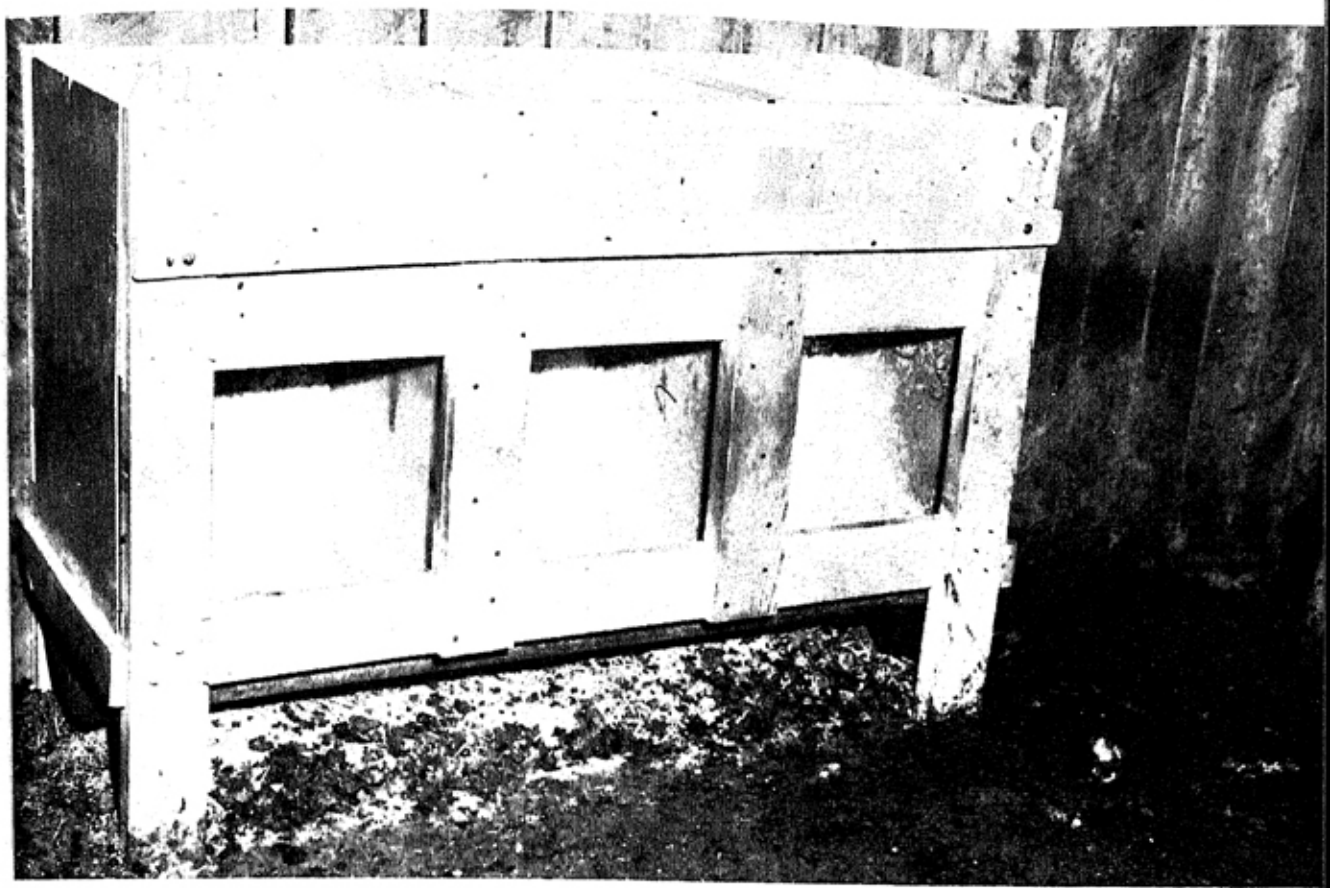
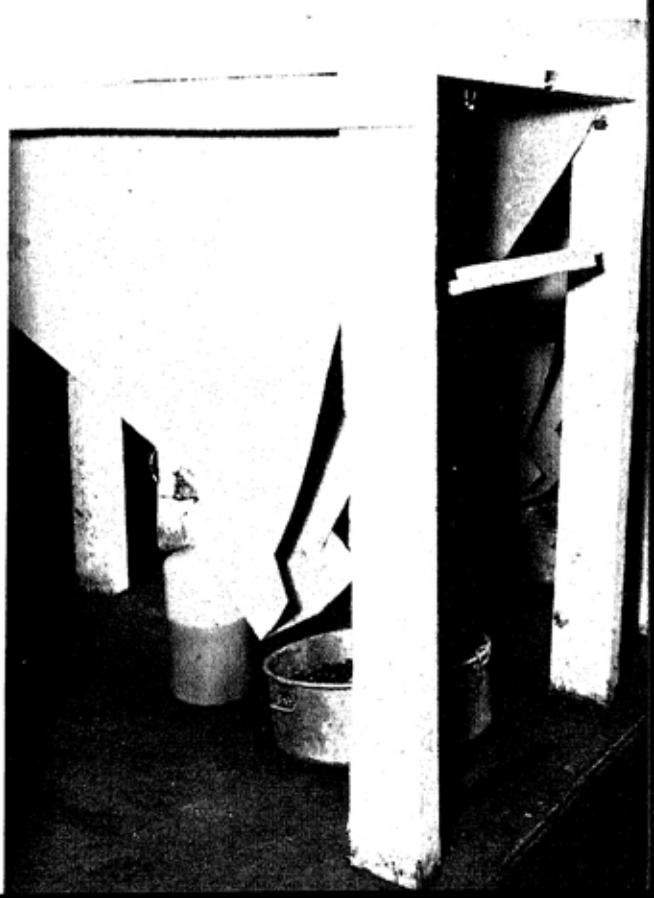


Figure 2. Feeders used in the trials from October, 1959 to May, 1960.

Figures 3 and 4. Collection Crate Used in the Calcium Balance Trial.



A sample of the milk of two ewes on each ration was taken in the last of April. The ewes were hand milked in the lot without a stimulus. An analysis was run to determine the amount of calcium present.

In May the X-ray density technique was employed to study the bone structure and density of the ewes fed the low calcium and high calcium rations. X-rays of the forelegs of the ewes were taken at the University of Missouri veterinary clinic by Dr. A. A. Case. A Welch Densichron was used to measure the optical density of the X-ray film of the cannon bones, the proximal sesamoids, and the phalanges. X-ray negatives of bones with the greater amounts if ash have less optical density than the other bones.

RESULTS AND DISCUSSION

Effects of Feeding a Low Calcium Ration to Ewes

The ewes were placed on this low calcium ration to evaluate their requirement for calcium, for growth, and reproduction. The following are the results of feeding ewes a ration containing .13 to .18 percent calcium.

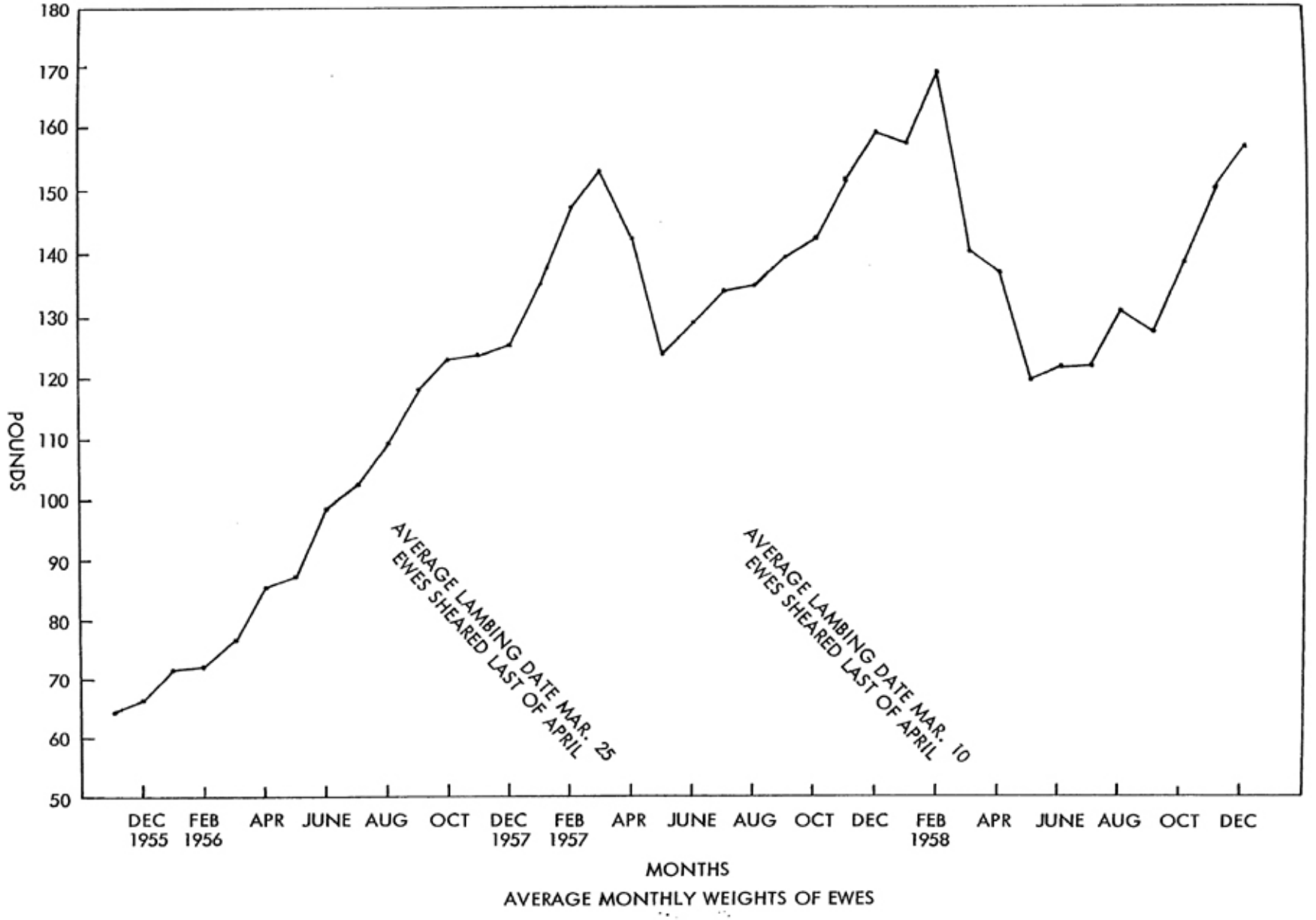
Growth and Condition of Ewes

The average monthly weights of the ewes are shown in Table 4 and Figure 5. The growth of the ewes from the time they were placed on the experiment until their first breeding time was considered normal. During the first pregnancy the ewes gained thirty pounds and during their second pregnancy they gained twenty-seven pounds. A gain of fifteen to thirty pounds during pregnancy is normally recommended. It appeared that a ration containing .13 to .18 percent calcium was adequate for normal growth of these ewes if weight gains alone were used for the criteria.

