Experiment Station Bulletin No. B-255 April, 1942

The Influence of Nutrition on the Reproduction of Ewes

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SUMMARY

"Flushing" or increasing the feed available to ewes just prior to and during the breeding season was not found beneficial in an eight-year study. The improved nutrition did not result in more lambs or an earlier lamb crop, which are benefits commonly suggested for the practice. Grain feeding was used to increase the plane of nutrition in all cases except one lot which was fed green cowpeas. Fertility of the rams was found to be low during the hot summer weather when the ewes first came in heat, but improved when cooler fall weather arrived. This may account in part for the difficulty sometimes experienced in getting an early lamb crop in Oklahoma.

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INTRODUCTION: THE PROBLEM

A common practice in the field of sheep husbandry is the "flushing" of breeding ewes, i. e., having ewes in a rising condition at the time of mating. If flushing gives the benefits claimed for it, it would be of great practical importance in the large areas of the United States were early lamb production is very profitable. The practice has been advocated for years by sheep and nutritional authorities and by practical flock men, and various benefits have been claimed for it; yet little data has existed to substantiate the claims.

Among the benefits most often suggested are: (1) Ewes may be brought into heat earlier in the season; (2) the initial estrus of the season will occur more uniformly among the ewes in the flock; (3) there will be increased fertility or more conceptions from a given number of services; and (4) the number of multiple births in a given flock of ewes will be increased. The latter is one of the most strongly advocated reasons for flushing.

States such as Oklahoma that are interested in and suited to the production of early lambs for the "Easter" or "spring milk lamb" trade are naturally interested in methods of management that will enable them to get a large part of their production on these special markets. In order to do this, ewes must become pregnant at an earlier date than it is a common practice to breed.

It is known that some breeds of sheep have the ability to conceive at times in the year when other breeds fail to even show signs of estrus. In some cases these breeds are not as desirable for certain types of production as are some of the other breeds. Then, too, ewes of these breeds do not always experience the onset of estrus during a desirable length of breeding season and one secures an ununiform lot of lambs.

Experience has also led sheepmen to believe that dropping temperatures bring on the estrual cycles. Ewes are said to

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* A. E. Darlow and L. E. Hawkins were in charge of the experiment from its origin in the fall of 1929 until their resignations in 1935.

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breed earlier in the mountains than in surrounding lowlands. This, of course, is not a practical means of securing a uniform early lamb crop for many producers.

The improved nutrition of ewes commonly called "flushing" would provide an easy way to alter the breeding behavior if some ration or type of ration were available that could accomplish the purpose in an economical manner. Such a discovery would be of great value to the commercial producer of early market lambs because it would allow him to market greater numbers on the high seasonal markets.

REVIEW OF LITERATURE

The changes of environment due to domestication had a marked effect on reproduction in sheep. According to Clark (7), Darwin stated that wild species of sheep seldom produce twin lambs and often have but one estrual cycle a year. In many domestic breeds, however, a large percentage of twin lambs are produced, and some breeds, such as the Dorset, have extensive estrual cycles. Most other breeds have a long period of anestrus in which they do not have heat cycles. This period usually lasts from the latter part of March until the latter part of August, according to Hammond (16). Grant (14) and Asdell (1) found the breeding season to be from October to February. Hammond (16) states that domestication seems to increase the number of eggs ovulated and also to increase the number of atrophic fetuses. Clark (7) states that changes due to a favorable environment on reproduction were noted by Aristotle.

The influences of heredity and environment are concerned with factors such as age, breed, season, individual differences, and nutrition.

The effect of age has been discussed mainly in relation to the number of lambs produced at the various ages. Carlyle and McConnell (3) found that the lambing rate increased until the ewe was five or six years old and then there was a decrease with increasing age. Humphrey and Kleinheinz (19) found a gradual increase in the number of lambs produced up to four years of age and then a gradual decline. Bell (2), Jones and Rouse (22), Roberts (30), Marshall and Potts (23), and Johansson (21), found similar results. McKenzie and Terrill (27), found that the ovulation rate increased to three or four years of age and thereafter there was a decrease in the number of eggs ovulated. McKenzie and Phillips (26), found that the period of estrus was longer for yearlings than for lambs. The tendency for age to increase the length of heat period was noted again by McKenzie and Terrill (26), but they found no variation in length of estrus cycle due to age.

Differences in the number of lambs produced by different breeds were noted by Carlyle and McConnell (3), Humphrey and Kleinheinz (19), and Marshall and Potts (23). Breed differences in rate of ovluation were found by McKenzie and Terrill (27) and McKenzie and Phillips (26). Cole and Miller (10) found differences in the length of the heat periods due to breed. No influence on the length of estrous cycle due to breed was found by McKenzie and Phillips (26), Clark (7), or McKenzie and Terrill (27). However, McKenzie and Terrill (27) found that the duration of estrus was longer for Hampshires than for Shropshires and Southdowns.

Grant (14) observed that ovluation occurred during an estrum before the onset of the first estrus cycle. The first heat periods were short and gradually increased in length as the breed season progressed. A peak in length is reached about the middle of the season, after which the length of the periods become shorter. Grant (14) made the following statement with regard to an early estrous period due to "flushing":

> "There is evidence to suggest that under highly favorable nutritive conditions such as are constituted by the farming practice of 'flushing' the spurious ovulation periods may be converted into normal estrus periods at which the mating instinct is exhibited."

Cole and Miller (9) confirmed Grant's results and found that ovulation occurred after a discontinuance of the estrus cycles in the spring. Carlyle and McConnell (3), Roberts (30), Marshall and Potts (23), and Asdell (1) found that there was a large number of multiple births earlier in the lambing season. Clark (7), however, found that the number of corpora lutea were no higher earlier in the breeding season.

Elpaljevski (13) states that low temperature, dull weather, and precipitation, especially snow, reduced the number of ewes coming heat and also lengthened the heat period. McKenzie and Phillips (25) ran a temperature trial in August and found that ewes kept in a cold cellar did not show evidence of estrus sooner, nor did increasing the food induce an earlier heat period.

