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CALCIUM REQUIREMENTS OF DAIRY CATTLE
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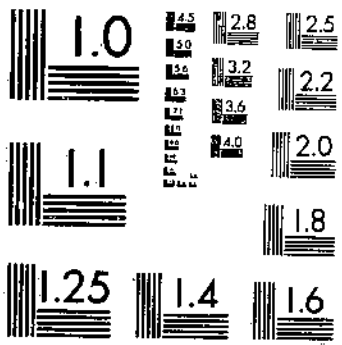
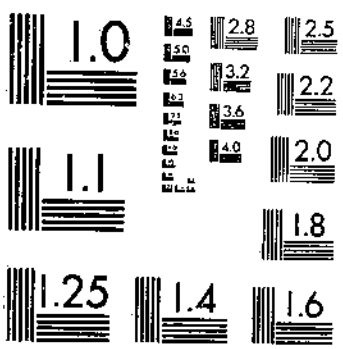


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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Calcium Requirements of Dairy Cattle

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INTRODUCTION AND REVIEW OF LITERATURE

The role of calcium metabolism in the nutrition of dairy cattle has been a subject of great interest for years.

In a study starting in 1912 at the Ohio Agricultural Experiment Station, Forbes and associates (*6, 7, 8, 9*) [2] showed that fairly heavy milking cows always lose more calcium than they take in during the early part of the lactation period but replace the lost body stores of calcium during the latter part of the lactation period and during the dry period. These negative balances (losses of calcium from body stores) were found in the early part of the lactation period whether timothy hay, clover hay, or alfalfa hay was fed, and even when calcium carbonate or bonemeal was added to a ration that included alfalfa hay.

In 1922, Forbes and associates (*9*) reported that cows under observation in their study retained calcium with a production as high as 9.98 pounds of milk daily. At that time they stated: "It is not clear that supplemental calcium is utilized, either during lactation or during the dry period."

In 1926, Meigs and associates reported (*13*) that experiments at Beltsville indicated that calcium from bonemeal is very poorly assimilated. In 1924, Meigs had reported (*12*) a very slight advantage in milk production when the roughage was supplemented with 3 percent of calcium carbonate in the grain mixture. He also felt there was a slight improvement in reproduction—that is, in ease of conception by cows fed this supplemental ration.

In 1929 at the Massachusetts Agricultural Experiment Station, Lindsey and Archibald (*10*) concluded that for average producers (5,000 to 8,000 pounds of milk) fed on good quality roughage no mineral supplement was needed, but that for high producers (10,000 pounds of milk or more) it was probably good insurance to supply supplemental lime and phosphorus. They added, however, that "the efficacy of such a practice is by no means well established." They also stated that, since their own experimental animals maintained a yearly milk-production level of 9,000 to 12,000 pounds over a period of years on low ash rations, it seems reasonable to infer that the average cow on good quality roughage must have a considerable margin of safety as far as minerals are concerned.

In 1932, workers at the Minnesota Agricultural Experiment Station reported (*5*) that both milk production and reproduction were essentially the same on 3 rations that contained 0.64, 0.32, and 0.18 percent

[1] Retired February 28, 1950.

[2] Italic numbers in parentheses refer to Literature Cited, p. 24.

of calcium, respectively, on the dry-matter basis. They later reported (*17*) that when the cows that had received calcium at the 0.18-percent level for several years were further reduced to a 0.12-percent level there was no adverse effect on reproduction or on the production of milk and fat.

Experiments begun at the Michigan Agricultural Experiment Station in 1922 and reported (*18*) in 1930 showed that growth, reproduction, and milk production by a group of cows fed grain, timothy hay, and silage, without pasture, was just as satisfactory as that by a similar group fed alfalfa hay in place of timothy hay.

In 1931 and 1932 Ellenberger, Newlander, and Jones reported (*3*, *4*) the results of their longtime balance experiments at the Vermont Agricultural Experiment Station. On the basis of these reports, Newlander in 1946 (*16*) stated—

> We have conducted mineral (calcium and phosphorus) balance trials for a number of years with moderate to heavy milking cows and in no case was there any need of a mineral supplement. These cows were fed good quality of roughages (timothy hay, corn silage, or cut grass in season), and a satisfactory grain mixture, all feeds being fed in proper proportions according to modern accepted practices.

In many carefully controlled experiments at Beltsville (*13*, *21*), high-producing dairy cows, at least during the early part of lactation, lost more calcium in the milk, urine, and feces than was contained in the feed. This actual loss of calcium from the body stores held true (*20*) even when rations consisting of well-cured alfalfa hay, a good grain mixture, and mangel beets were fed. As has been previously stated (*12*) the early impression at Beltsville was that a high-calcium ration, either one containing alfalfa hay or one containing grass hay (timothy) supplemented with mineral calcium (bonemeal or calcium carbonate), was better suited for the well-being of the dairy cow both for reproduction and for milk production than a ration containing the grass hay without any supplement.

At the Beltsville station (*2*) it was shown that heifers made as good gain on timothy hay and grain as they did on timothy hay and grain plus 3 or 6 percent of bonemeal. It was also reported that bone ash analyses on 12-month-old male calves showed that the same amount of calcium was present in those fed timothy hay as in those fed alfalfa hay.

LONGTIME EXPERIMENTS AT BELTSVILLE

This is a report of experimental work conducted by the Bureau of Dairy Industry at the Beltsville, Md., station from 1928 through 1947 to determine the calcium requirements of dairy cattle. Four experiments somewhat overlapping in time were conducted with a total of 51 animals.

The first experiment (beginning in 1928) was designed to compare the practical values of high-calcium and low-calcium rations for milk production and to note the effect on reproduction. U. S. No. 1 alfalfa hay and a suitable grain mixture made up the high-calcium ration, whereas U. S. No. 3 timothy hay and a higher protein grain mixture made up the low-calcium ration. Late-cut, weathered timothy hay was chosen for the low-calcium roughage, because it had been shown (*13*) that the assimilation of calcium from weathered hay was less than from hay cured without exposure.

In the next 3 experiments (beginning in 1933, 1938, and 1945, respectively) rations successively lower in calcium content were fed to the experimental animals, from early ages through one or more lactation periods, to determine the minimum calcium requirements for growth, milk production, and reproduction.