TABLE 4-AVERAGE MONTHLY EWE WEIGHTS

Month	Year			
	1955	1956	1957	1958
Jan.		71.7	136.8	158
Feb.		72.6	147.5	169
Mar.		76.7	153.4[1]	140[2]
Apr.		85.5	142.4	137
May		87.2	124.1[3]	120[4]
June		98.4	129.2	---
July		102.2	134	122
Aug.		109.1	135	131
Sept.		118.7	139.2	128
Oct.		123.3	142.3	138
Nov.	64.5	123.6	151.5	150
Dec.	66.3	130.7	158.2	157

[1]Average Lambing Date March 29
[2]Average Lambing Date March 10
[3]Average Wool Weights 11.1 Pounds Sheared Before May 1
[4]Average Wool Weights 10.8 Pounds Sheared Before May 1



AVERAGE MONTHLY WEIGHTS OF EWES

Figure 5.

Death Losses and Causes

On March 1, 1956, one of the ewes died. Post mortem examination revealed that the ewe died from inadequate rumen function resulting from a previous foundered condition possibly prior to the beginning of the experiment.

In January, 1957, one ewe was killed and another one was seriously injured by dogs. The latter ewe died two days later. On April 8, 1957, one of the ewes died of gangrene infection of the udder. She was in her fifth week of lactation.

Four ewes were added to the experiment in the fall of 1957 to return the number on experiment to twelve. In September, 1958, two ewes died of a toxic poisoning. The cause of the poisoning was not determined.

No association of nutrition to any of the above death losses was indicated.

Production Record

Complete production records are shown in Table 5. Nine ewes lambed in 1957. Three of these ewes had severe vaginal prolapse and two had ketosis. They

TABLE 5-PRODUCTION RECORDS

	1957	1958
Av. Lambing Date	Mar. 25	Mar. 10
No. of Ewes	9	12
No. of Lambs Born	12	16
No. of Lambs Raised to Weaning	8	10
No. of Twin Lambs	6	8
No. of Single Lambs	6	8
Av. Birth Wt. of Lambs (lb.)	10.82	9.56
Av. Birth Wt. of Singles (lb.)	11.93	10.53
Av. Birth Wt. of Twins	9.72	8.6
No. of Ewes Having Lambing Troubles	5[1]	2[2]
Av. Wool Wts. (lb.)	11.23	10.78

[1]Two ewes had ketosis and three ewes had severe vaginal prolapses. Lambs were taken by a Caeserean Section.
[2]Two ewes had ketosis.

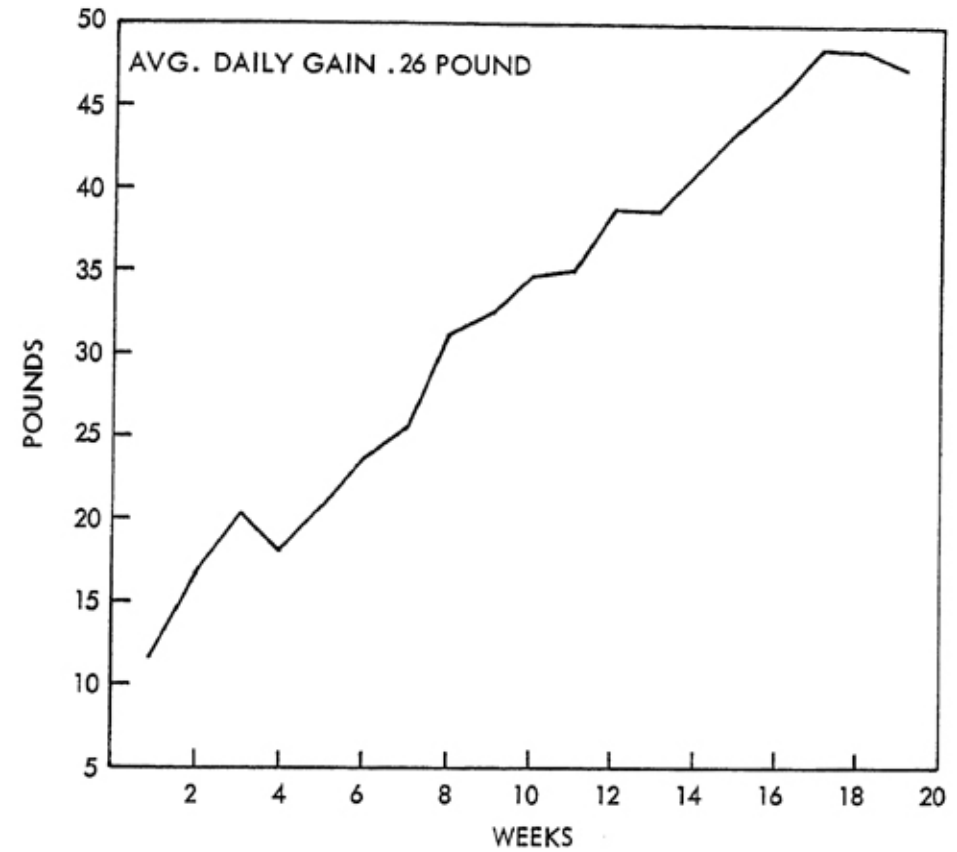
were taken to the veterinary clinic for treatment and all of the ewes recovered. The lambs of the ewes with prolapse were taken by Caesarean Section.

Average birth weight of the lambs was 10.84 pounds with a very wide range of 8.04 to 17.25 pounds. Weekly average weights of the lambs are shown in Figure 6.

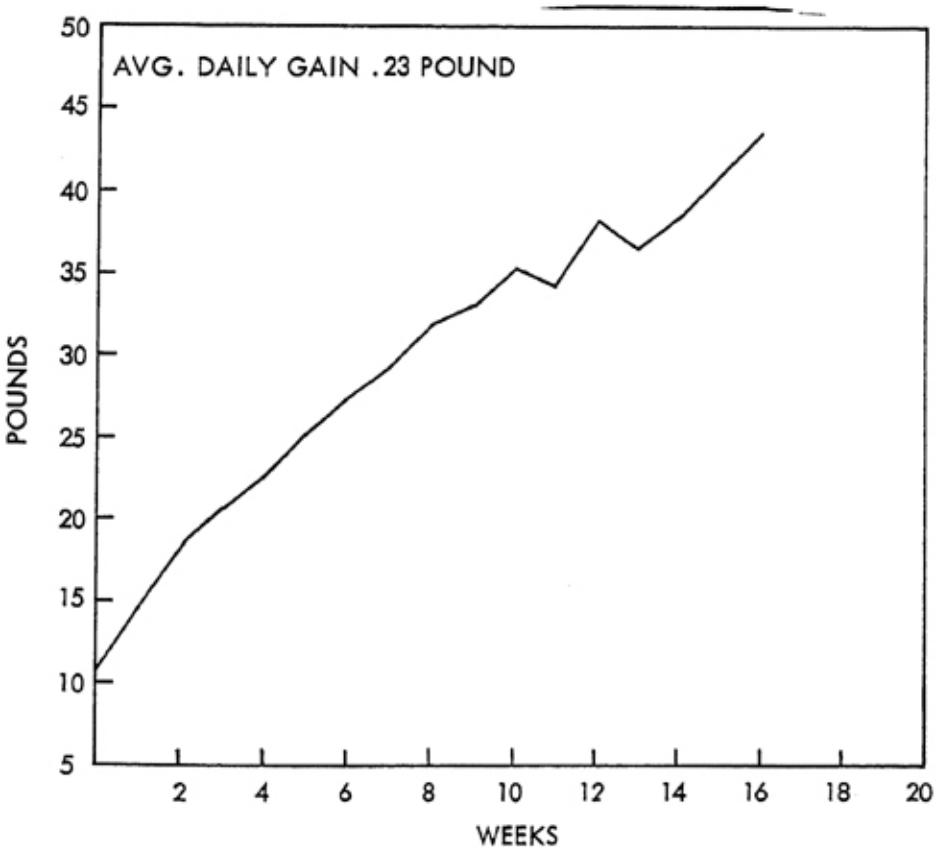
Eight of the 12 lambs born survived to weaning. One of the four lambs that did not live was born dead. A second lamb was weak and would not nurse. The lamb died two days later despite bottle feeding it with cows milk plus ten percent dextrose. A third lamb was born backwards and apparently was injured in delivery. The lamb was never able to walk and died at two days of age. Bottle feeding was initiated as well as assisting the lamb to nurse.

In 1957 the ewes had good quality fleeces averaging 11.23 pounds.

Twelve ewes dropped lambs in 1958. Two of these ewes had ketosis. Both ewes responded to treatment at the veterinary clinic and were returned to the



AVERAGE WEEKLY WEIGHTS OF LAMBS TO WEANING 1957



AVERAGE WEEKLY WEIGHTS OF LAMBS TO WEANING 1958

Figure 6.

experiment. The average birth weight of the lambs was 10.78 pounds with a range of 6 to 12.49 pounds for the individual lambs.