Bell (2), in an attempt to produce a strain of sheep that would produce all twins or triplets, selected those ewes that were multi-nippled in the belief that that characteristic was linked with multiparity. Castle (4) in his analysis of Bell's data concludes that the multi-nippled trait was hereditary, and that the twinning tendency was not inherited, but more apt to be due to feeding, age, and season. Smirnov (31) found that ewes producing single lambs at the first breeding were less fertile in subsequent years than those having mulitple birth the first time they lambed.

Clark (6) in a discussion of the mode of twinning stated that twins in sheep were produced by ovulation of two eggs rather than by a splitting of a single egg early in embryonic life. Similar conclusions were drawn by Chapman and Lush (5). Hammond (16) found that the number of eggs ovulated corresponds closely with the number of lambs dropped and that few losses occur due to unfertilized eggs or fetuses being absorbed or aborted. Clark (7) confirmed these findings. According to Hammond's (16) data, 87.1 percent of the ovulated eggs develop into normal lambs, 6.9 percent become atrophic fetuses, and 6.0 percent of the eggs are missing or unfertilized. These losses are low as compared to known losses in swine and rabbits. Hammon's contention is that as the number of eggs ovulated increases the losses become greater. Marshall and Potts (23) agree with these conclusions.

Marshall and Potts (23) state that the number of lambs dropped depends largely upon the number of barren ewes and the number of double and triple ovulations. They found that 78 percent of the twins dropped were born during the first half of the lambing season. This they attributed to the fact that the ewes that were better nourished came into heat sooner and produced two ova and that the feed and pasture were more nutritions in the early part of the breeding season. In their experimental work they compared flushed and unflushed lots with the following results:

UNFLUSHED				FLUSHED			
Lot No.	Ewe No.	Av. Gain in Weight	Lambs Dropped	Lot No.	Ewe No.	Av. Gain in Weight	Lambs Dropped
1	15	2.58	126.7	2	25	4.32	140.0
3	10	4.75	110.0	4	15	17.13	140.0
5	19	4.58	136.8	6	20	6.30	140.0
7	17	1.03	129.4	8	13	2.85	161.5
9	15	3.03	120.0	10	14	12.31	150.0
12	25	.76	136.0	11	11	10.96	145.5
15	24	1.46	129.2	13	21	10.80	147.6
				14	21	3.76	152.4
				16	20	5.80	150.0
				17	17	10.00	142.5
Average	18	1.76	128.8		18	7.98	146.9

From these results they concluded that flushing increased the lamb crop by 18.1 percent. They stated that the kind of feed used for flushing did not make a difference, but in order for flushing to be effective the ewes should gain at least seven pounds prior to or during the breeding season. Flushing had no influence on the estrous period nor on the conception date. These last two conclusions were confirmed by Clark (7).

Okuliov (29) found that flushing was beneficial in reducing the number of barren ewes and raising the percentages of multiple births. Coffey (8) makes a similar contention in *Productive Sheep Husbandry.*

Smith (32) in an experiment at Miles City, Montana, found flushing increased the lamb crop 7.4 percent, but reports that the average gain for those flushed lots was only 0.9 pound while the unflushed lots lost 3.6 pounds. He concludes that the results of the experiment did not justify the use of the extra feed (cottonseed meal) fed to the gaining ewes.

Clark (7) studied the effect of flushing by a count of the corpora lutea at breeding time and obtained the following results:

	Ewes showing double ovulation	Ewes showing single ovulation	Total gain in weight	Days on feed	Av. rate gain per day
Experiment I					
Flushed	8	12	245.4	1074	.228
Unflushed	0	20	27.7	1262	.022
Experiment II					
Flushed	10	10	136.8	646	.212
Unflushed	12	8	31.7	828	.038

He found no difference with respect to time that the ewes came in heat in either experiment, and double ovulations occurred throughout the breeding season. The ewes in Experiment II were in better condition than the average farm flock. Clark stated his conclusion: "The practice of flushing will lead to a higher ovluation rate, provided the ewes are not in high condition to start with."

McKenzie and Terrill (27) found, in a group of Western ewes, that flushing increased the ovulation rate (1.15 as compared with 1.06 for the unflushed). Most of the double ovulations took place before the first of November in both the flushed and unflushed group. (Seven of the ten in the flushed group and three of the four in the unflushed group.) The average end of the breeding season was nearly one and one-half months earlier for the unflushed group.

Hart and Miller (17), in an effort to find the relation of vitamin A to reproduction, reduced the amount of the vitamin in the ration so low as to induce night blindness, but normal conception still occurred in eleven out of seventeen cases. They concluded that vitamin A deficiency was not a limiting factor in conception rate.

Darlow and Hawkins (11, 12) report that in the early part of this experiment (1930-33) flushing did not influence the breeding date, but did in some way affect reproduction. Ewes that were starved to the point of emaciation failed to come in heat at regular intervals.

METHOD OF PROCEDURE

An experiment was started in the fall of 1930 to study the effects of nutrition on the breeding habits and reproduction of breeding ewes. During the nine years of the experiment, 80 head of grade Rambouillet ewes, 50 grade native ewes and 20 head of Hampshire ewes were under observation when fed submaintenance rations, maintenance rations, and rations that caused an increase in live weight prior to the breeding season. Various rations were used in an attempt to bring about the desired changes in breeding behavior of the ewes.

"Teaser" rams were used to determine heat, and hand breeding was practiced. The same rams were used on both groups to eliminate the possibility of the lamb crop in one group being decreased by a partially sterile ram.

The study was made on the numbers of lambs dropped rather than on the number of corpora lutea or ovulations. According to Hammond (16), the number of lambs born agrees closely with the number of ovulations.