In all these longtime experiments the grain rations carried an abundance of phosphorus, especially in the first 3 experiments. The grain mixture used in the first 2 experiments contained about 3.7 times as much phosphorus as calcium, whereas in the third experiment the grain contained over 6 times as much phosphorus as calcium. Since the late-cut timothy hay was not too palatable the cows in the first 2 experiments ate considerably more grain than hay—frequently from a third to a half more pounds of grain than hay. In the third experiment in which 2 cows were restricted to less than 5 pounds of hay daily, the grain fed was often 4 to 5 times the amount of the hay. Thus, very large amounts of phosphorus were fed. Even in the fourth experiment, in which a special grain mixture containing only about 0.08 percent of calcium was fed, the calculated phosphorus content was adequate according to accepted standards.

The energy intake for growth usually satisfied or exceeded the growth requirements, whereas the energy guide for cows of milking age was 10 percent more than the Savage requirements (*19*).

All animals were bedded on shavings instead of on straw, since an appreciable amount of straw would be eaten if used for bedding.

The First Experiment

Six Jersey heifers, all daughters of the same sire, were divided into 2 groups of 3 each just before calving time. One group was fed No. 1 alfalfa hay and grain ration No. 60 (corn meal, 40 parts; wheat bran, 30 parts; soybean meal, 20 parts; and linseed meal, 10 parts). The other group was fed No. 3 timothy hay and grain ration No. 65 (corn meal, 30 parts; wheat bran, 20 parts; soybean meal, 25 parts; and linseed meal, 25 parts).

Both groups had received alfalfa hay until just before the first calving, when one group was changed to timothy hay and grain ration No. 65. No. 1 timothy hay was fed to this group during the first 3 months of the first lactation, after which the group received No. 3 timothy hay.

Table 1 shows the milk production of the 2 groups, on an actual basis and also on a 4-percent fat-corrected basis. All cows were milked twice a day for 365 days.

On a 4-percent fat-corrected basis, milk production by the timothy-hay group averaged 19 percent more in the second lactation than in the first. Only 1 timothy-hay heifer milked through a third lactation. Her production in the third lactation was 23 percent more than in her second lactation and 36 percent more than in her first lactation.

The alfalfa-hay group, on a 4-percent fat-corrected basis, averaged about the same milk production in the second lactation as in the first but produced 20 percent more in the third lactation than in either the first or second.

In the timothy-hay group all first calves were normal since the heifers had alfalfa hay until shortly before calving. The second and third calves of these cows were abnormal as the result of vitamin A deficiency, as reported by Converse and Meigs (*1*). Three of these

TABLE 1.—*First experiment: Comparative effect of a low-calcium ration (timothy hay) and a high-calcium ration (alfalfa hay) on milk production*[1]

Group, and cow No.	First lactation			Second lactation			Third lactation		
	Milk	Fat	4-percent F. C. M.	Milk	Fat	4-percent F. C. M.	Milk	Fat	4-percent F. C. M.
Timothy-hay group:	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
N–301	5, 753	251	6, 066	6, 524	276	6, 735	7, 817	342	8, 257
N–401	8, 063	408	9, 345	9, 428	494	11, 181	----------	----------	----------
N–402	6, 714	334	7, 696	8, 544	415	9, 643	----------	----------	----------
Average	6, 843	331	7, 702	8, 165	395	9, 186	7, 817	342	8, 257
Alfalfa-hay group:									
N–302	8, 671	499	10, 953	9, 059	489	10, 959	9, 606	568	12, 362
N–303	6, 832	370	8, 283	7, 214	385	8, 661	8, 545	434	9, 928
N–403	5, 087	313	6, 730	4, 775	294	6, 320	6, 392	427	8, 962
Average	6, 863	394	8, 655	7, 016	389	8, 647	8, 181	476	10, 417

[1] Cows were milked twice a day for 365 days.

calves were born dead while the other three were born weak and blind. Cow N–301 became a nonbreeder after the third lactation. Cow N–401 died of a generalized infection 21 days after her third calf was born. Cow N–402 went dry following a very severe case of mastitis about 7½ months after her third calving.

The amount of milk produced by the animals was not adversely affected by the low intake of calcium supplied by the timothy ration. However, the late-cut timothy hay was so low in carotene or vitamin A that all the calves were abnormal and all 3 cows were nonproducers after 2 or 3 lactations because of vitamin A deficiency.

In the later experiments, cows on the timothy hay ration received a vitamin A supplement—either cod liver oil or garden carrots. The usual cod liver oil dosage was 20 cubic centimeters or 4 teaspoonfuls daily although a few cows were proved completely protected by half this amount, or 2 teaspoonfuls daily, from birth to the end of their productive life. The cows getting garden carrots usually got 20 pounds daily while milking and 5 po nds while dry.

The Second Experiment

The second experiment was conducted with 31 heifer calves born between January 1933 and June 1941. (See table 3.)

As the calves became available some of them were put on a ration of No. 3 timothy hay and grain No. 65, whereas others were put on the same timothy and grain ration plus either 3 or 6 percent of bonemeal in the grain. Usually the calves were started on timothy at birth, although a few of the first heifers were started at 6 months of age. All the animals were fed a vitamin A supplement, either cod liver oil or garden carrots. Some in each group received the cod liver oil and some the carrots. Skim milk was fed until the animals were 6 months of age.

Table 2 gives the calcium content of the timothy hays fed in this experiment and in other experiments at Beltsville over a period of years.

It was planned to purchase timothy hay with the lowest calcium content possible. Nearly every lot of hay purchased was analyzed for calcium. Many lots of hay were rejected because the calcium content was too high.

After about 1936 no lot of hay was accepted if it contained over 0.35 percent of calcium and after that time probably as many lots of hay were rejected as were purchased. Occasionally the supply of hay was exhausted before suitable hay could be found and an unsuitable lot was purchased to be fed in the meantime. The difficulty in finding the hay that was fed in the experiment indicates that the hay used was really much lower in calcium than average hay.

From 1936 to 1944, 58 lots of No. 3 timothy hay were fed, with an average calcium content of 0.288 percent. The calcium content of the No. 1 timothy fed at Beltsville during this period, insofar as the data are available, is given in table 2 just to show the range in calcium of the timothy hay recorded. In 1922 Meigs (*11*) mentions that all the lots of hay fed at Beltsville in the experiments he was then reporting contained less than 0.25 percent of calcium but that Hart at the Wisconsin station had fed timothy hay with a much higher calcium content, up to 0.57 percent.