Six of the 16 lambs born in 1958 did not survive until weaning. Two were born dead, one froze to death before it was found, and the other three were weak and only lived two or three days after they were born. Post mortem examinations revealed that the weak lambs had very little milk in their stomachs.

In 1958 the ewes had good quality fleeces averaging 10.78 pounds. The ration appeared to be adequate for wool growth.

Summary

A ration composed of shelled corn, timothy hay, and cottonseed meal containing 0.13 to 0.18 percent calcium was fed to ewes from approximately eight months to three years of age. The following is a summary of the results of feeding this low calcium ration:

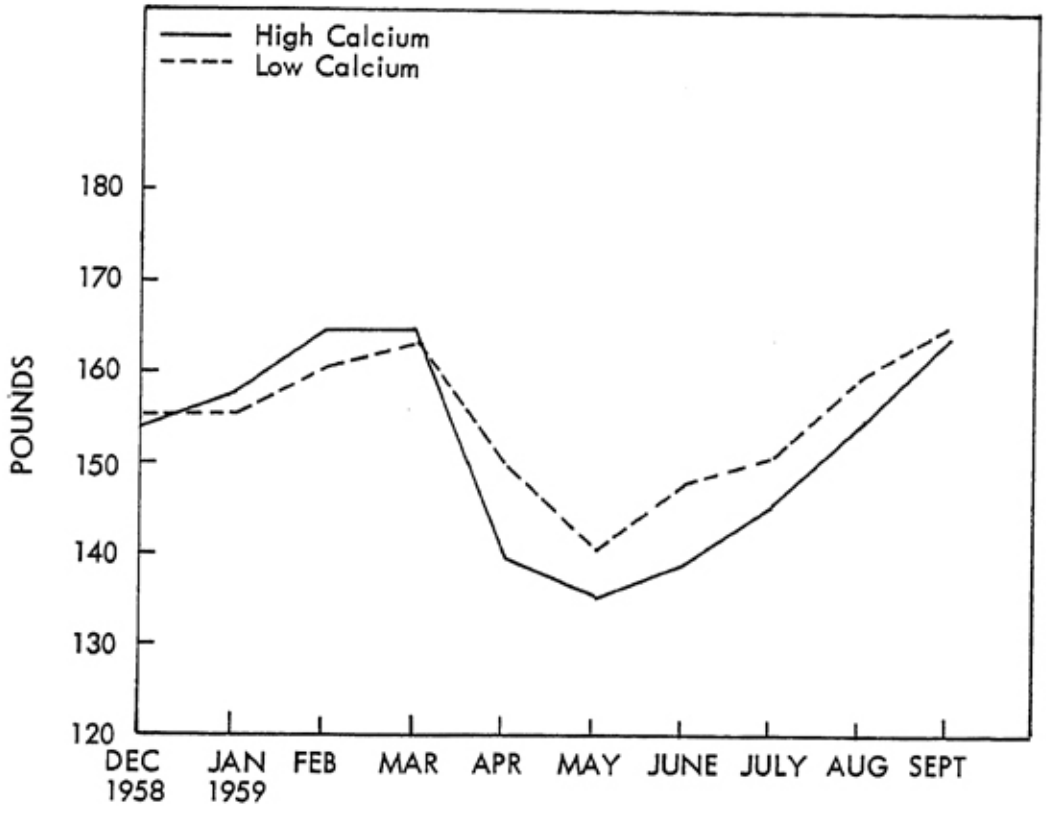
1. Weight gains of the ewes were adequate for growth and gestation.
2. Fleece weights of the ewes were good.
3. The ewes exhibited no signs of stiffness.
4. The ewes had frequent ketosis.
5. The ewes had frequent vaginal prolapse.
6. The lambs had a wide range in individual weights.
7. A large percentage of lambs were weak.

Effects of Feeding Ewes on Low Calcium and High Calcium Rations

This part of the experiment was conducted for two years to determine the calcium requirements of the ewes for production. The low calcium ration contained an average of 0.24 percent calcium and the high calcium ration contained an average of 0.49 percent of calcium. The ewes fed the low calcium ration received an average of 4.38 grams of calcium and the ewes fed the high calcium ration, an average of 9.7 grams of calcium daily per ewe.

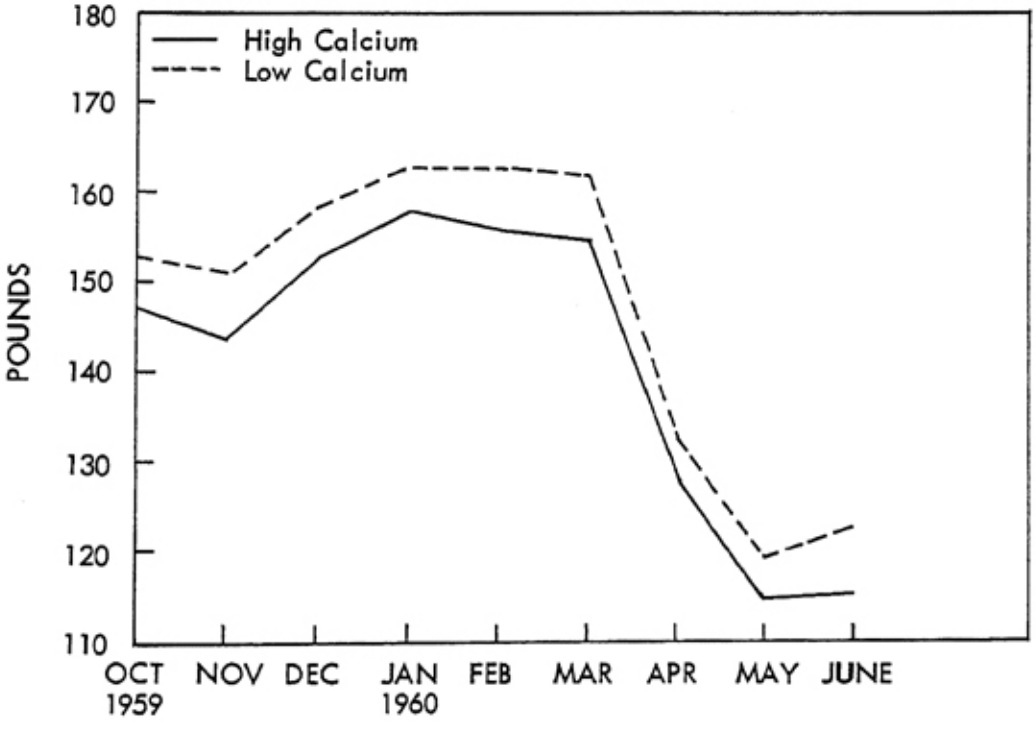
Gain and Condition of Ewes

The average monthly weights of the ewes from November, 1958, to June, 1960, are shown in Figures 7 and 8. Table 6 gives the gain or loss of the ewes from conception through parturition. The ewes gained adequately on both rations during pregnancy with the ewes dropping twins losing more weight at parturition than the ewes dropping singles. In 1960 the ewes on the low calcium ration lost more weight during parturition than the ewes on the high calcium ration. In 1960 just before parturition the roughage of both rations was changed from grass hay to corn cobs. The calcium content of the low calcium ration was reduced from 0.25 to 0.18 percent and in the high calcium ration from 0.49 to 0.47 percent. The ewes on the low calcium ration consumed less feed after the ration was changed, contributing to the weight loss. Figures 9 and 10 picture the ewes and lambs eight weeks after the average lambing date in 1960.



AVERAGE MONTHLY EWE WEIGHTS

Figure 7.



AVERAGE MONTHLY EWE WEIGHTS

Figure 8.

Figure 9. Ewes on Low Calcium Ration Eight Weeks After Average Lambing Date.

Figure 10. Ewes on High Calcium Ration Eight Weeks After Average Lambing Date.

TABLE 6-AVERAGE GAIN OR LOSS IN WEIGHT OF EWES FROM CONCEPTION THROUGH PARTURITION

Treatment	1959		1960	
	L[1]	H	L	H
A. Gain During Pregnancy of Ewes				
Singles (lb.)	42(1)[2]	27(1)	29(5)	24(2)
Twins (lb.)	45(2)	47(3)	20(2)	26(5)
B. Loss at Parturition of Ewes				
Singles (lb.)	30(1)	30(1)	20(5)	13(2)
Twins (lb.)	35(2)	45(3)	36(2)	28(5)
C. Gain or Loss From Conception to First Weight Following Parturition of Ewes				
Singles (lb.)	12(1)	3(1)	9(5)	11(2)
Twins (lb.)	10(2)	-2(3)	-16(2)	-2(5)

[1]L is the low calcium ewes. H is the high calcium ewes.
[2]Numbers in parenthesis indicate the number of ewes.

Lambing Records

In 1959 only four ewes lambed on each ration as one ewe failed to conceive on the low calcium ration. One of the ewes on the high calcium ration had ketosis but she recovered and lambed.

Production records are shown in Table 7 for the years of 1959 and 1960. Seven lambs were dropped by the ewes being fed the low calcium ration and

TABLE 7-PRODUCTION RECORDS

Year	1959		1960	
Treatment[1]	L	H	L	H
Av. Breeding Date	10-23-58	10-21-58	10-22-59	10-20-59
Av. Lambing Date	Mar. 18	Mar. 25	Mar. 21	Mar. 18
Av. Lg. of Gestation	144	153	151	150
No of Ewes	5	5	8	7
No. of Lambs Born[2]	7	7	8	12
No. of Lambs Raised to Weaning	4	6	6	8
No. of Twin Lambs	6	6	4	10
No. of Single Lambs	1	1	4	2
Av. Birth Wt. of Lambs (lb.)	9.3	10	9.08	7.99
Av. Birth Wt. of Singles (lb.)	14	13	9.91	10.98
Av. Birth Wt. of Twins (lb.)	8.5	9.5	8.03	7.39
No. of Ewes Having Lambing Troubles	1[3]	1[4]	3[5]	0
Av. Fleece Wts. (lb.)	10.62	9.01	10	9.3

[1]Abbreviations used are: L, for ewes fed low calcium ration; H, for ewes fed high calcium ration.
[2]Includes all lambs dead and alive.
[3]One ewe did not conceive and one ewe had ketosis and lost both lambs.
[4]One ewe had ketosis and died.
[5]One ewe had ketosis and died; one ewe would not dilate and the lamb was taken by a Caesarean Section; one ewe continued contracting after the lamb was born.

seven lambs were dropped by the ewes fed the high calcium ration in 1959. Four lambs from the ewes fed the low calcium ration and six lambs from the ewes fed the high calcium ration survived to weaning. The three lambs in the low calcium lot that did not survive were born dead while the lamb in the high calcium lot died of unknown causes at six weeks of age.