1930-31

The first year, 60 head of grade Rambouillet ewes were purchased and a preliminary trial was conducted to eliminate those ewes which showed any irregularities in breeding behavior. The ewes were fed oats, bran and alfalfa hay. Daily vaginal smears were made from 17 head of the ewes to note the changes in the number and kind of cells that were present during various phases of the estrous cycle. Most of the ewes that were the subject of smear tests were not bred until the third heat period, while the others were bred at the first period observed after October 5, 1930. Records were kept on the lengths of the estrous cycles and gestation periods of all remaining ewes.

1931-32

The lambs from the previous gestation were weaned July 1, 1931, and the ewes placed on native grass pastures until September 5. After August 1 they were tried daily but breeding did not start until after they were placed on the experimental rations. The ewes were divided into five lots of nine each and the rations shown in Table I were fed until December 2, the end of the breeding season. The ewes were then grouped together and fed oats, bran, and alfalfa hay until after lambing.

1932-33

All of the lambs were weaned June 1 and from then on the ewes were tried daily. Two ewes were in heat June 22, and by July 23 thirteen of the forty-five ewes had shown evidence of estrus. On July 23, the ewes were divided into two lots of 21 ewes each and breeding was started. The data secured are shown in Table II.

Seventeen head of native medium wool ewes were added to the experimental flock in the fall of 1932. These ewes were received Sepetmber 1 and received prairie hay as the sole ration until October 27. After that date they were fed a ration similar to that fed Lot I, as shown in Table II.

The native ewes that came in heat early were not bred the first period but were bred the second and third heat periods. This delayed breeding was for the purpose of checking the length of estrous cycles and to allow some time on the prairie hay ration.

1933-34

Fifteen head of fine wool ewes and their lambs were placed in a paved lot April 22. Thirty-three additional head of native ewes and their lambs were purchased April 22 and were confined to a paved lot and fed the same ration. On May 1 the remaining western and native ewes were likewise confined. After each group was confined to a paved lot, they were fed approximatly two pounds of prairie hay per head daily and given free access to a mineral mixture consisting of equal parts salt, steamed bone meal, and limestone.

1934-35

All of the ewes were placed on a prairie hay ration May 1 and were given a mineral supplement. The lambs were weaned on May 30 and the ewes kept on the hay ration until July 10. The ewes were then divided into five lots with 13 in each lot and were fed the ration indicated in Table V. They remained on the experimental ration until October 10, or a period of 91 days.

1935-36

The lambs were weaned July 12 and the experimental ewes were then separated into six lots July 13. In Lots I, II, III, and IV there were 10 ewes each, while Lots V and VI had only 9 ewes. Lots II and III were placed on a native grass pasture and Lots I, IV, V, and VI were fed prairie hay. On September 8, the experimental feeding period was started and continued until all ewes were bred. The experimental rations were discontinued on November 9.

1936-37

A different method of allotting ewes to their respective lots was used in 1936-37. The allotment started on August 31 by placing the ewe which was first found in heat in Lot I, the second in Lot II, the third in Lot I and so on until there were 10 ewes in each Lots I and II. The remaining ewes were then divided on the same basis between Lots II and IV. This division placed the ewes first found in heat in Lots I and II and the remainder of the ewes were allotted to Lots II and IV. The experimental rations shown in Table VI were started August 31 and continued until October 13. Breeding began September 14 and continued until all of the ewes were bred.

1937-38

In 1937, twenty-four Hampshire ewes and twenty yearling Western ewes were placed in the experiment and replaced the ewes previously used. The Hampshires were placed on a ration of one pound cottonseed hulls and three-fourths pound of alfalfa hay on June 12 to reduce them in weight and condition before flushing was started. Lot III was placed on Sudan grass pasture June 29 and one-half pound alfalfa hay was added July 20. This was continued until August 7, when the ewes were taken from pasture and fed the ration shown in Table VII. Lot IV, the unflushed Hampshires, was started on the experimental ration (Table VII) June 29.

The 20 head of Western ewes were placed on the same ration of hulls and hay on June 14. The Westerns were divided into two lots on June 22 and one lot was flushed by placing them on sudan grass pasture. The other lot of Western ewes received three-fourths pound alfalfa hay and one pound cottonseed hulls. This was decreased to one-half pound alfalfa hay and three-fourths pounds hulls on July 27. After August 5, Lot I was placed in dry lot and received four pounds silage, one pound oats, and one-fourth pound cottonseed meal. The ewes were kept on the rations for 94 days, the duration of the breeding season (until October 10), then placed together and fed the same ration.

1938-39

The lots of ewes that were on the experimental rations in 1937-38 were reversed for the 1938-39 study; therefore, the Western ewes that were flushed the previous year became the unflushed Western ewes. The same procedure was followed with the two lots of Hampshires. The lots were placed on experimental rations (Table VIII) May 28 and remained on these rations until the end of the breeding season, October 10. The ewes were bred after they had been in estrus about twelve hours.

One unflushed western ewe became so emanciated and weak she was bred in a sling September 11, 1938. She showed every indication of being in heat but could not hold the ram; she did not conceive. Three days later she was put on a ration of oats and alfalfa hay and conceived at the next estrus which occurred 34 days later.

EXPERIMENTAL RESULTS

1930-31

The vaginal smears that were taken on 17 head of the ewes gave an accurate measure of the phase of the estrous cycle. The time of estrus as denoted by the "teaser" ram and the smear technique* were in close agreement. The length of estrous cycles varied from 13 to 21 days, with an average length of 17.5 days. The average length of the gestation period for these grade Rambouillet ewes was 148 days.

* The observations made on the vaginal smears of the ewes studied showed that the number and kind of cells present was a reliable index of the constant rhythmic changes during the estrous cycle. For a more complete report of these observations see "The Estrous Cycle in Sheep," Darlow, A. E. and Hawkins, L. E., *Proceedings of American Society of Animal Production*, 1931, pp. 205-207.

Table I.—Breeding Behavior and Reproduction of Western Ewes at Different Levels of Nutrition, 1931-32.

