THE UTILIZATION OF CALCIUM AND PHOSPHOROUS BY DAIRY HEIFERS ON PRAIRIE HAY RATIONS

by

HAROLD OSMOND WALES

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INTRODUCTION

That prairie hay is of great importance in furnishing roughage for livestock is shown by the fact that during the five year period, 1930 to 1935, there was produced in Kansas a yearly average of 637,267 tons. This amount is equal to nearly one-half that of the alfalfa produced in the state during the same period, and receipts on the Kansas City hay market indicate that a large portion of it is consumed in Kansas.

Compared with alfalfa, prairie hay is low in protein and is decidedly inferior as a source of calcium and phosphorous. Since dairy cattle usually must depend upon their roughage for calcium, the type of roughage fed is of great importance. Recent work at the Kansas station (1) indicates that when prairie hay is used in the ration of fattening cattle, better results can be obtained if it is supplemented with calcium.

With these points in mind, and especially since very very little experimental work has been done in the testing of prairie hay as a major roughage, it seemed important that such a study be carried on. From this study carried on at the Kansas Agricultural Experiment Station, using prairie hay as the chief roughage in the dairy ration, it was hoped to

answer the following questions: Is it necessary to add a calcium supplement? can grain be used as the source of needed protein and phosphorous? are the vitamin requirements for growth, production and reproduction properly taken care of? and can a positive calcium and phosphorous balance be maintained?

REVIEW OF LITERATURE

The type of roughage used in the ration is an important factor in supplying calcium to the animal. Becker et al (6) state, "Dairy cows depend upon roughages as the principal natural source of calcium, and upon grains and milling by-products for most of the phosphorous. Grasses provide from one-fifth to one-third as much calcium, and about three-fifths as much phosphorous as the legumes under the same conditions." He found that lactating cows depending upon grass forage grown upon low lime soils often deplete their reserve of calcium to such an extent that their bones are weakened and their milk production affected. On the other hand, the work of Huffman and associates (24) and Ellenberger et al (12) indicate that mature cows which are fed for long periods on low calcium rations may readily assimilate enough calcium from such rations to supply what is needed for their milk and in some cases may be storing considerable amounts of this

element in their bodies. Reed and Huffman (33) concluded that a ration consisting of timothy hay, corn silage and grain, with no mineral supplement other than salt, furnished enough calcium and phosphorous for normal growth, good reproduction, and liberal milk production. Extra calcium furnished by alfalfa failed to have any beneficial effect. Cunningham et al (8) found that the lower calcium intake of heifers on low calcium roughage tended to be balanced by a higher percentage of utilization. Reed and Huffman (33) obtained good growth with dairy heifers fed timothy hay with no mineral supplements.

Considerable variation in results have been obtained when feeding rations where prairie hay is the principal roughage. Willard (39) reports that prairie hay of good quality may be more palatable to dairy cattle than alfalfa. Kuhlman and associates (27) have obtained successful results from feeding prairie hay as the only roughage to dairy cows when cottonseed meal was the only concentrate. On the other hand, Jacobson (25) reports very unsatisfactory results from cows fed prairie hay as the only roughage when fed with a ration practically free from vitamin A.

In a study to determine the effect of feeding different amounts of calcium and phosphorous, Henderson and Weakley (17) state "the amount of calcium and phosphorous required in a ration depends largely upon the retention of these elements

by the animal. It is of no use to feed large amounts if they are not retained. No definite results have been obtained as to the percentages of these elements which are retained in the body. It is now known that this depends upon several factors."

That the ratio between the amount of calcium and phosphorous in a ration is important has been shown by several workers. McCollum et al (30) found in the rat that changes in the calcium-phosphorous ratio caused disturbances in the deposition of lime salts in cartilage and bone. He concluded "It would seem that in so far as calcium and phosphorous are concerned, the proper ratio between the two is of vastly more importance in insuring normal calcification than the absolute amounts of these elements themselves." Gullickson and Eckles (16), however, noticed no ill effects on dairy heifers from feeding rations in which the phosphorous content almost invariably exceeded the calcium content--most of the time by the ratio of two to one.

That farm animals are more apt to suffer from a lack of calcium or phosphorous than from any other minerals except salt is stated by Morrison (29). He says that under present farm conditions animals suffer from a lack of calcium and phosphorous much more often now than previously. He attributes this to two factors: first, the supply of mineral in

the common feeds, especially the roughages, has decreased as the calcium and the phosphorous content of the soil has become less; second, the requirements of farm animals have become greater, as their rates of production have increased due to more efficient breeding and more intensive feeding and management.