Seven ewes lambed in each lot in 1960. There were eight ewes in the lot being fed the low calcium ration to begin with, but one of the ewes had ketosis in the fourth month of pregnancy and died. None of the ewes in the high calcium lot had lambing troubles but two of the ewes in the low calcium lot did have lambing troubles. One ewe would not dilate and she was taken to the veterinary clinic where the lamb was taken by Caeserean Section. The second ewe continued contracting after the lambs were born. She was treated at the veterinary clinic and recovered.

Eight lambs were born to the ewes on the low calcium ration in 1960 and twelve lambs were born to the ewes on the high calcium ration. Two lambs did not survive on the low calcium ration. One of these lambs was born dead and the other lamb was lain upon by the ewe and smothered. Four lambs were weak and did not survive on the high calcium ration. A post mortem revealed that they had very little milk in their stomachs. It was very cold weather when these lambs were born and they probably were chilled, also. There was not much difference in the size of the lambs on the two rations either year. In 1959 the lambs from the ewes on the high calcium ration were a little larger. In 1960 the lambs from the ewes on the low calcium ration were the largest. Part of the reason for this could be that there were five sets of twins on the high calcium ration and only two sets born to the ewes on the low calcium ration.

The average weekly weights of the lambs are shown in Figures 11 and 12. The single lambs had greater gains than the twins. In 1959 the gains on both rations were about the same while in 1960 the lambs from the ewes on the high calcium ration gained at a faster rate.

Fleece Weights

The fleece weights are shown in Table 7. Both years the ewes had good quality heavy fleeces with the ewes on the low calcium ration having the heavier fleeces. This may be due to the difference in the individual ewes rather than a difference in the rations.

Milk Production

Milk production is based on the amount of milk the ewes gave in a twelve hour period once a week. The weekly milk production is shown in Figures 13, 14, and Table 8. Figures 15 and 16 show the milk production per 100 pounds of body weight of the ewes. The ewes with twins gave more milk than the ewes with singles. In 1959 the ewes fed the high calcium ration gave slightly more milk. In 1960 there was very little difference in the milk production of the ewes on the two rations. The ewes on the low calcium ration with twins gave more

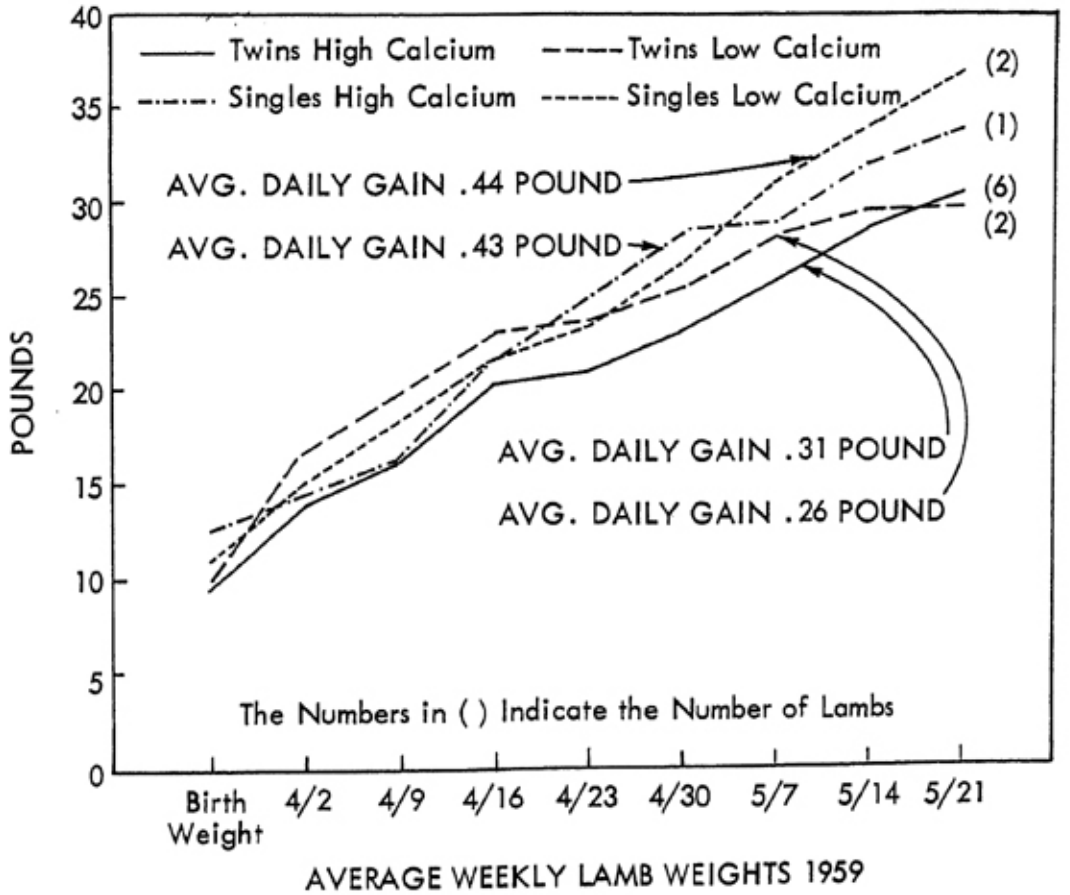


Figure 11.

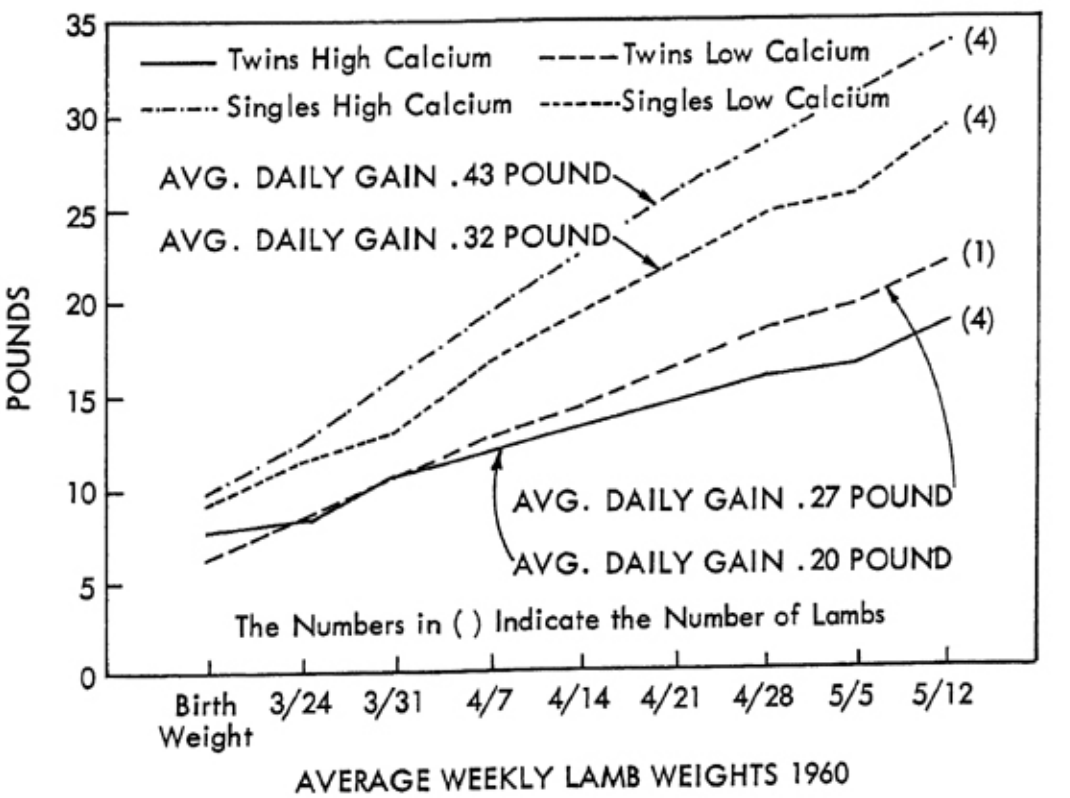
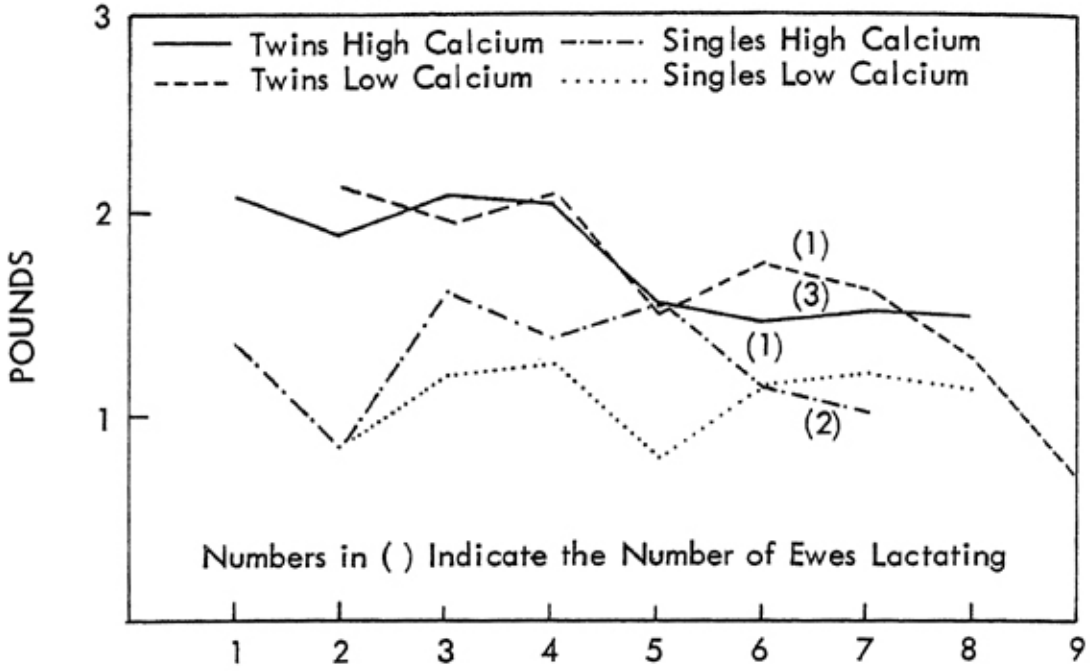