Lot number	I	II	III	IV	V
Ewes per lot	9	9	9	9	9
Rations (pounds): Yellow corn	.487	.096	.487	.29	.763
Rations (pounds): Linseed meal	.243	.144	.243	.58	.095
Rations (pounds): Prairie hay	1.980	1.72	cowpeas	1.94	1.87
Total digestible nutrients	1.555	1.035	.581 +cowpeas	1.637	1.611
Nutritive ratio 1:	7.2	7.2	7.2 +cowpeas	4.6	9.1
Characteristic of ration*	gain	maintenance	maintenance +cowpeas	gain	gain
Average weight Sept. 4, 1931 (lbs.)	91.4	88.2	89.8	90.1	85.0
Average weight Nov. 2, 1931 (lbs.)	100.2	92.0	100.0	101.0	96.0
Average gain in weight (lbs.)	8.8	3.8	10.2	10.9	11.0
Average daily gain (lbs.)	.15	.07	.18	.19	.19
Average first breeding date	9/26	9/25	9/28	---	9/25
Number of apparent conceptions, first service	7	7	6	7	8
Total returns on experimental ration	3	3	6	3	1
Absence of heat on experimental ration	0	0	0	0	0
Ewes settled after change of ration	0	0	0	0	0
Ewes that failed to come in heat	0	0	0	0	0
Number of ewes lambing	8	8	9	9	9
Number of lambs dropped	8	8	9	9	9
Percent lamb crop	89%	89%	100%	100%	100%

* For purpose of classification, an increase of over 7 pounds is referred to in these tables as a gain, a loss of 7 pounds to an increase of 7 pounds is referred to as maintenance, and a loss of over 7 pounds is referred to as sub-maintenance.

1931-32

As shown in Table I, no twin lambs were produced on the experiment in 1931-32 in either the flushed or unflushed lots. The average time of the first heat period was the same for both groups and there was no difference in the average breeding date.

1932-33

Twenty of the 21 ewes in Lot I came in heat and were bred with an average first breeding date of August 6. Five of the ewes returned in heat but only one returned more than once. Twelve of the ewes in Lot II had been bred by October 28. Eight of these returned to heat with a total of 12 returns. The average first breeding date of the 12 ewes bred before October 28 was August 6. Two of the ewes were sacrificed for an ovarian examination.

On October 28 the ration of Lot II was changed to the same as that fed Lot I. The seven ewes in Lot II that had not shown signs of estrus came in heat and were bred. Five of them settled but two failed to conceive. The breeding results of these two lots of western ewes are shown in Table II.

Table II.—Breeding Behavior and Reproduction of Western Ewes at Different Levels of Nutrition, 1932-33.

Lot number		I	II
Ewes per lot		21	19*
Alfalfa hay		1.0	
Rations: Cowpeas		Full feed	
Oats		1.0	
(pounds) Prairie hay			2.0
Total digestible nutrients		1.341	.984
Nutritive ratio	1:	4.67	17.9
Characteristic of ration		gain	maintenance
Average weight August 9, 1932 (lbs.)		70.0	70.0
Average weight October 28, 1932 (lbs.)		110.7	69.1
Average gain in weight (lbs.)		40.7	—.9
Average daily gain (lbs.)		.51	—.01
Average first breeding date		8/6	8/6
Number of apparent conceptions, first service		16	4
Total returns on experimental ration		6	12
Absence of heat on experimental ration		0	7
Ewes settled after change of ration		0	5
Ewes that failed to come in heat		0	2
Number of ewes lambing		21	17
Number of lambs dropped		21	17
Percent lamb crop		100%	89%

* Two ewes sacrificed for an ovarian examination.

Table III.—Breeding Behavior and Reproduction of Western and Native Ewes at Different Levels of Nutrition, 1933-34.

Lot number		I	II	III	IV	V	VI	VII	VIII
Ewes per lot		7[1]	8[2]	10	8[3]	7[4]	10	10	10
Rations: (pounds)	Casein			.48	.08		.12		.08
	Cane sugar		.32		.28		.41		.28
	Yellow corn					.48			
	Oats							.33	
	Wheat bran							.33	
	Prairie hay	1.48	.95	1.43	.97	1.44	1.43	1.00	.99
	Alfalfa hay							.50	
	Green cowpeas								2.99
Total digestible nutrients		.709	.775	1.165	.825	1.093	1.215	1.170	1.164
Nutritive ratio	1:	11.00	19.4	1.2	5.9	10.7	5.9	6.0	5.1
Characteristic of ration		main.	main.	gain	main.	main.	gain	gain	gain
Average initial weight Aug. 15 (lbs.)		72	68	67	72	72	71	73	65
Average final weight Oct. 18 (lbs.)		68	62	78	76	75	85	89	77
Average gain in weight (lbs.)		—4	—6	11	4	3	14	16	12
Average daily gain (lbs.)		—.06	—.09	.31	.06	.05	.22	.25	.19
Average first breeding date		9/1	7/7	9/6	9/8	8/29	9/4	9/12	9/8
Number of apparent conceptions, 1st service		5	1	6	5	6	9	8	7
Total returns on experimental ration		1	3	4	1	1	1	2	3
Absence of heat on experimental ration		1	4	1	3	2	0	0	1
Ewes settled after change of ration		1	1	0	1	0	0	0	0
Ewes that failed to come in heat		0	1	1	0	1	0	0	1
Number ewes lambing		5	4	7	5	5	10	9	8
Number of lambs dropped		5	4	7	5	5	11	10	9
Percent lamb crop		71%	50%	70%	62%	71%	110%	100%	90%

[1] Two ewes died without coming in heat, a third after two heats.
[2] One ewe died from choking one month after breeding. One died without coming in heat.
[3] One ewe died without coming in heat.
[4] Two ewes died without coming in heat, a third after breeding.

The average length of the 21 cycles observed in the native ewes was 17 days. The average date of first heat after arrival was September 22 and the first average breeding date was October 29. One ewe failed to show signs of estrus, but 13 of the 16 ewes which were bred settled to the first service. A second service settled one of the three remaining ewes, but the other two failed to conceive. Two ewes did not show evidence of heat until after October 27.