TABLE 2.—*Average calcium content of timothy hays fed in various nutrition experiments at Beltsville, 1925–45*

4-year period	U. S. grade of hay	Number of lots	Calcium content		
			Maximum	Minimum	Average
			Percent	*Percent*	*Percent*
1925–28	No. 1	11	0.362	0.175	0.286
	No. 3	1			.533
1929–32	No. 1	12	.564	.255	.336
	No. 3	10	.735	.241	.362
1933–36	No. 1	10	.463	.287	.365
	No. 3	18	.489	.238	.347
1937–40	No. 3	22	.400	.159	.282
1941–44	No. 3	27	.345	.160	.290
1945	No. 1	8	.472	.338	.388

Morrison (*15*) gives the average calcium content of timothy hay as 0.27 percent. However, in our experiments it was impossible to get timothy hay regularly with as little as 0.30 percent of calcium. In fact, although the 111 lots of timothy hay fed from 1925 to 1944 averaged only 0.318 percent of calcium, 27 lots, or 24 percent of the total, contained over 0.35 percent.

It will be clear from these statements about the hay fed at Beltsville that the animals in the second experiment received timothy hay lower in calcium than most of the timothy hay grown in the areas from which hay was bought—Ohio, Pennsylvania, New York, Maryland, and Virginia. For instance, in the Shenandoah Valley at Mt. Jackson, Va., a limestone area, a large lot of clean timothy hay was found with no legumes and no weeds, and over 0.50 percent of calcium; whereas in the Middletown Valley in Maryland, just over the Blue Ridge Mountains in a nonlimestone area, we purchased several lots of timothy hay with about 0.25 percent of calcium or slightly lower than the average given by Morrison for the average of all analyses. One lot of timothy hay bought in Maryland, in what is supposed to be a nonlimestone area, with only the barest trace of legumes but with considerable weeds, contained 0.533 percent of calcium.

GROWTH

The growth study was confined to the 12-month period from the 6th to the 18th month of age. Table 3 shows the results.

During this 12-month period, the Holstein heifers that were fed the basal ration of grain No. 65 and timothy hay plus a vitamin A supplement gained on the average 9 pounds less in body weight but measured on the average 0.3-inch higher at the shoulders at 18 months than did similar heifers fed the same ration, except that the grain contained either 3 or 6 percent of bonemeal. With the Jerseys, the weight gains for the year and the height at the shoulders at 18 months of age were both slightly higher in the basal-ration group than in the group that received the same ration with bonemeal in addition.

TABLE 3.—*Second experiment: Effect of ration on growth rate of heifer calves from 6 months of age to 18 months*

Breed, and calf No.	Born	Weight at 18 months	Gain in weight from 6 to 18 months of age	Height at withers at 18 months
BASAL RATION [1]				
Holstein:		*Pounds*	*Pounds*	*Inches*
N–113	Jan. 23, 1933	800	426	
N–114	Feb. 9, 1933	672	349	
N–117	Oct. 20, 1934	874	503	
N–242	Feb. 12, 1935	875	493	
N–243	Feb. 16, 1935	767	455	
N–119	July 29, 1935	824	471	
N–120	Jan. 27, 1936	844	431	
N–247	Aug. 30, 1936	762	433	48.7
N–121	Nov. 3, 1936	737	433	47.0
N–124	July 16, 1937	760	436	49.0
N–126	Sept. 30, 1938	869	507	48.9
N–129	Jan. 29, 1940	782	441	49.5
N–132	Apr. 26, 1941	776	448	49.8
N–260	June 29, 1941	769	475	49.3
Average		794	450	48.9
Jersey:				
N–441	Jan. 12, 1937	589	346	45.4
N–442	Sept. 1, 1937	554	343	45.9
N–444	May 24, 1938	701	502	45.9
N–445	Oct. 3, 1940	584	379	46.5
Average		607	393	45.9
BASAL RATION [1] PLUS BONEMEAL [2]				
Holstein:				
N–116	Oct. 9, 1934	754	460	
N–244	Jan. 10, 1936	786	395	
N–246	Aug. 28, 1936	776	422	49.5
N–122	Dec. 14, 1936	764	431	47.6
N–250	Sept. 3, 1937	849	500	49.2
N–127	Jan. 7, 1939	885	512	48.4
N–256	Aug. 13, 1940	769	490	47.9
Average		798	459	48.6
Jersey:				
N–440	Nov. 15, 1936	572	313	43.2
N–314	Mar. 1, 1937	621	373	45.1
N–443	Apr. 29, 1938	695	468	46.0
N–446	Dec. 5, 1938	665	437	45.3
N–316	Apr. 20, 1939	664	396	45.9
N–454	Apr. 6, 1940	598	335	46.9
Average		636	387	45.4

[1] The basal ration consisted of No. 3 timothy hay and grain mixture No. 65 (cornmeal, 30 parts; wheat bran, 20 parts; soybean meal, 25 parts; and linseed meal, 25 parts).

[2] In addition to the basal ration, some of the calves received 3 percent of bonemeal in the grain ration and some received 6 percent.

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MILK PRODUCTION

Twenty-three of the heifers shown in table 3 continued on their same rations throug . their first lactation. Their production records are given in table 4.

TABLE 4.—*Second experiment: Effect of ration on milk production during first lactation*

Breed, and calf No.	Actual production [2]		4-percent fat-corrected milk production
	Milk	Butterfat	
BASAL RATION [1]			
Holstein:	*Pounds*	*Pounds*	*Pounds*
N–242	12, 127	499	12, 336
N–243	14, 317	415	11, 952
N–119	12, 878	463	12, 096
N–120	18, 193	642	16, 907
N–121	13, 186	452	12, 054
N–124	15, 042	460	12, 917
N–126	9, 981	390	9, 842
N–132	11, 262	397	10, 475
N–260	9, 780	390	9, 762
Average	13, 088	458	12, 100
Jersey:			
N–445	4, 873	258	5, 819
BASAL RATION [1] PLUS BONEMEAL [3]			
Holstein:			
N–116	14, 066	415	11, 851
N–244	12, 699	433	11, 575
N–246	15, 492	470	13, 247
N–122	11, 844	349	9, 973
N–250	14, 900	528	13, 880
N–127	14, 425	514	13, 480
N–256	13, 942	424	11, 937
Average	13, 910	448	12, 278
Jersey:			
N–440	7, 130	372	8, 432
N–314	10, 315	440	10, 726
N–443	6, 163	353	7, 760
N–446	10, 007	516	11, 771
N–316	10, 692	527	12, 182
N–454	8, 276	458	10, 180
Average	8, 764	444	10, 175

[1] The basal ration consisted of No. 3 timothy hay and grain mixture No. 65 (corn meal, 30 parts; wheat bran, 20 parts; soybean meal, 25 parts; and linseed meal, 25 parts).