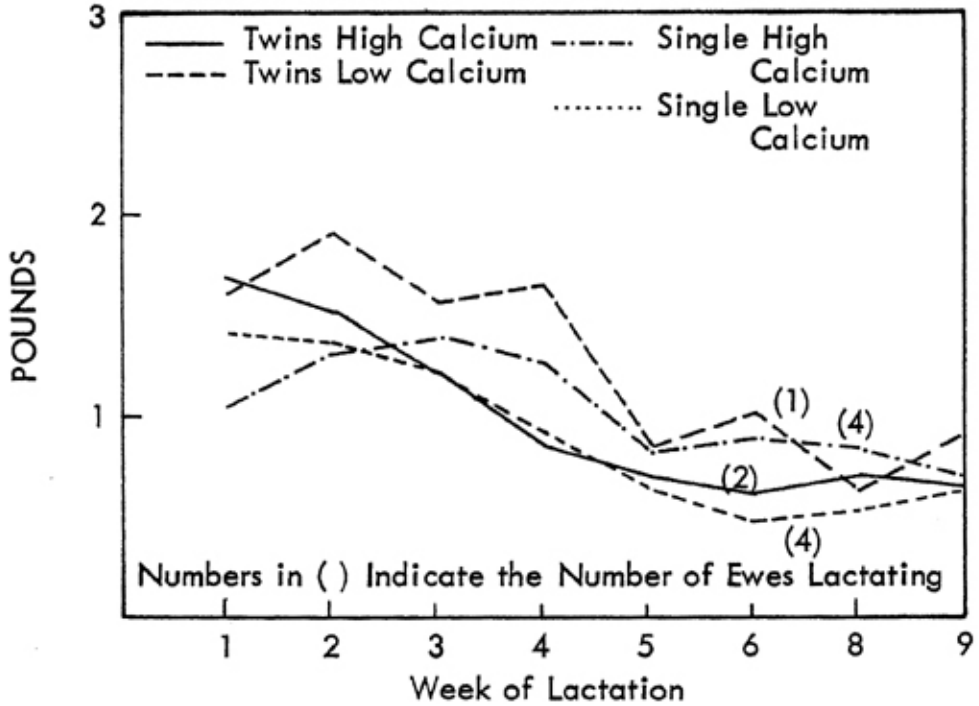
Figure 12.



LACTATION CURVE 1959

Determined by a 12 hour milk production period once a week

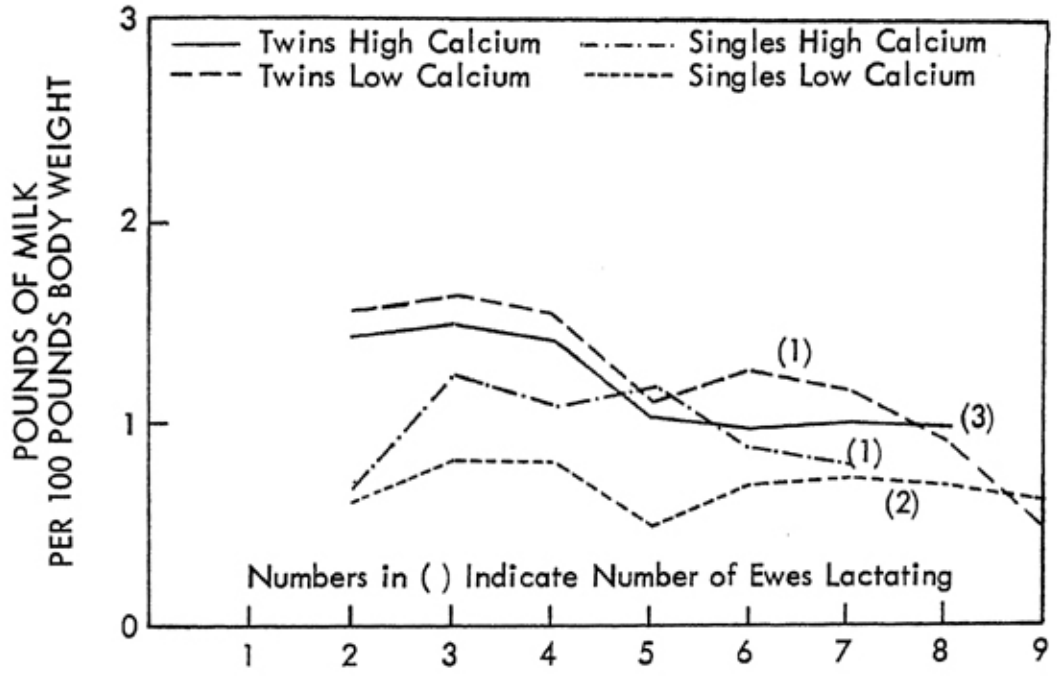
Figure 13.



LACTATION CURVE 1960

Determined by a 12 hour milk production period once a week

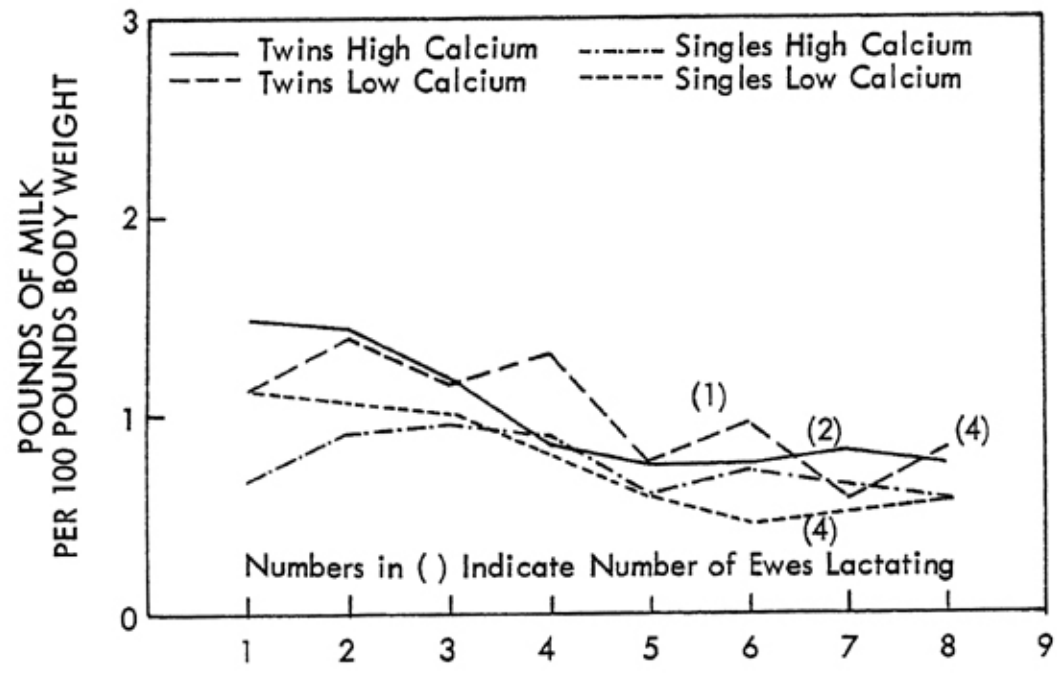
Figure 14.



LACTATION CURVE 1959

Determined by a 12 hour milk production period once a week

Figure 15.



LACTATION CURVE 1960

Determined by a 12 hour milk production period once a week

Figure 16.

TABLE 8-MILK PRODUCTION IN POUNDS[1]

	1959				1960			
	Singles		Twins		Singles		Twins	
Treatment	L	H	L	H	L	H	L	H
No. of Ewes	2	1	1	3	4	4	1	2
Week of Lactation								
1		1.36		2.18	1.42	1.03	1.62	1.67
2	.86	.86	2.14	1.91	1.34	1.31	1.92	1.52
3	1.22	1.60	1.98	2.09	1.22	1.39	1.56	1.22
4	1.28	1.40	2.08	2.07[2]	.90	1.26	1.64	.85
5	.80	1.56	1.52	1.55	.65	.81	.86	.68
6	1.16	1.16	1.76	1.49	.47	.87	1.00	.64
7	1.22	1.04	1.66	1.53	.52	.81	.64	.70
8	1.15		1.28	1.51	.59	.73	.90	.66
9	1.00		.72					

[1]Milk production was determined for a twelve hour period once a week.
[2]One lamb died.

milk than the ewes on the high calcium ration with twins. The ewes on the high calcium ration with twins were the smaller, younger ewes that were placed on the trial in 1959. This may be the cause of the above results. All of the results indicate that the calcium content of the ration had little effect on the milk production. The lower milk production in 1960 may be due to changing the roughage of the rations to corn cobs just before parturition as this resulted in a lowered feed intake. There was very little difference in the calculated T.D.N. of the two rations.

Table 9 shows the amount of calcium in the milk of the ewes in the eighth week of lactation. There is very little difference between the ewes fed the two

TABLE 9-PERCENT OF CALCIUM IN MILK OF LACTATING EWES--APRIL 1960

Ewe Number	Calcium %
66[2]	.077
73[2]	.109
59[3]	.081
68[3]	.073

[1]Ewes were milked by hand without a stimulus.
[2]Ewes being fed low calcium ration. These ewes were in their 5th week of lactation.
[3]Ewes fed high calcium ration. These ewes were in their 6th week of lactation.

different rations. Barnicoat *et al.* (1949) reported that 0.27 percent was the normal calcium level of ewe's milk. The values found in this experiment are considerably lower.