Calcium and phosphorous are perhaps the most significant inorganic elements involved in the development of normal skeletal structures, besides their many other physiological functions in the body. While there is no definite knowledge as to the optimum amount of phosphorous required by growing dairy heifers, several investigators have stated what they believed to be the requirements, while other investigators have calculated the amounts retained by these animals. Kellner (26) calculated the amount of phosphorous retained by growing calves to be 8.3 grams daily for the first year. He also states, "The feed should contain two or three times the amount required by the body, or from 16.6 to 24.9 grams daily." Laws and Gilbert (28) reported that a calf contained 1.2 per cent calcium and 0.67 per cent phosphorous. Armsby (4) from Laws and Gilbert's analysis of the ash content of the entire body of farm animals, has computed that cattle retain 8.14 grams of phosphorous daily for the first year. These figures are in accord with Kellner's.

Archibald and co-workers (3) found that dairy heifers can make an average growth on rations supplying 1.8 grams of phosphorous daily per 100 pounds of live weight for the first year, 1.7 grams daily for the second year, and 1.2 grams daily during the third year. They are of the opinion that these amounts are somewhere near the minimum.

Heifers receiving rations low in one or both of these elements seem to make as good growths for a short period of time but over a longer period their growth is less than a group receiving a normal ration which supplies sufficient amounts of these elements. This indicates that heifers have the ability to draw upon their bodies for these elements until they become low enough to show results of the deficiency. Theiler and co-workers (35) found that a ration supplying 2.23 grams of calcium daily was deficient, and that animals from 12 to 18 months of age could withstand this level only from three to six months after which they showed symptoms of mineral deficiency. Henderson and Weakley (17) found that growing dairy heifers when fed a ration low in calcium (0.286%) or low in both calcium (0.331%) and phosphorous (0.298%) grow nearly as well as normally fed heifers for a short period of time, but over a period of two years do not make as good growth as measured by their weight and height at withers. The heifers receiving a ration low in

both calcium and phosphorous not only grew more slowly than the control group, but also developed weak backs and legs. They also showed evidence of their first oestrum period about a month and a half later than the control group. Theiler, Green and duToit (36) found that heifers receiving 5 grams of phosphorous per day responded with fair growth, and those receiving 13 grams per day made good growth.

Theiler and Green (35) and Archibald and Bennett (3) both found that the phosphorous requirements were reduced with age. Huffman and associates (23) suggested the possibility that the phosphorous requirements for growth depend largely upon the rate of growth rather than upon body weight. They also interpret the results of Hogan and Nierman (20) as indicating that the rate of growth is a good criterion for determining the phosphorous requirement for growth. Van Landingham and co-workers (38) found a correlation between both the body weight and height at withers and the phosphorous required to keep the blood phosphorous constant. However, the correlation was much closer and the variation was less in the case of the height at withers. From these results they conclude, that the phsophorous requirement for growth as measured by height at withers, depends to a greater extent upon the rate of skeletal growth than upon gain in body weight.

Meigs, Blatherwick and Cary (31), Robinson and Huffman (34) and others have obtained results on dairy animals indicating that the inorganic phosphorous content of the blood is influenced by the amount of phosphorous in the ration. Theiler and Green (35) reported 5.2 milligrams of inorganic phosphorous per 100 cubic centimeters of blood for heifers receiving a normal ration, while from those on a phosphorous deficient diet they reported values as low as 1.3 milligrams per 100 cubic centimeters of blood. Henderson and Weakley (17) and Eckles et al (11) show that when the phosphorous in the feed is lowered the inorganic phosphorous content of the blood decreases in a relatively short time.

Van Landingham and Henderson (38) as a result of working with dairy heifers state, "The inorganic phosphorous content of the blood is an important index of the severity of the phosphorous deficiency in the ration." He found that a low phosphorous ration will cause an immediate lowering of the phosphorous content of the blood. The rate of lowering depends upon the extent of the deficiency, and there is always a lowering of the inorganic phosphorous content of the blood for a period of several weeks before any physical symptoms become apparent. He found that an average daily intake of 318 grams of phosphorous per 100 pounds of body weight was sufficient to maintain a normal level of inorganic phosphorous in the blood of dairy heifers up to 25 months of age.