[2] All heifers were milked 3 times a day for 365 days.

[3] In addition to the basal ration, some of the heifers in this group received 3 percent of bonemeal in the grain and some received 6 percent.

Unfortunately a good comparison can be had only with the Holsteins. On the basis of 4-percent fat-corrected milk, the group getting the bonemeal supplement produced about 1.5 percent more than the group on the lower calcium ration.

Three of the cows in the low-calcium group milked through 3 lactations each; whereas in the high-calcium group, 2 cows milked 3 lactations, 1 milked 2 lactations, and 1 milked 4 lactations. The results of these lactations, as given in table 5, show that the timothy hay fed without calcium supplement was not deficient in calcium for long-time production. The 3 cows on the basal ration produced an average of 14 percent more 4-percent fat-corrected milk per lactation than did the 4 cows that got a bonemeal supplement to the basal ration.

TABLE 5.—*Second experiment: Effect of ration on lifetime milk production of 7 Holstein cows*

Holstein cow No.	Lactations	Total actual production [2]		4-percent fat-corrected milk production
		Milk	Butterfat	
BASAL RATION [1]				
	Number	*Pounds*	*Pounds*	*Pounds*
N–242	3	37, 755	1, 566	38, 592
N–120	3	54, 456	1, 867	49, 787
N–124	3	44, 533	1, 366	38, 303
Average per lactation		15, 196	533	14, 075
BASAL RATION [1] PLUS BONEMEAL [3]				
N–244	2	28, 157	968	25, 783
N–246	4	57, 961	1, 840	50, 784
N–122	3	32, 849	1, 010	28, 290
N–250	3	45, 944	1, 643	43, 023
Average per lactation		13, 742	455	12, 323

[1] The basal ration consisted of No. 3 timothy hay and grain mixture No. 65 (corn meal, 30 parts; wheat bran, 20 parts; soybean meal, 25 parts; and linseed meal, 25 parts).

[2] All cows were milked 3 times daily for 365 days.

[3] In addition to the basal ration, some cows received 3 percent of bonemeal and some received 6 percent.

CALCIUM ASSIMILATION

Although the relation of the calcium secreted in the milk to the calcium in the feed will be discussed later, reference will be made to it here. Table 4 shows that one cow (N–120) stands out as the heaviest producer in either group. The calcium content of almost every lot of timothy hay fed during her first and third lactations was determined. Also numerous determinations of the calcium of her milk were made. The relation of the milk calcium to the feed calcium for this cow is shown in table 14. In her first lactation she consumed

9,993 pounds of grain and 5,632 pounds of timothy hay and produced 16,907 pounds of 4-percent fat-corrected milk. In her third lactation she consumed 9,260 pounds of grain and 6,951 pounds of timothy hay and produced 17,159 pounds of 4-percent fat-corrected milk.

The calcium content of the timothy hay fed in her first lactation averaged 0.270 percent, the total calcium intake in the feed was 15,593 grams, and the calcium in the milk was 8,944 grams, or 57 percent of that in the feed. If we add to this lactation the feed of the succeeding dry period, then the calcium of the milk is 51 percent of that in the feed. In the third lactation the calcium in the feed was 18,283 grams whereas that in the milk was 9,426 grams or 52 percent of that in the feed.

Other experiments at Beltsville (*14*) indicated that dairy cows can readily utilize 50 percent of the calcium intake. This would make the calcium in the feed 0.245 percent of the dry matter in the first lactation and 0.276 percent of the dry matter in the third lactation.

Even though great effort was made to select timothy hay with the lowest possible calcium content and this cow was the heaviest producer in the herd, the average percentage of calcium in the dry matter of the feed was higher than other investigators (*5*, *17*) have claimed necessary.

The Third Experiment

In 1938 an attempt was made to further restrict the calcium intake of growing heifers and milking cows by feeding a grain mixture of lower calcium content and also by either feeding a timothy hay of much lower calcium content or restricting the amount of hay fed.

Four Holstein heifers were reared in this experiment and milked through at least one lactation. Two of them were restricted to less than 5 pounds of hay daily during the growing period and also when milking. The other two received the restricted amount of hay during the growing period, but when milking they received normal amounts of hay and a grain mixture particularly low in calcium.

During the year of growth (6 months of age to 18 months of age), the calcium content of the dry matter of the ration fed to the 4 Holstein heifers was 0.194, 0.153, 0.165, and 0.151 percent, respectively, or an average of 0.166 percent. During the first lactation, the calcium content of the dry matter of the ration fed to the 4 heifers was 0.142, 0.158, 0.153, and 0.149 percent, respectively.

Two Jersey heifers were also included in this experiment for growth study only. One was fed the basal low-calcium ration and the other was fed the same ration plus bonemeal.

GROWTH

The growth rate of the 4 Holstein heifers from the 6th to the 18th month of age is shown in table 6.

If the data in this table are compared with those in table 3, it will be seen that these 4 heifers (fed a ration containing 0.166 percent of calcium in the dry matter) averaged heavier in weight and higher at the withers at 18 months of age, and made a greater average gain in body weight during the year, than did similar animals in the second experiment (which received approximately 0.32, 0.58, or 0.95 percent of calcium in the dry matter of the ration, depending on whether they

received the basal ration alone or the basal ration plus bonemeal, as either 3 or 6 percent of the grain mixture).

The comparative results with the 2 Jersey heifers are quite informative. Table 7 gives the growth in weight, height at the withers, and the daily intake of calcium and of energy, from birth to 2 years of age. N–489, the low-calcium heifer, gained more in body weight and was just as high at the withers as was heifer N–486, although the latter, after the milk-feeding period, received 4 to 5 times as much calcium as did the former.

TABLE 6.—*Third experiment: Effect of a low-calcium ration (0.166 percent of calcium in dry matter) on growth rate of 4 Holstein heifers from 6 months of age to 18 months*

Calf No.	Born	Weight at—		Gain in weight (6–18 months)	Height at withers at 18 months
		6 months of age	18 months of age		
		Pounds	*Pounds*	*Pounds*	*Inches*
N–252	July 19, 1938	321	828	507	50. 7
N–257	Aug. 2, 1940	310	761	451	48. 7
N–267	Sept. 17, 1943	386	851	465	48. 6
N–135	Nov. 16, 1943	386	853	467	50. 3
Average		351	823	473	49. 6

MILK PRODUCTION

The calcium content of the milking ration was 0.14 to 0.15 percent of the dry matter. The milk records of the last 3 cows, as shown in table 8, do not seem to reflect the value or deficiency of the ration.