Blood Calcium

The National Research Council states that 9 to 12 mg. percent of calcium in blood serum is normal. In whole blood the range would be approximately 4.5 to 7.2 mg. percent.

The milligrams percent of calcium in the whole blood of the ewes is shown in Tables 10, 11, and 12. The calcium level of the blood of the ewes that were

TABLE 10-PERCENT OF CALCIUM IN WHOLE BLOOD OF PREGNANT EWES--MARCH 1959[1]

Ewe No. L[2]	Calcium mg.%	Ewe No. H[2]	Calcium mg.%
55	6.02	56	6.64
60	5.18	59	6.24
66	6.08	63	6.00
78	6.43	67	5.24
av.	5.93	71	7.75
		Av.	6.37

[1]Blood samples taken 13 days before av. lambing date.
[2]Abbreviations used are: L, for ewes fed low calcium ration: H, for ewes fed high calcium ration.

TABLE 11-PERCENT OF CALCIUM IN WHOLE BLOOD OF EWES--SEPTEMBER, 1959[1]

Ewe No. L[2]	Calcium mg.%	Ewe No. H[2]	Calcium mg.%
66	5.66	63	6.47
78	6.30	59	6.49
62	7.79	67	7.93
60	7.83	71	11.30
55	9.58		
Av.	7.43	Av.	8.05

[1]Blood samples were drawn one month before breeding.
[2]Abbreviations used are: L, for ewes fed low calcium ration; H, for ewes fed high calcium ration.

TABLE 12-BLOOD CALCIUM AND OPTICAL DENSITY[1] OF THE BONES OF EWES, 1960

	Number of Lambs		Blood Calcium		
Ewe No.	Carried	Live After Birth	Gestation	Lactation	Optical Density
Low Calcium Ewes			mg.%	mg.%	
73	1	1	7.68	7.27	.70
55	2	2	5.90	5.38	2.19
74	1	1	6.56	12.00	1.46
62	1		7.10		1.32
66	1	1	7.23	4.72	2.16
60	2		6.82	8.88	1.00
70	1	1	6.40	6.57	1.79
Av.			6.70	7.47	1.51
High Calcium Ewes					
63	2	1	7.06	9.60	1.48
71	1	1	6.63	5.43	2.02
75	2	2	7.39	4.54	1.67
67	2		6.44	8.17	.43
68	2	1	7.18	4.84	1.42
167	2	2	6.33	4.10	1.61
59	1	1	6.60	6.35	1.90
Av.			6.80	6.15	1.50

[1]Optical density is a measure of the average optical density of the x-rays of the cannon bones of ewes taken in the eight week of lactation.
[2]This was taken 30 days prior to parturition.
[3]This was taken in the sixth week of lactation.

fed both rations was about the same both years in late pregnancy. The blood calcium values all fall within the normal blood calcium levels for sheep. Just before breeding in 1959 the blood calcium levels of the ewes were scattered over a wide range with some of the ewes having blood calcium levels above the normal range. There was not much difference between the ewes being fed on the different rations. In the sixth week of lactation in 1960 the blood calcium levels were scattered over a wide range. All of the ewes had blood calcium levels that were in the normal range or higher.

Calcium and Phosphorus Balance

The calcium and phosphorus balance of six of the ewes one month prior to the average lambing dates is shown in Tables 13 and 14. Two ewes on each

TABLE 13-CALCIUM BALANCE--FEBRUARY 1960

Ewe No.	No. of Lambs[3]	Intake			Excretion			
		Water	Feed	Total	Feces	Urine	Total	Balance
63[1]	2	.98	35.94	36.92	34.32	.68	35.00	+1.92
68[1]	2	.72	32.33	33.05	28.2	1.00	29.20	+3.85
67[1]	2	1.38	8.77	10.15	10.73	1.59	12.32	-2.17
55[2]	2	1.19	19.55	20.74	14.92	.60	15.52	-5.22
74[2]	1	.75	20.16	20.91	15.96	.80	16.76	-4.15
66[2]	1	.69	10.35	11.04	15.40	.30	15.70	-3.66

[1]High calcium ewes.
[2]Low calcium ewes.
[3]Number of lambs that were carried by the ewes

TABLE 14-PHOSPHORUS BALANCE--FEBRUARY 1960

Ewe No.	No. of Lambs[3]	Intake			Excretion			
		Water	Feed	Total	Feces	Urine	Total	Balance
63[1]	2	.02	14.24	14.26	15.84	.08	15.92	-1.64
68[1]	2	.02	12.63	12.65	13.2	.25	13.45	- .80
67[1]	2	.03	3.46	3.46	3.49	4.07	8.61	-5.16
55[2]	2	.03	16.29	16.32	16.32	.92	13.5	+2.82
74[2]	1	.02	16.8	16.82	14.25	.14	14.39	+2.43
66[2]	1	.01	8.62	8.63	12.63	1.00	13.63	-5.00

[1]High calcium ewes.
[2]Low calcium ewes.
[3]Number of lambs that were carried by the ewes

ration had positive calcium balances while one ewe from each ration had a negative calcium balance. The ewes on the low calcium ration had slightly greater positive calcium balances. All three of the ewes from the low calcium ration had negative phosphorus balances. Two of the ewes on the high calcium ration had positive phosphorus balances. At the beginning of the trial one ewe from each lot did not eat at all. They were removed from the trial and replaced by ewes from the respective high calcium or low calcium group. Both of the ewes that were removed from the balance trial developed ketosis. The ewes on the high

calcium ration recovered after treatment while the other ewe died. All of the ewes ate considerably less feed while they were in the collection crates and the longer they remained in the crates the less feed they consumed.

Calcium in the Water.

The water consumption of the ewes and the amount of calcium in the water is shown in Table 15. The water contained an average of 51 ppm and at this time it was supplying the ewes with 0.138 gm. of calcium per ewe per day. In some types of mineral work it would be best to use demineralized water.

TABLE 15-WATER CONSUMPTION OF THE EWES DECEMBER 16 TO DECEMBER 23, 1959

	L[1]	H[1]
Number of Ewes	8	7
Total Intake for One Week	151,424 ml.	143,465 ml.
Total Daily Intake	18,928 ml.	20,495 ml.
Intake Per Ewe Per Day	2,704 ml.	2,785 ml.
Amount of Calcium In the Water	50 PPM	51 PPM
Calcium Intake Per Ewe Per Day From Water	.135 Grams	.142 Grams

[1]Abbreviations used are; L, for ewes fed low calcium ration and H, for ewes fed high calcium ration.

Optical Density of the Bones

The optical densities of the bones in the forelegs of the ewes are shown in Table 16. The right forelegs of six of the ewes are pictured in Figures 17, 18, 19, 20, 21, and 22. The x-rays were taken eight weeks after the average lambing date.

TABLE 16-AVERAGE OPTICAL DENSITY[1] OF VARIOUS BONES IN THE FORELEG OF EWES

	Right Leg			Left Leg		
	Cannon	Proximal[2] Sesamoids	Phlanges	Cannon	Proximal[2] Sesamoids	Phlanges
H[4] with singles	1.70	1.15	1.99	1.70	1.03	1.90
L[4] with singles	1.51	1.13	1.82	1.54	1.22	1.85
H with twins	1.61	1.66	2.58	1.23	1.13	2.25
L with twins	2.17	1.85	2.38	2.2	1.86	2.46
H with no lambs	.44	.33	.95	.42	.29	.87
L with no lambs	1.12	.58	1.48	1.20	.70	1.56
All ewes with no lambs	.89	.50	1.30	.94	.56	1.33
All ewes with singles	1.61	1.14	1.91	1.62	1.12	1.87
All ewes with twins	1.79	1.40	2.28	1.85	1.37	2.31

[1]Optical density readings taken by a Welch Densichron.
[2]Average of four proximal sesamoids per leg per ewe.
[3]Average of two phlanges per leg per ewe.
[4]Abbreviations used are: L, for ewes on low calcium ration; H, for ewes on high calcium ration.

Figure 17. Foreleg of a Ewe on the Low Calcium Ration Raising No Lambs.

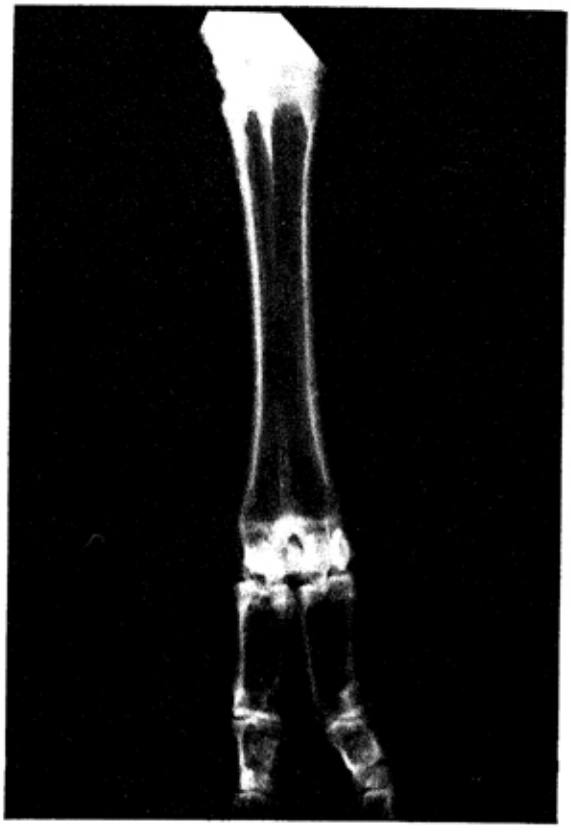


Figure 18. Foreleg of a Ewe on the High Calcium Ration Raising No Lambs.