Fourteen of the native ewes produced single lambs and three failed to produce. No twin births were secured.

1933-34

The various feeds fed to different lots in 1933-34 seemed to have very little effect on the reproduction of the ews. All lots had approximately the same first breeding date. There was no correlation between the date of the first heat observed and the amount of gain made by the ewes in the lot. More ewes that failed to conceive to their first service were found among those receiving adequate rations than among those receiving restricted diets. These results were the opposite of those of the previous year, but it must be remembered that Lot I in 1932-33 received more total digestible nutritients than were received by any lot in 1933-34. The lambing percentage was very low, especially for those lots that lost weight or gained only a small amount. This was largely due to the number of barren ewes. Only three pairs of twins were dropped, one pair in each of Lots VI, VII, and VIII, as shown in Table III. These were the lots that made the largest gain during the breeding season.

1934-35

In 1934-35 only one lot (III) gained a sufficient amount to be called "flushed" according to the standard of Marshall and Potts (23). The other four lots were about maintained. The average first breeding date for all lots was about the same with no correlation between gain in weight and first breeding date. The number of returns was greater for those lots losing weight, but the difference was by no means significant. Again the number of barren ewes was greater in the lots that lost weight, although the distribution of twin lambs was even between the flushed and unflushed lots. Table IV gives a summation of the results for 1934-35.

Table IV.—Breeding Behavior and Reproduction of Western and Native Ewes at Different Levels of Nutrition, 1934-35.

Lot number	I	II	III	IV	V
Ewes per lot	12*	13	12*	13	12*
Rations: (pounds) Casein	.248	.078	.078		
Sugar		.274	.247		
Corn				.500	
Linseed oil meal					.487
Prairie hay	1.104	.955	.952	1.500	.730
Darso silage			2.151		
Total digestible nutrients	.777	.809	1.182	1.138	.728
Nutritive ratio 1:	1.66	5.07	7.89	10.72	3.14
Characteristic of ration	maintenance	maintenance	gain	maintenance	maintenance
Average weight July 10 (lbs.)	82	79	80	90	79
Average weight Oct. 10 (lbs.)	80	84	94	87	78
Average gain in weight (lbs.)	−2	5	16	3	−1
Average daily gain (lbs.)	−.02	.06	.18	.03	−.01
Average first breeding date	8/2	8/12	8/25	8/25	8/25
Number of apparent conceptions, 1st serv.	7	8	11	9	6
Total returns on experimental rations	3	5	1	2	4
Absence of heat on experimental ration	2	1	0	1	3
Ewes settled after change of rations		0	0	0	0
Ewes that failed to come in heat	2	1	0	1	3
Number of ewes lambing	10	12	12	11	9
Number of lambs dropped	12	12	13	11	10
Percent lamb crop	100%	92%	108%	85%	83%

* One ewe in Lots I, III, and V died in course of the tests.

1935-36

As shown in Table V, there was no marked gain in weight by any of the lots, and Lot III lost a large amount of weight for the short period of time. The first breeding date was the same for all lots. Returns to estrus from the first breeding occurred only in Lots V and VI, two of the lots on a gaining rations. The number of barren ewes was evenly distributed between the lots. The lambing percentage was highest in those three lots that seemed to be on the lowest plane of nutrition.

1936-37

In the 1936-37 experiment a definite attempt was made to bring Lots II and IV to a flushed condition and hold Lots I and III at decidedly lower levels of nutrition. This purpose was accomplished. The ewes on the lower levels of nutrition lost slightly in weight or were on sub-maintenance ration. The average first breeding date was slightly earlier for the unflushed lots, although the difference was not appreciable. The only returns from the first breeding occurred in Lot IV, a flushed lot. The number of barren ewes and the twins produced were about the same for the flushed and unflushed lots. These results are presented in Table VI.

1937-38

Before being placed on the experimental ration in 1937-38, the Hampshire ewes that were secured for the experiment were given a sub-maintenance ration to get them down to a thin condition. According to Clark (7), ewes must be in a thin condition before the benefits due to flushing would be expressed to the fullest extent. The Western ewes were in a thinner condition at the beginning of the experiment, but the unflushed Hampshire ewes lost a good deal more weight during the course of the experiment than the unflushed Westerns. There was no significant difference in the first breeding dates of the lots and the number of returns from the first service was about equal for flushed and unflushed groups. The number of returns was very high, probably due to the sterility of the rams in the early part of the summer. Semen smears were not taken until early September, but at that time showed a large number of inactive sperm. The high temperatures of the late summer and early fall were no doubt responsible. The smears changed to normal with lower temperature, and the number of barren ewes did not exceed the number for

Table V.—Breeding Behavior and Reproduction of Native and Western Ewes at Different Levels of Nutrition, 1935-36.

Lot number	I	II	III	IV	V	VI
Ewes per lot	10	10	10	10	9	9
Rations: (pounds) Casein					.12	
Cane sugar					.42	
Yellow corn	.575	.86	.50	.66		.50
Linseed oil meal						
Prairie hay	.75	1.28	.75	.98	1.46	1.50
Total digestible nutrients	.749	1.283	.749	.984	1.236	1.147
Nutritive ratio 1:	3	3	3	3	6	11
Characteristic of ration	main.	main.	sub-main.	main.	gain	main.
Average weight Sept. 8 (lbs.)	95	112	112	88	90	88
Average weight Nov. 9 (lbs.)	91	113	100	94	98	92
Average gain per head (lbs.)	—4	1	—12	6	8	4
Average daily gain (lbs.)	— .07	.02	— .20	.10	.13	.07
Average first breeding date	10/8	10/12	10/10	10/8	10/14	10/12
Number of apparent conceptions, 1st service	8	10	9	9	8	5
Total returns on experimental rations	0	0	0	0	1	2
Absence of heat on experimental ration	1	0	1	0	0	1
Ewes settled after change of ration	0	0	0	0	0	0
Ewes that failed to come in heat	1	0	1	0	0	1
Number of ewes lambing	8	10	9	9	8	7
Number of lambs dropped	11	15	12	11*	10	7
Percent lamb crop	110%	150%	120%	110%	111%	78%

* Includes one set of triplets.

preceding years. Table VII shows that the number of twins produced was a bit higher for the unflushed lots, but the difference was not significant.