The second cow (N–257) had difficulties before she freshened for the first time, and her actions throughout her first lactation indicated the presence of a foreign body. She died 2 days after her second calving due to the presence of a foreign body.

The third and fourth cows in the experiment (N–267 and N–135) were milked only twice a day whereas the cows previously referred to, except in the first experiment, were milked 3 times a day. This resulted in a material difference in the production (perhaps 20 percent). There was reason to believe that the inheritance of N–267 and N–135 for milk production was not high, so their low production was probably not the fault of the ration.

Although the production records of all 4 cows are given in table 8, only that of N–252 was considered good. This cow received calcium at the rate of about 0.19 percent of the dry matter of her ration during the growing period and not over 0.15 percent during her milking period, certainly very much less than most cows receive when fed grass hay or grass hay and corn silage as roughage. This cow died during her third lactation and post mortem examination showed death was due to the presence of a nail and a piece of baling wire.

It should be pointed out that the very good production of cow N–252 for over 2 lactations was made when she was fed less than 5 pounds

TABLE 7.—*Third experiment: Comparative effect of high-calcium and low-calcium rations on growth of 2 Jersey heifers*

Items compared	N–486 (High-calcium ration)	N–489 (Low-calcium ration)
Heifer born	Nov. 5, 1942	Jan. 5, 1943
Weight:		
At 6 months of age—pounds	269	256
At 18 months of age—do	623	674
12 months' gain—do	354	418
Height at withers:		
At 18 months of age—inches	45.9	46.1
PERCENTAGE OF EXPECTED WEIGHT		
At birth—percent	102	109
At 6 months of age—do	111	105
At 9 months of age—do	107	[1] 103
At 12 months of age—do	112	110
At 15 months of age—do	107	110
At 18 months of age—do	104	112
At 21 months of age—do	103	109
At 24 months of age—do	[2]	113
PERCENTAGE OF EXPECTED HEIGHT AT WITHERS		
At 1 month of age—percent	104	101
At 6 months of age—do	101	99
At 9 months of age—do	99	99
At 12 months of age—do	100	100
At 15 months of age—do	100	101
At 18 months of age—do	102	102
At 21 months of age—do	101	103
At 24 months of age—do	[2]	102
AVERAGE DAILY CALCIUM INTAKE BY 3-MONTH PERIODS		
Birth to 6 months of age—grams	18.5	20.2
6 to 9 months of age—do	62.9	7.0
9 to 12 months of age—do	46.4	7.4
12 to 15 months of age—do	43.1	8.1
15 to 18 months of age—do	29.8	8.4
18 to 21 months of age—do	47.3	8.6
21 to 24 months of age—do	[2]	9.8
AVERAGE DAILY TDN INTAKE AS PERCENTAGE OF THEORETICAL REQUIREMENTS		
Birth to 6 months of age—percent	103	102
6 to 9 months of age—do	107	108
9 to 12 months of age—do	118	111
12 to 15 months of age—do	101	105
15 to 18 months of age—do	95	103
18 to 21 months of age—do	104	102
21 to 24 months of age—do	[2]	103

[1] N–489 had pneumonia at 9 months of age.
[2] N–486 died before 24 months of age.

TABLE 8.—*Third experiment: Milk production records of 4 Holsteins on a ration containing 0.14 to 0.15 percent of calcium*

Cow No.	Lactation	Milkings per day	Days milked	Actual production		4-percent fat-corrected milk production
				Milk	Butterfat	
		Number	*Number*	*Pounds*	*Pounds*	*Pounds*
N–252	First	3	365	11, 566	395	10, 551
	Second	3	365	10, 907	370	9, 913
	Third	3	[1] 244	8, 569	311	8, 093
N–257 [2]	First	3	365	7, 657	265	7, 061
N–267 [3]	First	2	365	7, 965	340	8, 286
N–135 [4]	First	2	365	5, 132	208	5, 173

[1] Cow N–252 died during her third lactation as a result of the presence of a foreign body.

[2] Cow N–257 was in distress before and during her first lactation and died immediately after her second calving, as a result of the presence of a foreign body.

[3] Cow N–267 was by a sire that transmitted low milk production, as evidenced by the fact that he had 6 daughters that produced much less than their dams.

[4] Cow N–135 was sired by a bull that had been discarded from the Beltsville breeding herd. The bull was blind as a result of being used in an experiment in which the ration was deficient in vitamin A.

of hay daily. It might be pointed out that in the first 244 days of her third lactation, cow N–252 produced more milk than she had produced in the same portion of her first lactation, indicating that she was not adversely affected by any cumulative deficiency of calcium.

THE FOURTH EXPERIMENT

In March 1945 an attempt was made to further reduce the calcium content of the ration of growing heifers. Since it was no longer possible to find hay with as little as 0.20 percent of calcium, a grain mixture very low in calcium was devised. This grain mixture was called No. 53 and was composed of corn meal, 2 parts; barley, 1 part; wheat bran, 1 part; wheat middlings, 1 part; linseed meal, ½ part; and corn gluten meal, 1 part.[3] This grain mixture contained on the average only 0.078 percent of calcium.

Four Jersey and four Holstein calves were put on this experiment. The Holsteins were fed skim milk from birth until they were from 120 to 144 days of age, or for an average of 133 days. The Jerseys were fed skim milk a little longer (until they were from 122 to 165 days of age) or for an average of 149 days.

The amount of hay fed was very much restricted. The daily average consumption of hay by the Holsteins was 2.2 pounds during the first year and 3.0 pounds during the second year. The daily average for

[3] Corn gluten meal is theoretically very low in calcium. However, several samples when analyzed showed from 0.31 to 0.77 percent. Through Mr. Floyd J. Hosking of the Corn Industries Research Foundation we were informed that most producers of the meal use lime in the processing, leaving a considerable residue. Mr. Hosking found for us a supply of "Diamond Brand" meal from the Derwood Mills, Derwood, Md. A sample analysis showed that it contained only 0.008 percent of calcium.

the Jerseys was 1.6 pounds during the first year and 2.7 pounds during the second year.