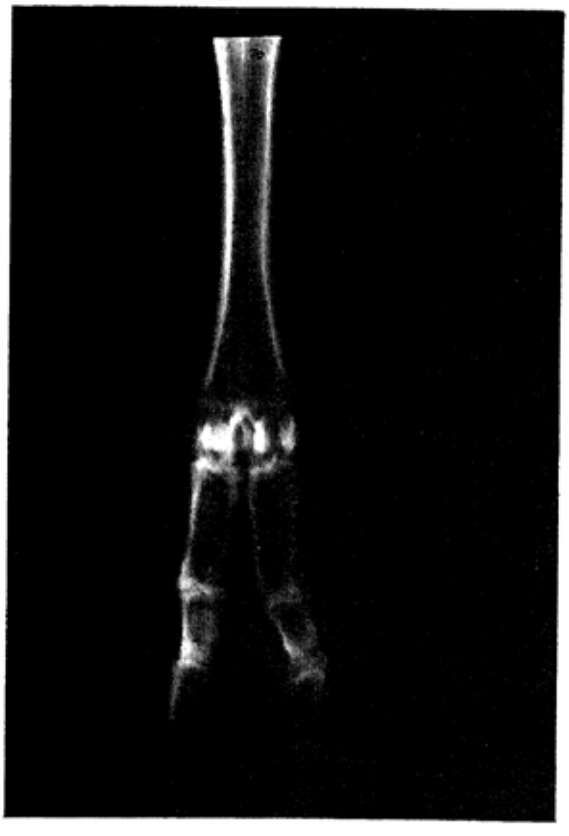


Figure 19. Foreleg of a Ewe on the Low Calcium Ration Raising a Single Lamb in the Eighth Week of Lactation.

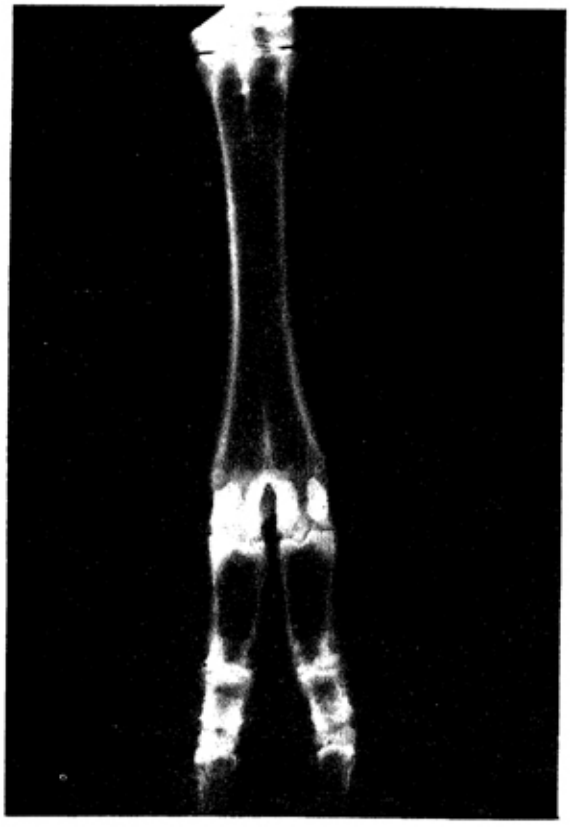


Figure 20. Foreleg of a Ewe on the High Calcium Ration Raising a Single Lamb in the Eighth Week of Lactation.

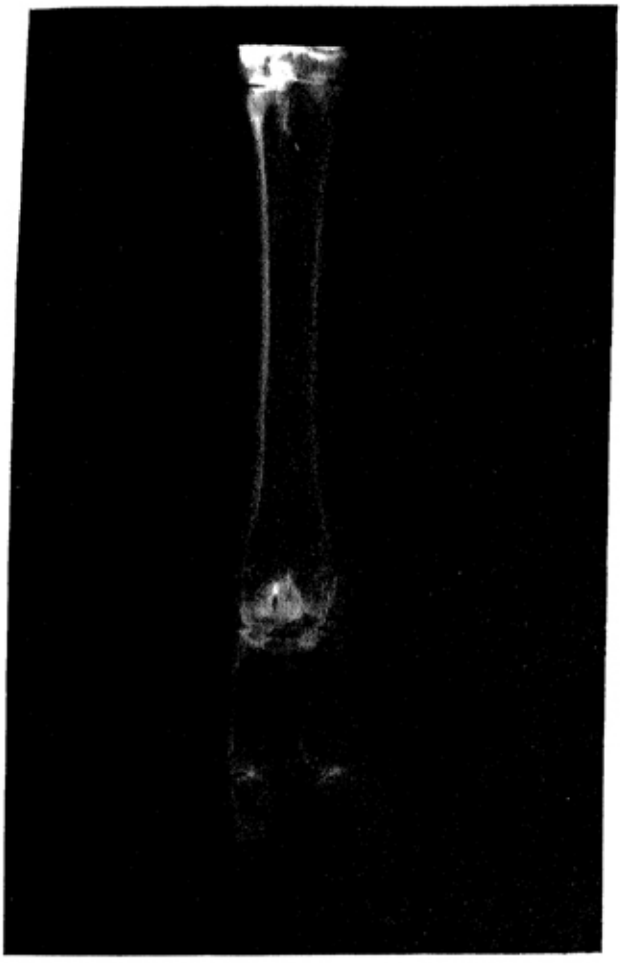


Figure 21. Foreleg of a Ewe on the Low Calcium Ration Raising Twin Lambs in the Eighth Week of Lactation.

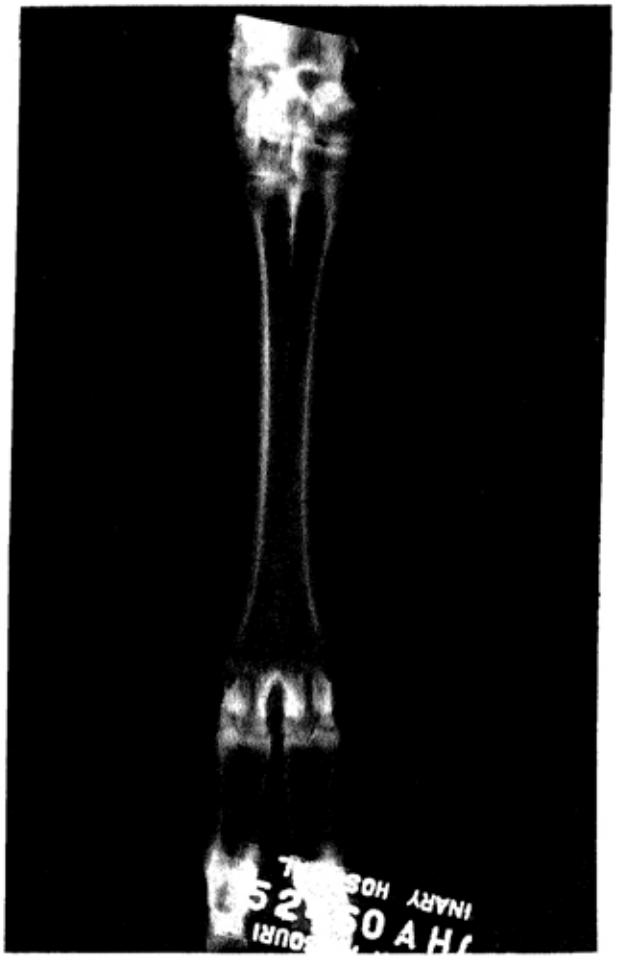


Figure 22. Foreleg of a Ewe on the High Calcium Ration Raising Twin Lambs in the Eighth Week of Lactation.

The low calcium ewes that raised singles had more ash in their bones than the high calcium ewes raising singles. This is indicated by the ewes with the larger amounts of ash in their bones having a lower optical density. The ewes fed the high calcium ration raising twins have more ash in their bones than the ewes fed the low calcium ration raising twins. The greatest difference is shown among the ewes not raising any lambs. The ewes on the high calcium ration raising no lambs have considerable more ash in their bones than the ewes on the low calcium ration raising no lambs. This optical density shows greater differences between ewes raising no lambs, raising single lambs, and raising twin lambs than it does between the different levels of calcium indicating that the ewes lactating the most have the least amount of calcium in their bones.

Table 12 shows the average optical density of the cannon bones as well as the blood calcium levels of the ewes. There does not appear to be any correlation between blood calcium levels and optical density of the bones.

General Discussion

The basal ration used in these experiments contained 0.13 to 0.18 percent calcium the first three years. The last two years the basal ration contained an

average of 0.24 percent calcium with a mean daily intake per ewe of 4.38 gm. of calcium. This is approximately in the middle of the levels of calcium used in previous experiments and it falls within the range of the National Research Councils requirements of 0.22 to 0.28 percent for pregnant and lactating ewes. The high calcium ration contained an average of 0.49 percent calcium with a mean daily intake of 9.7 gm. of calcium per ewe.

In general it has been reported that ewes fed calcium deficient rations gained less weight, had lower blood serum calcium especially during lactation, and lower ash content of their bones. Fetal growth, birth weight, and number of lambs born were normal.

The ewes on both rations in this experiment grew at a normal rate and had normal gains in weight during lactation. The fetal growth, birth weight, and the number of lambs born were normal. This supports the work of Benzie *et al.* (1955) that the level of calcium does not affect fetal growth, birth weight, or the number of lambs born.

Franklin *et al.* (1951) reported that a ration containing 0.16 percent calcium lowered blood serum calcium. Benzie *et al.* (1956) observed that ewes fed 1 to 3 gm. of calcium daily had lower blood serum calcium during lactation. The ewes on both rations in the experiments reported in this bulletin had normal blood calcium levels during lactation. Therefore, the basal ration appears to be adequate for the maintenance of blood calcium.

Optical densities of the bones of the ewes indicated that there was a greater difference among ewes with no lambs, ewes with single lambs, and ewes raising twin lambs, than there was between levels of calcium. The ewes raising no lambs and the ewes raising twins on the high calcium ration had considerable more ash in their bones than the ewes raising no lambs and the ewes raising twins on the low calcium ration. There has not been enough work done with the optical densities of the bones at the present to make any definite conclusions.