The unflushed western ewes conceived an average of 10 days earlier than the unflushed western ewes. The flushed ewes lambed on an average date of January 5 and the unflushed group on January 15. The reverse was true with the Hampshires. The flushed Hampshires lambed on an average of February 12 and the unflushed on an average of February 3. These differences are no doubt largely due to the unsatisfactory breeding behavior of the rams used.

1938-39

The ewes were placed in the same lots as they were in the previous year, but the unflushed lots of 1937-38 were given a flushing ration and the flushed lots of the previous year were

Table VI.—Breeding Behavior and Reproduction of Native and Western Ewes at Different Levels of Nutrition, 1936-37.

Lot number	I	II	III	IV
Ewes per lot	10	10	12	11
Rations: (pounds) Alfalfa hay	.5	1.0	.5	1.0
Silage	2	2.5	2	2.5
Ground yellow corn		1.0		1.0
Linseed oil meal		.20		.20
Total digestible nutrients	.600	1.999	.600	1.999
Nutritive ratio 1:	4.2	4.26	4.2	4.25
Characteristic of ration	main.	gain	main.	gain
Average weight Aug. 31 (lbs.)	110.9	112.4	108.3	101.0
Average weight Oct. 13 (lbs.)	107.5	123.0	103.5	118.5
Average gain per head (lbs.)	—3.4	10.6	—4.8	17.5
Average daily gain (lbs.)	-.08	.25	—.11	.41
Average first breeding date	9/23	10/13	9/17	9/20
Number of apparent conceptions, 1st service	7	6	12	8
Total returns on experimental rations	0	0	0	5
Absence of heat on experimental ration	0	4	0	0
Ewes settled after change of ration	0	0	0	0
Ewes that failed to come in heat	0	4	0	0
Number of ewes lambing	7	6	12	11
Number of lambs dropped	10	8	14	15
Percent lamb crop	100%	80 %	117%	136%

Table VII.—Breeding Behavior and Reproduction of Ewes at Different Levels of Nutrition, 1937-38.

Lot number		I	II	III	IV
Breed of ewes		Western	Western	Hampshire	Hampshire
Ewes per lot		10	10	12*	12
Rations: (pounds)	Alfalfa hay		.50		.50
	Corn silage	4		4	
	Cottonseed hulls		.75		.75
	Oats	1		1	
	Cottonseed meal	.25		.125	
	Pasture (Sudan grass)	Until Aug. 5		Until Aug. 7	
Total digestible nutrients		1.603	.579	1.56	.579
Nutritive ratio 1:		6.13	8.8	7.7	8.8
Characteristic of ration		gain	main.	gain	sub-main.
Average weight July 7 (lbs.)		77.0	77.1	156.1	162.8
Average weight Oct. 10 (lbs.)		97.5	71.7	179.6	141.2
Average gain in weight (lbs.)		20.5	−5.4	23.5	−21.6
Average daily gain (lbs.)		.22	−.06	.25	−.23
Average first breeding date		7/23	7/21	7/25	7/20
Number of apparent conceptions, 1st service		0	2	0	0
Total returns on experimental rations		15	17	37	40
Absence of heat on experimental rations		0	0	0	0
Ewes settled after change of ration		0	0	0	0
Ewes that failed to come in heat		0	0	0	0
Number of ewes lambing		8	9	10	11
Number of lambs dropped		8	9	13	17
Percent lamb crop		80%	90%	118%	142%

* One died Aug. 21 of congested lungs.

given a maintenance ration. The average first breeding date was later for the flushed lots than for the unflushed lots. The number of returns was large, but there was no difference between lots. Semen smears of the Hampshire rams were studied under a microscope and several of the semen samples contained no living sperm. The samples were studied about the middle of August. This condition, no doubt, accounted for a considerable number of returns in both 1937-38 and 1938-39, when breeding was started early in the summer. As shown in Table VIII, the flushed lots produced a few more twin lambs than did the unflushed lots, but there was not a significant difference.

Table VIII.—Breeding Behavior and Reproduction of Ewes at Different Levels of Nutrition, 1938-39.

Lot number	I	II	III	IV
Breed of ewes	Western	Western	Hamp-shire	Hamp-shire
Ewes per lot	10	10	8	10
Rations: Alfalfa hay	.5		.5	
Prairie hay	.5		.75	
Oats		.5	1.	
pounds) Cottonseed meal		.125		.125
Pasture (Sudan grass)		Pasture		
Total digestible nutrients	.497	------	.620	------
Nutritive ratio 1:	10.8	------	7.67	------
Characteristic of ration	sub-main.	gain	sub-main.	gain
Average initial weight May 28 (lbs.)	89.5	87.4	159.4	148.2
Average final weight Oct. 10 (lbs.)	72.9	114.7	123.7	172.9
Average gain per head (lbs.)	−16.6	27.3	−35.7	24.7
Average daily gain (lbs.)	−.12	.20	— .27	.18
Average first breeding date	6/24	7/30	7/30	8/14
Number of apparent conceptions, 1st service	1	5	0	3
Total returns on experimental rations	22	14	17	17
Absence of heat on experimental rations	0	0	0	0
Ewes settled after change of ration	1	0	0	0
Ewes that failed to come in heat	0	0	0	0
Number of ewes lambing	9	10	7	8
Number of lambs dropped	9	12	9	12
Percent lamb crop	90%	120%	113%	120%

The unflushed western ewe that was removed from the experimental ration September 14, 1938, after having been bred three days earlier in a sling, responded immediately to the change in ration. She returned to heat 34 days after her previous heat. was bred, and produced a normal, thrifty lamb. The heat periods on this ewe were of varying lengths. She showed evidences of heat and was bred at intervals of 18, 27, 35, 21 and 34 days before settling. Her initial weight was 83 pounds but she had declined to a weight of 53 pounds on September 10, the day previous to being bred in the sling. After a 31-day feeding period of alfalfa and oats she weighed 74 pounds the day she conceived, or October 15.