Grain mixtures Nos. 65, 75, and 53 with an average calcium content of about 0.200, 0.126, and 0.078 percent, respectively, were fed. These grain mixtures were changed from time to time so that the lowest practical amounts of calcium might be fed. The changes of grain mixtures were frequently made on the basis of blood calcium analyses. Calcium carbonate was administered for brief periods to some of the calves when blood calcium values were particularly low. The calcium content of the total ration fed was 0.12 to 0.14 percent of the dry matter.

GROWTH

Table 9 shows the gains in body weight of the 8 calves in this experiment, for the 12-month period from the time they were 6 months of age until they were 18 months of age.

TABLE 9.—*Fourth experiment: Effect of low-calcium ration (0.12 to 0.14 percent of calcium in dry matter) on growth rate of heifer calves from 6 months of age to 18 months*

Breed, and calf No.	Born	Weight at—		Gain in weight (6–18 months)	Height at withers at 18 months of age
		6 months of age	18 months of age		
Holstein:		*Pounds*	*Pounds*	*Pounds*	*Inches*
N–140	Mar. 15, 1945	343	738	395	47.3
N–141	Mar. 19, 1945	347	762	415	47.4
N–142	Apr. 2, 1945	329	793	464	46.7
N–275	Apr. 23, 1945	327	841	514	49.6
Average		337	784	447	47.8
Jersey:					
N–605	Mar. 2, 1945	248	598	550	43.8
N–607	Apr. 26, 1945	203	572	369	44.7
N–611	July 22, 1945	237	596	359	45.3
N–613	Aug. 18, 1945	226	567	341	44.6
Average		229	583	355	44.6

Although not considered quite normal, the 12-month gains for these calves were as great as for the animals recorded in table 3 which got as much timothy hay as they could eat. However, during the period from 21 to 24 months of age or until calving time, the gains in weight for a number of the animals in this experiment were much less satisfactory. Each of the 4 Holsteins declined in rate of gain, starting at 19 to 21 months of age. They were 97 percent of the expected weight at 19 months of age and only 88 percent of the expected weight at 24 months.

The four Jerseys remained somewhat more nearly at the expected weights. One died during the twenty-third month at just about the expected weight (99 percent). One dropped from 94 percent of the expected weight at 21 months to 86 percent at 24 months. The other

2 heifers improved in rate of gain—they were 97 and 93 percent, respectively, of their expected weight at 21 months and 101 and 95 percent, respectively, at 24 months of age.

The height at the withers at 18 months of age for the animals in both groups appears slightly low. However, if the individual measurements or the group averages are examined, they appear to be not more than 2 percent lower than similar measurements of animals that got all the timothy hay they would eat and which had nearly 3 times as much calcium during the growing period as did the calves in this experiment.

By 21 months of age these heifers, with one exception, were in the later stages of pregnancy. Pregnancy probably affected the rate of gain, both in weight and height, in several heifers in the later months. Pregnancy also must have been a serious drain on the organism, since 1 heifer died several months before she was due to calve and 3 others died within 4 days after calving.

Of the 7 calves born, 2 were dead at birth and 2 live Holstein calves were considerably under weight at birth. As may be seen from table 10, the number of services necessary for conception was quite satisfactory. Six of the 8 animals, including all 4 Jerseys, conceived at the first service.

RELATION OF CALCIUM INTAKE TO GROWTH

Table 11 gives the calcium intake during the growing period of 5 representative animals in the second experiment, in which the animals had unrestricted amounts of timothy hay during the growing period. The calcium content of the hay was probably about 0.30 percent for most of the animals in this experiment. It is considered that the animals on the basal ration without added bonemeal in this experiment grew as large on the average, both in weight and in height at the withers, as did similar calves on similar rations supplemented with either 3 percent or 6 percent of bonemeal in the grain mixture. The basal ration allowed from 15 to 21 grams of calcium daily for Holstein heifers from 6 to 18 months of age.

Table 12 gives the calcium intake of 4 Holstein heifers in the third experiment that received a somewhat lower calcium intake than those in the second experiment. They were fed both grain and hay with a lower calcium content. The daily calcium intake in the third experiment varied from about 7 to 12 grams. This is about half that of the animals shown in table 11. The weight gains and height at the withers of the animals in the third experiment were just as satisfactory.

Table 13 shows the average daily calcium intake for the animals in the fourth experiment that got the smallest amounts of calcium fed. These animals received on the average from 6.5 to 9.0 grams daily. The calcium content of the ration fed in this experiment was about 0.12 to 0.14 percent of the dry matter. As has been stated, the gains in body weight by these animals during the period from 6 to 18 months of age were quite satisfactory, although their height at the withers seems to be a trifle low. However, from 21 to 24 months of age or until calving, the weight gains slowed up perceptibly with a number of the animals.

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TABLE 10.—*Fourth experiment: Effect of low-calcium ration (0.12 to 0.14 percent of calcium in dry matter) on reproduction by 8 heifers*

Breed, and heifer No.	Born	Number of services	Due to calve	Date calved	Calving result	Birth weight of calf (pounds)
Holstein:						
N–140	Mar. 15, 1945	1	May 1, 1947	[1] Apr. 6, 1947	Live male	59
N–141	Mar. 19, 1945	3	Sept. 3, 1947	Aug. 22, 1947	Live female	62
N–142	Apr. 2, 1945	2	July 31, 1947	July 23, 1947	Dead male	95
N–275	Apr. 23, 1945	1	June 6, 1947	[2] May 28, 1947	Dead female	94
Jersey:						
N–605	Mar. 2, 1945	1	[3] Apr. 20, 1947			
N–607	Apr. 26, 1945	1	June 15, 1947	[4] June 8, 1947	Live female	43
N–611	July 22, 1945	1	Sept. 26, 1947	Sept. 15, 1947	Live male	57
N–613	Aug. 18, 1945	1	Oct. 26, 1947	Oct. 16, 1947	Live male	52

[1] N–140 died Apr. 9, 1947. [2] N–275 died May 28, 1947. [3] N–605 died Jan. 9, 1947. [4] N–607 died June 12, 1947.