Huffman and associates (23) also found an immediate lowering of the inorganic phosphorous content of the blood following a low phosphorous intake, and that a daily intake of 5.7 to 9.9 grams of phosphorous was not sufficient for animals from 3 to 18 months of age. Henderson and Weakley (17) found that rations containing less than 0.20% phosphorous will decrease the amount of inorganic phosphorous in the blood. Also that a ration containing only 0.25% calcium will affect the calcium content of the blood.

Henderson and Weakley (17) state that the growing dairy heifer must depend upon her food supply for her phosphorous, especially when she is receiving sufficient calcium in her feed, whereas, animals have the ability to draw upon their bodies for calcium when their ration is low in this element. It is much easier to affect the inorganic phosphorous content of the blood than the calcium, and when the calcium supply is low enough to affect the blood, the ration is dangerously low in this element. Animals receiving insufficient calcium show slower growth and their general physical condition is depressed.

METHODS

Description of Animals

The original plan called for the use of heifers six months of age at the start of the experiment. Since all

animals had to be of known breeding and free from tuberculosis and Bang's disease, it was impossible to secure sufficient uniform animals of this age. All animals were obtained from Kansas state institutions and several were somewhat over six months of age when received.

The heifers were divided into three groups of six heifers each. Four heifers were started in each group on May 20, 1934, and two more were added to each group on August 7, 1934.

The three groups were balanced as evenly as possible in respect to size, weight and possible future production, based on inheritance. After being divided into groups the heifers in group I were numbered from E35 to E40, group II from E41 to E46 and group III from E47 to E52.

Withdrawals. Heifer E50 reacted to the test for abortion when she was 27 months old. She was immediately withdrawn and sold for slaughter. After calving, E35 was pronounced sterile as a result of a retained placenta. As she was in a run-down condition, with little chance of recovery, she was withdrawn from the experiment on March 21, 1936.

Rations

Group I was fed the basal ration which consisted of prairie hay and a grain mixture of equal parts white corn,

cottonseed meal, bran and one per cent salt. Group II was fed the same basal ration supplemented with forty grams daily of calcium carbonate. Group III in addition to the basal ration was fed silage. In general these rations were selected because they represent feeds commonly used on Kansas farms. The high percentage of cottonseed meal in the grain ration was fed to furnish enough protein to balance the ration. The calcium carbonate was fed to group II to determine the effects of supplementing the prairie hay ration with calcium. The silage was added to the ration fed group III to determine whether or not better results could be obtained when a succulent feed was fed.

Table 1 shows the composition of the various feeds used in the experiment and the periods which the various analyses covered.

The amount of digestible nutrients per hundred pounds of the various feeds used was obtained by using the figure for the average digestibility of American feeding stuffs as given by Henry and Morrison (18) whenever possible; otherwise the digestibility of some closely related feed was used. Since the grain mixture was of equal parts cottonseed meal, white corn, and bran, and the analyses were made of the mixture, the average digestion coefficient for the three feeds was calculated, and from this the digestible nutrients contained in the grain mixture were calculated.

Table 1. Composition of feeds used for the different periods

Feeds	Water	Ash	Protein	Carbohydrates: Crude Fiber	Carbohydrates: N.F.E.	Extract	Calcium	Phosphorous
Used from beginning of experiment to Jan. 1935								
Prairie hay	6.29	7.35	6.81	30.60	46.25	2.70	0.34	0.14
Grain Mixture	10.67	5.44	22.88	6.86	49.15	5.00	0.15	0.89
Silage	68.50	2.30	2.67	8.19	17.43	0.92	0.09	0.07
Calcium carbonate							39.05	
Used from Jan. 1935 to Oct. 1935								
Prairie hay	6.35	6.65	5.88	28.99	50.25	1.88	0.32	0.10
Grain mixture	9.28	4.93	20.75	7.44	53.69	3.91	0.15	0.71
Silage	73.20	2.72	3.56	7.34	12.59	5.87	0.13	0.07
Calcium carbonate							39.05	
Used from Oct. 1935 to April 1936								
Prairie hay	8.51	7.28	5.25	28.65	48.08	2.23	0.42	0.10
Grain mixture	10.12	5.14	22.25	7.79	50.13	4.57	0.14	0.76
Silage	70.30	2.66	4.09	8.35	13.94	6.60	0.18	0.10
Calcium carbonate							39.05	
Used since April 1936								
Prairie hay	7.69	6.52	5.25	32.83	45.60	2.11	0.47	0.12
Grain mixture	9.47	5.08	24.88	8.38	48.03	4.26	0.14	0.80
Silage	70.70	2.30	2.65	8.52	15.35	6.54	0.11	0.05
Calcium carbonate							39.05	

The rations fed were rather high in phosphorous in proportion to calcium. This was due partly to the fact that prairie hay is low in calcium, and that the grain mixture contained considerable amounts of cottonseed meal and bran, both of which are high in phosphorous.