DISCUSSION

The results of these experiments are difficult to interpret because of the small number of ewes in each lot. The failure of an ewe to lamb or the production of a pair of twins by one ewe causes great fluctuation in the percent crop of a lot. The amount of twinning, however, was within the range expected for the particular breeds that were used in the study, according to the figures given by Marshall and Potts (23).

Lamb Production

In order to be able to sum up the data from the series of experiments, the lots were divided into three classes. The lots that had gained more than seven pounds during the breeding season were termed flushed, according to the suggestion by Marshall and Potts (23). Those lots that gained up to seven pounds or lost not more than seven pounds in weight were considered maintained, and those that lost more than seven pounds were placed in the sub-maintenance group. This arbitrary grouping of the lots gave the results shown in Table IX. Over the entire length of the experiment, the flushed group had a higher percent lamb crop than did the maintained group, but those that lost considerable weight had a higher lambing rate than either of the other two groups.

A similar criterion of liveweight gain during the breeding period was used in dividing the ewes in the last four years of the experiment into three groups: (1) flushed, (2) maintenance, and (3) sub-maintenance. The rations fed were disregarded and the sole basis for the divisions was the gain in weight. The number of lambs produced by these 182 ewes is shown in Table X. The 66 ewes that gained in weight during the experiment from 1934-35 had a higher lambing percentage than either the maintenance or sub-maintenance group. The analysis of these data is shown in Table XI. An F value of .3378 was secured, whereas a value of 3.06 represents the 5 percent point and a value of 4.75 the 1 percent point. The results in Table X show the difference not to be highly significant when the data are analyzed according to the method of Snedecor (3).

Estrous Cycle

In the early part of this experiment (Darlow and Hawkins), it was observed that more 32-to-38-day intervals occurred in the oestrous cycles of unflushed than in flushed ewes.

Table IX.—Relation of Lamb Crop to Live Weight Gain of Ewes 1931-39.

	Number of ewes	Number of lambs	Percent lamb crop
Flushed	159	172	108.18
Maintenance	166	149	89.76
Sub-maintenance	40	46	115.00
Total	365	367	100.55

Table X.—Relation of Lamb Crop to Live Weight Gain of Ewes 1935-39.

Treatment	Number of ewes	Average gain in weight	Number of lambs	Percent lamb crop
Flushed	66	+20.33 lbs.	77	116.67
Maintenance	54	+ 2.26 lbs.	59	109.26
Sub-maintenance	62	−19.29 lbs.	67	108.06
Total	182	----------	203	111.54

Table XI.—Analysis of Variance of the Effect of Live Weight Gain During Breeding Upon the Size of the Subsequent Lamb Crop.

	Degrees of freedom	Sum of squares	Mean squares	F value	P
Total	181	71.58			
Between lots	2	.27	.135		
Within lots	179	71.31	.3996	.3378	>.05

Smear studies indicated that the ewes almost came in heat but never actually showed an interest in the ram. The ewes observed in these smear studies received more drastic treatment than those represented in the data analyzed in Tables XII and XIII.

A more detailed study was made of the length of estrous cycles for the last three years of the investigation, when there was a sufficient number of cycles to study because of the large number of returns during those years.

Grade Shropshires and Westerns, 1936-37.—For the year 1936-37, there was no difference in length of estrous cycle between the flushed and unflushed groups of grade Shropshire and western ewes being used in the experiment at that time.

Westerns, 1937-38 and 1938-39.—The average length of the estrous cycle for the unflushed western ewes the last two years of the study was 17.75 days, for the flushed group 16.93 days. The difference was highly significant as shown by the analysis of variance in Table XII. No cycle of more than 19 days was included in the analysis of the data on western ewes. No cycles of less than 15 days occurred.

Some cycles of abnormally long length were experienced. In 1937-38 one ewe in the flushed group had a cycle of 32 days, or a double interval, and one ewe returned in the same group after having passed several times. In 1938-39 two ewes in the unflushed lot that were losing considerable weight contributed three such periods, and three ewes returned to heat after appearing safely settled for more than two periods. Two ewes in the flushed group each showed one double interval.

Table XII.—Analysis of Variance of the Effect of Live Weight Changes on the Length of Estrous Cycles of Ewes, 1937-38 and 1938-39.

	Degrees of freedom	Sum of squares	Mean squares	F value	P
Total	55	47.500			
Between lots	1	5.906	5.906		
Within lots	54	41.594	.770	7.67	>.01

Hampshires, 1937-38 and 1938-39.—There was a significant difference between flushed Hampshires and unflushed Hampshires in estrous cycle length, as shown in Table XIII. The unflushed ewes had a mean estrous cycle of 17.17 days and the flushed group 16.50 days. One ewe was included in this study that had more than a 19-day interval. This particular ewe, which was in the unflushed group had a series of three cycles of 20, 21, and 19 days before she conceived.

Several abnormal cycles were experienced during the two-year period. In 1937-38, one ewe in the unflushed group had a double interval and one in the flushed group returned to service after passing several. During the following year one flushed ewe had a double interval between periods. In the unflushed group, one ewe returned to heat after 47 days and then conceived after another interval of 40 days. One other ewe also returned to heat after it appeared she had settled.

Table XIII.—Analysis of Variance of the Effect of Live Weight Changes on the Length of Estrous Cycles of Hampshire Ewes 1937-38 and 1938-39.

	Degrees of freedom	Sum of squares	Mean squares	F value	P
Total	105	146.567			
Between lots	1	10.532	10.532		
Within lots	104	136.035	1.308	8.052	$>.01$

Combined Groups.—When the results for 1936-37 were combined with those in Tables XII and XIII and the three years' results analyzed as a unit, the flushed ewes had an estrous cycle which was shorter to a highly significant extent.