TABLE 11.—*Second experiment: Relation of calcium intake to growth* [1]

Breed, and heifer No.	Average daily intake of feed calcium from—				
	Birth to 6 months of age	6 to 9 months of age	9 to 12 months of age	12 to 15 months of age	15 to 18 months of age
Holstein:	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
N–120	-------	17.3	20.5	22.3	24.1
N–121	-------	13.5	19.1	19.9	19.6
N–124	-------	12.6	19.8	19.9	19.0
N–247	-------	16.3	19.6	22.2	21.0
Average	[2] 12.4	15.0	19.8	21.1	20.9
Jersey:					
N–441	[2] 9.3	12.6	13.0	13.3	15.4

[1] These 5 heifers are representative of those in the second experiment that received the basal ration of grain No. 65 and timothy hay.
[2] Closely approximate.

It should be remembered that, at the Minnesota Agricultural Experiment Station (*17*), the reproduction performance and the milk production of cows fed several years at the 0.18-percent calcium level and later reduced to a 0.12-percent level were not adversely affected. This level of calcium in the ration was just about the same as that of the 8 animals in the fourth experiment during the entire growing period. Thus the necessary level of calcium for dairy animals may depend very markedly on the age of the animals.

The calves in the fourth experiment were weaned from milk at an early age. From this early age therefore they were on a very low level of calcium. In only a few cases did these calves average as much as 10 grams of calcium daily, whereas a calf fed the usual ration would get as much as 8 grams of calcium daily from 14 pounds of skim milk, not including that from the grain and hay.

RELATION OF CALCIUM INTAKE TO CALCIUM IN MILK

The relation of feed calcium intake to milk production and to calcium secreted in the milk, by representative cows in the first three experiments, is shown in table 14.

Results for only 3 of the 6 animals in the first experiment (table 1) are shown in table 14. The cows on the low-calcium timothy hay ration in the first experiment produced, on the average, almost as much 4-percent fat-corrected milk in the first two lactations as those that received U. S. No. 1 alfalfa hay, in fact more pounds of actual milk. The average milk production of the two groups for the first two lactations was as follows:

Group:	*Actual milk production (pounds)*	*F. C. M. production (pounds).*
Timothy hay	7,504	8,444
Alfalfa hay	6,940	8,651

Yet, as shown in table 14, the 2 timothy-hay (or low-calcium) cows secreted from 35 to 43 percent of their feed calcium in the milk, whereas

TABEL 12.—*Third experiment: Relation of calcium intake to growth*

Holstein heifer No.	Average daily intake of feed calcium from—						
	Birth to 6 months of age	6 to 9 months of age	9 to 12 months of age	12 to 15 months of age	15 to 18 months of age	18 to 21 months of age	21 to 24 months of age
	Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
N–252	11. 7	8. 7	8. 6	9. 4	10. 1	10. 4	15. 3
N–257	10. 7	6. 3	7. 7	8. 1	8. 7	8. 9	9. 1
N–267	9. 3	7. 2	7. 4	10. 1	9. 4	10. 9	12. 2
N–135	23. 8	5. 6	8. 7	9. 3	9. 5	9. 5	11. 1
Average	[1] 10. 6	7. 0	8. 1	9. 2	9. 4	9. 9	11. 9

[1] Average does not include N–135 for this period since she had no milk after 60 days of age but received grain No. 65 plus 3 percent of bonemeal during part of this period.

TABLE 13.—*Fourth experiment: Relation of calcium intake to growth*

Breed, and heifer No.	Average daily intake of feed calcium from—						
	Birth to 6 months of age	6 to 9 months of age	9 to 12 months of age	12 to 15 months of age	15 to 18 months of age	18 to 21 months of age	21 to 24 months of age
	Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
Holstein:							
N–140	7.9	7.3	9.3	7.5	7.0	7.0	9.5
N–141	7.9	5.5	6.4	7.1	7.0	7.0	6.7
N–142	7.5	7.0	7.7	6.8	6.9	6.7	6.3
N–275	7.4	6.3	7.6	7.1	6.9	6.7	7.8
Average	7.7	6.5	7.6	7.1	7.0	6.9	7.6
Jersey:							
N–605	7.6	7.6	9.7	6.8	6.3	6.5	[1]
N–607	6.8	8.7	8.1	7.4	7.5	7.5	9.7
N–611	8.0	8.0	9.5	6.0	5.6	6.6	11.3
N–613	6.4	7.5	6.3	5.7	5.2	5.6	6.5
Average	7.2	8.0	8.4	6.5	6.2	6.2	9.0

[1] Dead.

TABLE 14.—*Relation of feed calcium intake to calcium secreted in the milk, by representative cows from the first 3 experiments*

Cow No., and feeding period	Feed intake		Average calcium content of the hay	Calcium content of the feed dry matter	Total calcium intake from the feed	Milk produced [1]	Calcium in the milk produced	Percentage of calcium intake secreted in the milk
	Grain	Hay						
REPRESENTATIVE JERSEYS FROM FIRST EXPERIMENT								
	Pounds	*Pounds*	*Percent*	*Percent*	*Grams*	*Pounds*	*Grams*	*Percent*
N–301:								
First lactation	4, 997	2, 851	0. 325	0. 269	8, 606	6, 066	3, 335	39
Second lactation	4, 809	3, 634	. 399	. 314	10, 806	6, 735	3, 781	35
N–402:								
First lactation	4, 655	2, 412	. 387	. 289	8, 331	7, 696	4, 391	53
Second lactation	5, 418	4, 432	. 417	. 327	13, 139	9, 643	5, 588	43
N–302:								
First lactation	5, 555	4, 750	1. 444	. 801	34, 343	10, 953	5, 643	16
A REPRESENTATIVE HOLSTEIN FROM SECOND EXPERIMENT								
N–120:								
First lactation	9, 993	5, 632	0. 270	0. 245	15, 593	16, 907	8, 944	57
First dry period [2]	1, 241	1, 202	. 292	. 267	2, 669	99	50	2
Total	11, 234	6, 834	. 274	. 248	18, 262	17, 006	8, 994	49
Third lactation	9, 260	6, 951	. 324	. 276	18, 283	17, 159	9, 426	52

HOLSTEINS FROM THIRD EXPERIMENT

N–252:								
First lactation	7, 820	1, 602	0. 159	0. 142	6, 248	10, 555	5, 995	96
Second lactation	7, 890	1, 606	. 159	. 149	6, 266	9, 913	5, 654	90
Third lactation [3]	6, 075	1, 184	. 159	. 152	4, 736	8, 334	4, 595	97
First dry period [2]	1, 394	529	. 159	. 154	1, 278	1, 189	621	49
Second dry period [2]	1, 316	538	. 159	. 153	1, 240	498	271	22
Total	24, 495	5, 459	. 159	. 152	19, 768	30, 489	17, 135	87
N–257:								
First lactation	6, 560	1, 590	. 159	. 158	5, 269	7, 038	3, 371	64
N–267:								
First lactation	5, 935	2, 736	. 264	. 149	5, 467	8, 279	4, 203	77
N–135:								
First lactation	5, 348	2, 594	. 269	. 153	5, 125	5, 173	2, 389	47

[1] 4-percent fat-corrected milk.
[2] Some milk production is shown for the dry period when the cows were milked beyond the 365-day lactation period.
[3] Milked for 272 days only, before death caused by the presence of a foreign body.

the cow getting alfalfa hay secreted only 16 percent of her feed calcium in the milk.