Feed Analysis. Analyses of the individual grains were not made, but at approximately six month intervals composite samples of the grain mixture fed were analyzed. The first sample for analysis was taken from the delivery chute of the feed mixer at the time of mixing the first batch of feed. Representative samples from later mixtures were composited for analyses. A representative silage sample was taken for analysis at the outset. Thereafter at the end of each month, samples were secured, air dried, and analyzed on the air dry basis. Composite samples of hay for analysis were taken over approximately six month periods.

The data secured from the analyses of the feeds included moisture, protein, ether extract, crude fiber, ash, nitrogen-free extract, calcium and phosphorous.

Management

All of the heifers were fed in the college experimental dairy barn, in individual mangers where they had access to salt in block form. Except while being fed and during extremely cold weather they were turned out in a vegetation-

free corral, where they had free access to water.

Bedding. To avoid the consumption of any nutrients other than that from the feed, the stalls were bedded with shavings.

Photographing. The animals were all photographed when they started on the experiment and at six month intervals until they were about 24 months of age.

Weighing and Measuring. The animals were weighed on three consecutive days at the end of each month, and the average of these three weights taken for the weight at the end of the period. On one of the weighing days they were also measured for height at withers.

Breeding. It was planned to breed the heifers so that they would freshen when they were about 26 months of age, however, due to difficulty in getting the heifers bred, their age of calving varied from 24 to 31 months.

Adjusting the Ration. At the beginning of each month the ration for each heifer was adjusted to her weight according to the Morrison feeding standard.

Blood Analysis. It was planned to run calcium and inorganic phosphorous analyses on the blood serum at monthly intervals until the heifers were 24 months of age, after which they were to be determined every three months. Due to the destruction, by fire, of the chemical analysis laboratory

there was a three month interval at the start of the experiment when analyses were not made.

EXPERIMENTAL RESULTS

Discussion of the Rations Fed

Amounts of Digestible Crude Protein and Total Digestible Nutrients. The average amount of digestible protein and of total digestible nutrients consumed by each group is shown in tables 2, 3 and 4. These tables are divided into monthly intervals and include the average requirements for normal growth of dairy heifers.

Tables 2, 3 and 4 show that there were some variations among the groups in nutrients consumed, but the differences are only slight and are thought to carry little significance. Groups I and II received slightly more digestible crude protein but less total digestible nutrients than group III. It will be noted that the average consumption of total digestible nutrients was slightly below the requirements for growing heifers, but the digestible crude protein was in most cases above the Morrison requirements. Since the protein was above the requirements it seems that the nutrients consumed should be sufficient for approximately normal growth.

Table 2. Average daily consumption of digestible crude protein and total digestible nutrients and average growth requirements of the animals according to the Morrison Standard. Group I.

Age of Animals	Average Weight	DCP consumed daily	DCP consumed per 100 lbs. live weight	TDN consumed daily	TDN consumed per 100 lbs. live weight	Average requirements Morrison Standard DCP	Average requirements Morrison Standard TDN
months	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
9	502.8	1.194	.238	7.123	1.417	1.000	5.575
10	558.4	1.215	.218	7.294	1.306	1.045	8.140
11	598.8	1.244	.208	7.405	1.237	1.110	8.640
12	632.0	1.230	.195	7.524	1.191	1.170	9.100
13	669.0	1.256	.188	7.827	1.170	1.170	9.100
14	697.7	1.240	.178	8.126	1.165	1.225	9.520
15	719.3	1.240	.172	8.421	1.171	1.225	9.520
16	741.8	1.238	.167	8.597	1.159	1.275	9.900
17	776.5	1.250	.161	8.890	1.145	1.275	9.900
18	798.5	1.285	.161	9.108	1.141	1.320	10.240
19	818.2	1.320	.161	9.386	1.147	1.320	10.240
20	840.7	1.365	.162	9.958	1.184	1.335	10.540
21	868.5	1.413	.163	10.454	1.204	1.350	10.800
22	910.2	1.451	.159	10.496	1.153	1.350	10.800
23	944.7	1.462	.155	10.485	1.110	1.365	11.020
24	979.0	1.459	.149	10.918	1.115	1.370	11.200

Table 3. Average daily consumption of digestible crude protein and total digestible nutrients and average growth requirements of the animals according to the Morrison Standard. Group II.