The ewes on the low calcium ration had lambing troubles which was not observed on the high calcium ration. The troubles were vaginal prolapse, continued contractions after lambing, not dilating so the lamb could drop, and ketosis. Ewes on both rations in 1960 had ketosis but this was caused by the ewes being in the metabolism crates and going off feed. Pregnancy disease was observed by Fraser *et al.* (1933) in ewes on calcium deficient rations.

The lambs growth rate was about equal on both rations and it appeared to be independent of the calcium level. It was lower in 1960 than in 1959. In 1959 the calculated digestable protein and TDN of both rations met the N.R.C. requirements for lactating ewes. In 1960 the calculated digestable protein met 75 percent and TDN met the N.R.C. requirements for lactating ewes. This supports the observations of Barnicoat *et al.* (1933) that the plane of nutrition is the most important factor affecting milk production and growth of lambs.

It appears that the basal rations used in these experiments are adequate for growth and maintenance of the ewes but not for lambing and lactation. The

high calcium ration does not appear to be adequate for lactation either. The high calcium ration is not recommended as containing the optimal level of calcium for ewes.

SUMMARY AND CONCLUSIONS

The first trial began in November, 1955, with 12 ewe lambs to study "stiff lambs" disease, which did not develop on the ration containing 0.13 to 0.18 percent calcium. In November, 1958, the ewes were divided into two groups. One group of ewes remained on the low calcium ration and the other group of ewes was fed the low calcium ration supplemented with 1 percent ground limestone.

The rations were evaluated by using production records, weekly weights, feed intake, fleece weights, and milk yields. Blood samples were drawn and analyzed for calcium in late pregnancy and again during lactation in 1959 and 1960. A calcium balance trial was conducted in February, 1960, on three ewes from each ration. In the eighth week after the average lambing date in 1960 the ewes' forelegs were x-rayed and the optical density of the x-ray pictures of the cannon bones, proximal sesamoids, and phalanges of each leg was determined.

Results indicated:

1. The low calcium ration was adequate for normal growth and weight gains of the ewes. There was little difference between the rations after 1958.
2. The low calcium ration was adequate for fetal growth of the lambs.
3. The low calcium ration may not have been adequate for normal lambing. Each year there were some ewes on this ration having lambing troubles. Some of the troubles were ketosis, vaginal prolapse, ewes not dilating so the lambs could drop, and continued contractions after the lambs were dropped. The only trouble observed on the high calcium ration was one ewe with ketosis in 1960.
4. There was very little difference in the milk production of the ewes on the low calcium and high calcium rations.
5. Blood calcium levels of all of the ewes were within the normal range in late pregnancy. During lactation the blood calcium levels of the ewes were scattered over a wide range but all of the ewes had normal blood calcium levels or higher than normal blood calcium levels.
6. Wool growth was good on both rations.
7. There was very little difference in the calcium balance of the ewes on either ration, but the ewes did not eat as much feed while they were in the collection crates and this may have affected the results.
8. The optical densities of the bones in late lactation revealed a greater difference in the amount of ash in the bones of ewes without lambs, raising single lambs, and raising twin lambs than there was between the ewes on the different rations. Some of the ewes with twins had large amounts of ash depleted out of their bones.

The following conclusions are drawn, based on results of this experiment.

1. The rations containing 0.13 to 0.18 percent calcium, and later an average of 0.23 percent calcium were adequate for:
   a. Normal growth and maintenance of the ewes.
   b. Normal fetal growth of the lambs.
   c. Good fleece production.
   d. Normal blood calcium levels.
2. These rations may not be adequate for:
   a. Normal lambing of the ewes.
   b. Milk production of the ewes.
3. Weight gains and wool growth are not a good criteria for measuring calcium requirements.
4. There was not any advantage in the rations containing an average of 0.49 percent calcium except the ewes on this ration had no lambing troubles.
5. The National Research Council requirements for pregnant ewes appear to be adequate. Extra calcium may be needed during the last six weeks of pregnancy to insure normal parturition.

BIBLIOGRAPHY

Barnicoat, C. R., Logan, A. G., and Grant, A. I. 1949. Milk Secretion Studies With New Zealand Romney Ewes. Parts II and III. *J. Agri. Sci. 39:*237-248.

Barnicoat, C. R., Murray, P. F., Roberts, E. M., and Wilson, G. S. 1956. Milk Secretion Studies With New Zealand Romney Ewes. Parts V to IX. *J. Agri. Sci. 48:* 9-35.

Becker, R. B., Neal, W. M., and Shealy, A. L. 1933. Effect of Calcium Deficient Roughages Upon Milk Production and Welfare of Dairy Cows. *Univ. of Fla. Expr. Stat. Bull. 262.*

Bell, D. S. and Kick, C. H. 1935. Calcium, Phosphorus, and Vitamin D Requirement of Lambs. *Ohio Agri. Expr. Stat. Bull. 561.*

Bell, D. S. and Kick, C. H. 1936. Calcium Requirements of Lambs. *Ohio Agri. Expr. Stat. Bull. 579:*88.

Benzie, D., Boyne, A. W., Dalgarno, A. C., Duckworth, J., Hill, R., and Walker, D. M. 1955. Studies of the Skeleton of the Sheep. I. The Effect of Different Levels of Dietary Calcium During Pregnancy and Lactation on Individual Bones. *J. Agri. Sci. 46:*425-39.

Benzie, D., Boyne, A. W., Dalgarno, A. C., Duckworth, J., Hill, R., and Walker, D. M. 1956. Studies of the Skeleton of the Sheep. II. The Relationship Between Calcium Intake and Resorption and Repair of the Skeleton in Pregnancy and Lactation. *J. Agri. Sci. 48:*175-186.

Bruman, F. and Delachaux, A. 1937. The Nutritional and Biochemical Effects of a Low Calcium Diet on Sheep. *Chemical Abstracts 31:*7486.

Dowe, T. W., Matsushima, J., and Arthaud, V. H. 1957. The Effects of Adequate and Excessive Calcium When Fed With Adequate Phosphorus in Growing Rations for Beef Calves. *J. An. Sci. 16:*811-820.

Eaton, H. D., Avampato, J. E., Curme, G. O. III, Matterson, L. D., and Brown, B. H. 1953. Blood Levels and Retention of Calcium, Magnesium, and Potassium in Lambs Fed Alfalfa Hay Containing Narrow and Wide Potassium to Calcium Ratios. *Univ. of Conn. Bull. 295.*

Franklin, M. C., Reid, R. L., and Johnston, I. L. 1951. Studies on Dietary and Other Factors Affecting the Serum-Calcium Levels of Sheep. Parts 1 to 6. *Commonwealth Australia Council Science Industrial Research Bull. 240:*77.

Fraser, A. H. H. 1932. The Reciprocal Relationship of Calcium and Inorganic Phosphorus of the Blood of Sheep. *Biochem. J. 26:*2168.

Fraser, A. H. H., Godden, W., and Auchinachie, D. W. 1933. Methods of Determining the Degree of Calcium Deficiency of Sheep. *Biochem. J. 28:*157-161.

Fraser, A. H. H., Godden, W., and Thomson, W. 1933. The Effect of a Calcium Deficient Diet on Pregnant Ewes. *Vet. J. 89:*408-11.

Greaver, J. E., Maynard, E. J., and Reeder, W. 1934. Influence of Calcium Phosphorus Intake on Bovine Blood. *J. Agri. Res. 48:*1033-1042.

Hansard, S. L., Comar, C. L., and Davis G. K. 1954. Effects of Age Upon the Physiological Behavior of Calcium in Cattle. *Amer. J. Physiol.* 177:383-389.

Hansard, S. L., Comar, C. L., and Plumlee, M. P. 1952. Absorption and Tissue Distribution of Radio Calcium in Cattle. *J. An. Sci. 11:*524.

Hansard, S. L., Comar, C. L., and Plumlee, M. P. 1954. The Effects of Age Upon Calcium Utilization and Maintenance Requirements in the Bovine. *J. An. Sci. 13:*25-36.

Hansard, S. L., Crowder, H. M., and Lyke, W. A. 1957. The Biological Availability of Calcium in Feeds for Cattle. *J. An. Sci. 16:*437-443.

Jones, J. M. and Stangel, W. L. 1938. Effects of Calcium Supplements on Gains of Lambs Fed Sorghum Fodder or Sorghum Silage as the Roughage Portion of the Fattening Ration. *Texas Agri. Expr. Stat. Bull. 563.*

Kruger, J. H. and Beckdel, S. I. 1928. Studies in the Normal Deposition of Minerals in the Bones of Dairy Calves. *J. Dairy Sci. 11:*24-34.

Lewis, J. K., Burkett, W. H., and Willson, F. S. 1951. The Effect of Excess Calcium With Borderline and Deficient Phosphorus in the Rations of Steer Calves. *J. An. Sci. 10:*1053.

Marsh, H. and Swingle, K. F. 1955. Blood Phosphorus, Calcium and Vitamin A in Range Sheep. *Amer. J. Vet. Res. 16:*418-424.

National Research Council. Nutrient Requirements of Domestic Animals. V. Nutrient Requirements of Sheep. *Publication 504.* 1957.

Payne, M. G., Clark, A. G., Kingman, H. E., and Stansbury, W. M. 1946. Blood Levels of Calcium and Inorganic Phosphorus in Hereford Cattle. *J. Agri. Res. 72:* 357-363.

Pearson, P. B., Gray, J. H., and Reiser, R. 1949. The Calcium, Magnesium and Potassium Contents of the Serum of Ewes Fed High Levels of Potassium. *J. An. Sci. 8:*52-56.

Thompson, A., Hansard, S. L., and Bell, M. C. 1959. The Influence of Aluminum and Zinc Upon the Absorption and Retention of Calcium and Phosphorus in Lambs. *J. An. Sci. 10:*187.

White, T. W., Grainger, R. B., Baker, F. H., and Stroud, J. W. 1958. Effect of Supplemental Fat on Digestion and the Ruminal Calcium Requirement of Sheep. *J. An. Sci. 17:*797-803.