Results for only one cow (N–120) from the second experiment are recorded in table 14. The calcium intake and milk production figures for this cow have been discussed. However, it might be noted that in her first and third lactations cow N–120 secreted over 50 percent of the feed calcium in the milk.

It should also be remembered (see table 5) that the lifetime milk production of 3 cows on the basal ration of grain No. 65 and timothy hay averaged materially more per lactation than the lifetime production of 4 cows that got the same ration plus 3 or 6 percent of bonemeal, which materially increased both the calcium and phosphorus content of the ration.

Probably the most interesting figures in table 14 are those for cow N–252. The ration of this cow averaged only about 0.15 percent of calcium in the feed dry matter and for the 3 lactations, including 2 dry periods, she secreted 87 percent of the feed calcium in the milk. Yet this cow produced 31,000 pounds of milk (28,557 pounds 4-percent fat-corrected milk) in 3 lactations.

From the data shown in table 14, no need can be demonstrated for adding a calcium supplement to a ration containing grass hay as the roughage, at least as long as the ration contains 0.15 percent of calcium on the dry-matter basis.

SUMMARY AND CONCLUSIONS

Longtime feeding experiments intended to ascertain the calcium requirements of dairy cattle are reported. Four experiments, somewhat overlapping in period of time, were conducted. The first experiment was started in 1928 and the fourth experiment was concluded in 1947. A total of 51 animals were used in the 4 experiments.

In the first experiment, 6 Jersey heifers (half sisters), all reared on a ration with alfalfa hay as roughage to first pregnancy, were divided into 2 groups. One group continued on alfalfa hay as a roughage. The other group was changed to U. S. No. 1 timothy hay shortly before calving and to U. S. No. 3 timothy hay after milking for 3 months. In 2 lactations (2×365 days) the alfalfa group produced on the average per cow 6,940 pounds of 5.65 percent milk, whereas the timothy group (low calcium) produced 7,504 pounds of 4.84 percent milk, or 8,651 pounds and 8,444 pounds respectively, of 4-percent fat-corrected milk. In the second lactation the alfalfa-fed cows produced almost exactly the same amount of 4-percent fat-corrected milk as they produced in the first lactation, whereas the timothy-fed cows produced 19 percent more in the second lactation than in the first lactation.

In the second experiment (1933–41) a comparison was made between cows fed U. S. No. 3 timothy hay, using hay as low in calcium content as was currently obtainable and a suitable grain mixture, and cows fed similar hay and the same grain mixture to which was added either 3 or 6 percent of bonemeal as a calcium supplement. In both groups either garden carrots or cod liver oil was fed as a vitamin A supplement because of the low carotene content of the timothy hay. The average calcium content of the hay was about 0.30 percent. The calcium content of the dry matter of the ration without the bonemeal supplement was about 0.25 to 0.27 percent.

The cows in this experiment on the basal ration (low calcium) grew normally and produced as much milk as those fed the bonemeal supplement.

In the third experiment (1938–46) an attempt was made to further restrict the calcium content of the ration by using a grain mixture lower in calcium and hay with a lower calcium content. The quantity of hay fed was for the most part restricted to less than 5 pounds daily. The calcium content of the dry matter of the entire ration was about 0.16 percent. The four Holstein heifers used in the experiment attained a heavier average weight and were higher at the withers at 18 months of age and made a greater gain in body weight during the period from 6 to 18 months of age than similar animals in the second experiment that received approximately 0.32, 0.58, 0.95 percent of calcium in the dry matter of the ration. A Jersey heifer on this same low-calcium ration made a greater gain in body weight, and was just as high at the withers, as a similar heifer that got a bonemeal supplement to the ration, or 4 to 5 times as much calcium. One of the Holstein cows milked through 2 lactations and died after 272 days in her third lactation. In the first 272 days of her third lactation this cow produced more milk than she had produced during the similar period of her first lactation. The animals in this experiment, which were fed a total ration containing only 0.16 percent of calcium on a dry-matter basis, showed no evidence of calcium deficiency during growth or milk production.

In the fourth experiment (1945–47) 4 Holstein and 4 Jersey calves were reared on still smaller amounts of calcium than those in the third experiment by restricting the hay consumption to 2 to 3 pounds daily and feeding a grain mixture that averaged about 0.078 percent of calcium for most of the experiment. The calcium content of the dry matter of the ration was 0.12 to 0.14 percent. The gains in body weight in these animals from 6 to 18 months of age, although not considered quite normal, were as great as for the animals in the second experiment, which received as much timothy hay as they would eat and received from 2 to 3 times as much calcium. The gains in weight of a number of the animals during the period from 21 to 24 months of age were much less satisfactory. All 8 animals showed difficulties at or before the first calving. All of the animals showed a subnormal content of calcium in the blood by or before the end of gestation. Four of the 8 animals died either during late pregnancy or not later than 4 days after calving.

The calcium content of the ration in the fourth experiment (0.12 to 0.14 percent of calcium in the dry matter) appeared adequate for growth of the animals but not for gestation. However, this ration was completely abnormal because of the small allowance of hay. Although the ration in the third experiment was abnormal in that the quantity of hay was restricted, it contained about 0.16 percent of calcium and proved adequate for growth, gestation, and lactation. Thus, the minimal requirement of calcium for animal growth appears to be 0.14 percent for the total ration on a dry basis, and 0.16 percent for gestation and lactation.

The lowest calcium content of timothy hay found was 0.16 percent, whereas the average of the timothy hay fed over a period of nearly 20 years of experimentation was about 0.30 percent.

These experiments confirm somewhat similar experiments at the Michigan and Minnesota Agricultural Experiment Stations, which show that there is no justification for feeding a calcium supplement with rations of (1) grain and timothy hay; (2) grain, timothy hay, and silage; or (3) grain, timothy hay, and pasture.

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