Breed Differences.—There was a difference in length of estrous cycle between the Western Hampshire ewes studied in 1937-38 and 1938-39. The Westerns averaged 17.25 days to an estrous cycle and the Hampshire average 16.77. The difference was significant, but not highly significant, as shown in Table XIV. These data agree with Cole and Miller (10) who also found a difference in estrous cycles due to breed. As previously pointed out, other workers have not noted these differences (7, 26, 27).

The Hampshire ewes produced a larger lamb crop in both of the last two years than did the Westerns.

Table XIV.—Analysis of Variance of the Effect of Breed on the Length of the Estrous Cycle in Breeding Ewes.

	Degrees of freedom	Sum of squares	Mean squares	F value	P
Total	161	202.383			
Between breeds	1	8.166	8.166		
Within breeds	160	194.217	1.214	6.727	$>.05$

Effect of Age of Ewes.—Statistical analysis indicated there was no significant difference in length of estrous cycle nor in the size of the lamb crop due to an age increase of one year from 1937-38 to 1938-39, in either the flushed or unflushed groups of ewes. These results secured on a small number of ewes should not be regarded as too important in light of their disagreement with the more extensive study made by McKenzie and Terrill (27).

Effect of Nutrition.—There seem to be two ways in which nutrition could affect the number of eggs ovulated at a given heat period: (1) By directly increasing the supply of nutrients to the ovary, or (2) indirectly by increasing the amount of hormone produced by the anterior pituitary and supplied to the ovary to stimulate the egg production. Just how much of an increase in body metabolism is necessary to produce the desired increase in ovulation is questionable. This gives rise to the question of whether a group of ewes can be considered "flushed" because of being fed a ration that is nutritionally superior to a so-called "non-flushing" ration or whether a gain in weight should be used as the measuring stick. It would seem that the gain in weight is the only tangible measure that could possibly be used. Marshall and Potts (23) have arbitrarily set the gain in weight at seven pounds for the flushing period. They, however, do not adhere to this standard when they give "flushing" credit for an 18.1 percent increase in lamb crop. They refer to several of their lots, namely, 2, 6, 8, 14, and 16 as flushed lots, yet these lots gained an average of only 4.32, 6.30, 2.85, 3.76, and 5.80 pounds respectively. These lots are equaled in gain in weight by several of the unflushed lots and produced a large lamb crop. If these lots were considered to be "non-flushed" the lambing rates of the flushed and unfushed lots would be approximately equal.

Smith (32) states that the small gain in weight of the flushed lots in his experient did not produce a "flushing" condition. In only one case did a flushed lot gain as much as seven pounds. His results are very probably not significant and the 7.4 percent difference is apt to be due to chance.

Clark's (6) results during the first year of an experiment comparing the number of corporea lutea in the ovaries of flushed and unflushed lots show a marked difference in favor of flushing. Although in the second year the ovaries of the unflushed lots showed a few more double ovulations than did the flushed lots, the difference was not great enough to be significant.

Although flushing does have some effect on reproduction, in its influence on the length of estrous cycle, it does not affect the number of lambs dropped. It is possible that the rise in nutrition causes an increase in the amount of follicular stimulating hormone from the anterior pituitary which causes a more rapid maturation of the follicles, but does not increase the number of follicles. The rapid maturing of the follicle may cause an earlier heat period and therefore a shorter cycle. Why then does it not cause the flushed ewes to come into estrus earlier in the season, especially if Grant's finding, that one or several ovulation take place without the accompanying heat period, is correct? In this experiment it was found that the unflushed ewes came in heat as early in the season as did the flushed ewes. Direct increase of the nutrients to the ovary would offer no better explanation of the results obtained.

The estrous cycles of the ewes did not become shorter as the breeding season advanced. The mean length of the first estrous cycle of the breeding season was 16.96 days, the second cycle 16.79 days, the third 17.34 days, and the fourth (17 in number) 16.82 days. It appears that these data, secured over a period of eight years, do not furnish an entirely satisfactory explanation of the manner in which nutrition affects the reproductive organs.

Low fertility during the summer of the rams used the last two years resulted in the large number of returns that were experienced. The ewes came in heat as early as June and July but few conceived. Semen smear tests of the rams showed a lack of motility of sperm. When sperm activity returned to normal, the rams became fertile and the ewes conceived. Some individual difference was observed in the rams as to the effect of the hot weather on their sperm motility but all rams were adversely influenced by the high temperatures. McKenzie and Berliner (24) have reported that the fertility of rams was adversely influenced by hot summer weather but returned to normal during the cool weather of the fall. The ewes in this experiment settled in the fall as the sperm motility improved.

CONCLUSIONS

1. The ability of flushing to increase the number of lambs dropped has not been substantiated in a summation of the eight-year results.

2. No difference was noted between the flushed and unflushed lots as to time of the first estrous period in the season.

3. The difference in estrous cycle length between the flushed and unflushed lots showed that nutrition did affect the productive organs in some manner.

4. It was observed that the heat periods of ewes could be lengthened by low levels of nutrition. "Passing over" or doubling of heat periods was observed in some ewes. Visual signs of heat were halted in a few ewes that had reached an emaciated condition.

5. The first heat periods for the ewes were observed in June, July, and August, but at that time the fertility of the rams was low.

6. Individual differences were noted between ewes in the number of lambs produced, length of estrous cycle, and in gain in weight.

7. The cost of increasing the amount of feed fed during the breeding season was not justified by an increase in lamb crop.

8. The twin lambs dropped were dispersed evenly throughout the lambing season.

9. There was no significant difference between one-year-old and two-year-old ewes in the length of estrous cycle nor in the number of lambs produced under the condition of the experiment.

10. There was a significant difference between breeds, both in number of lambs produced and in the length of estrous cycle. The Hampshire ewes had a shorter estrous cycle and produced more lambs than did the Westerns.

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