Age of Animals	Average Weight	DCP consumed daily	DCP consumed per 100 lbs. live weight	TDN consumed daily	TDN consumed per 100 lbs. live weight	Average requirements Morrison Standard	
						DCP	TDN
months	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
9	501.8	1.192	.238	6.930	1.381	1.000	5.575
10	546.0	1.183	.217	7.127	1.305	1.045	8.140
11	592.7	1.205	.203	7.237	1.221	1.110	8.640
12	612.5	1.203	.196	7.518	1.227	1.110	8.640
13	661.3	1.233	.186	7.862	1.189	1.170	9.100
14	693.2	1.235	.178	8.066	1.163	1.225	9.520
15	727.7	1.232	.169	8.304	1.141	1.275	9.900
16	753.7	1.230	.163	8.509	1.129	1.275	9.900
17	780.5	1.252	.160	8.825	1.131	1.320	10.240
18	804.6	1.281	.159	9.010	1.120	1.320	10.240
19	829.8	1.316	.159	9.329	1.124	1.335	10.540
20	860.0	1.387	.152	9.896	1.151	1.335	10.540
21	905.3	1.391	.146	10.019	1.107	1.350	10.800
22	937.3	1.427	.152	10.226	1.091	1.365	11.020
23	970.5	1.440	.148	10.422	1.074	1.370	11.200
24	1005.0	1.523	.152	11.252	1.120	1.370	11.200

Table 4. Average daily consumption of digestible crude protein and total digestible nutrients and average growth requirements of the animals according to the Morrison Standard. - Group III.

Age of Animals	Average Weight	DCP consumed daily	DCP consumed per 100 lbs. live weight	TDN consumed daily	TDN consumed per 100 lbs. live weight	Average requirements Morrison Standard DCP	Average requirements Morrison Standard TDN
months	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
9	516.3	1.090	.211	7.072	1.370	1.000	7.575
10	566.0	1.100	.194	7.309	1.291	1.045	8.140
11	613.0	1.139	.186	7.538	1.230	1.110	8.640
12	659.6	1.143	.173	8.022	1.216	1.170	9.100
13	697.3	1.192	.171	8.401	1.205	1.225	9.520
14	724.9	1.228	.169	8.943	1.234	1.225	9.520
15	753.5	1.214	.161	9.299	1.265	1.275	9.900
16	783.0	1.229	.157	9.682	1.237	1.320	10.240
17	806.0	1.226	.152	9.839	1.221	1.320	10.240
18	828.0	1.278	.154	10.078	1.217	1.335	10.540
19	852.7	1.223	.143	10.207	1.197	1.335	10.540
20	884.0	1.313	.148	10.426	1.179	1.350	10.800
21	918.2	1.338	.146	10.472	1.140	1.350	10.800
22	952.8	1.388	.146	10.648	1.118	1.365	11.020
23	995.2	1.434	.144	10.803	1.086	1.370	11.200
24	1037.5	1.479	.143	10.901	1.051	1.370	11.200

Amounts of Calcium and Phosphorous Fed. The average amount of calcium and phosphorous consumed by the heifers in each group per day, and the amount consumed per 100 pounds of live weight is shown in tables 5, 6 and 7.

Tables 5, 6 and 7 show that the heifers during the early part of the experiment received a relatively large amount of phosphorous in proportion to calcium. This was due largely to a lower consumption of roughage in proportion to grain. The amount of phosphorous consumed per 100 pounds body weight by each of the three groups was nearly the same. Groups I and III were similar in calcium intake, but were much lower than group II, which received the calcium carbonate supplement. The amount of calcium and of phosphorous received by groups I and III was nearly the same but they were on a much lower level of calcium than was group II.

Figure 1 shows the higher proportions of phosphorous to calcium early as compared with later in the experiment. The especially large proportion of phosphorous to calcium will be noted in groups I and III.

Calcium and Phosphorous Ratio. A number of workers maintain that the ratio between calcium and phosphorous in the ration is important. Hoag and Palmer (19) working with rats obtained results which indicated that a more or less balanced condition of calcium, magnesium and phosphorous in

Table 5. The average daily consumption of calcium and phosphorous and the calcium-phosphorous ratio. Group I.

Age of Animals	Average Weight	Calcium consumed daily	Calcium consumed per 100 lbs. live weight	Phosphorous consumed daily	Phosphorous consumed per 100 lbs. live weight	Calcium-phosphorous ratio
months	lbs.	grams	grams	grams	grams	
9	502.8	14.645	2.913	25.457	5.063	0.58 : 1
10	558.4	14.973	2.681	26.088	4.672	0.57 : 1
11	598.8	14.988	2.503	26.605	4.443	0.56 : 1
12	632.0	15.411	2.438	24.768	3.919	0.62 : 1
13	669.0	16.220	2.425	26.359	3.940	0.62 : 1
14	697.7	16.950	2.429	24.897	3.568	0.68 : 1
15	719.3	16.863	2.344	23.415	3.255	0.72 : 1
16	741.8	17.891	2.412	23.731	3.199	0.75 : 1
17	776.5	18.419	2.372	23.100	2.975	0.80 : 1
18	798.5	18.905	2.368	23.716	2.970	0.80 : 1
19	818.2	19.644	2.401	24.489	2.993	0.80 : 1
20	840.7	20.864	2.482	26.202	3.117	0.80 : 1
21	868.5	24.438	2.802	26.548	3.057	0.92 : 1
22	910.2	23.808	2.616	27.108	2.978	0.88 : 1
23	944.7	25.470	2.696	26.896	2.847	0.95 : 1
24	979.0	29.860	3.050	27.066	2.765	1.14 : 1

Table 6. The average daily consumption of calcium and phosphorous and the calcium-phosphorous ratio. Group II.

Age of Animals	Average Weight	Calcium consumed daily	Calcium consumed per 100 lbs. live weight	Phosphorous consumed daily	Phosphorous consumed per 100 lbs. live weight	Calcium-phosphorous ratio
months	lbs.	grams	grams	grams	grams	
9	501.8	29.628	5.904	25.455	5.073	1.16 : 1
10	546.0	30.089	5.511	25.442	4.660	1.18 : 1
11	592.7	30.619	5.166	25.778	4.349	1.19 : 1
12	612.5	31.021	5.065	24.662	4.026	1.26 : 1
13	661.3	32.013	4.841	25.184	3.808	1.37 : 1
14	693.2	32.446	4.681	24.470	3.530	1.33 : 1
15	727.7	32.948	4.528	26.089	3.585	1.36 : 1
16	753.7	33.235	4.410	23.276	3.088	1.43 : 1
17	780.5	33.747	4.324	23.008	2.948	1.48 : 1
18	804.6	34.257	4.258	23.560	2.928	1.45 : 1
19	829.8	35.036	4.222	26.176	3.154	1.34 : 1
20	860.0	36.291	4.220	25.287	2.940	1.44 : 1
21	905.3	38.995	4.307	25.703	2.839	1.52 : 1
22	937.3	39.831	4.250	26.436	2.820	1.51 : 1
23	970.5	41.038	4.229	26.594	2.740	1.54 : 1
24	1005.0	43.706	4.349	28.475	2.833	1.54 : 1

Table 7. The average daily consumption of calcium and phosphorous and the calcium-phosphorous ratio. Group III.

Age of Animals	Average Weight	Calcium consumed daily	Calcium consumed per 100 lbs. live weight	Phosphorous consumed daily	Phosphorous consumed per 100 lbs. live weight	Calcium-phosphorous ratio
months	lbs.	grams	grams	grams	grams	
9	516.3	14.368	2.781	23.196	4.493	0.62 : 1
10	566.0	14.985	2.648	23.716	4.190	0.63 : 1
11	613.0	15.716	2.564	24.369	3.975	0.65 : 1
12	659.6	16.625	2.520	24.955	3.783	0.67 : 1
13	697.3	17.825	2.556	24.922	3.574	0.72 : 1
14	724.9	19.095	2.634	24.114	3.327	0.79 : 1
15	753.5	20.154	2.675	22.838	3.031	0.88 : 1
16	783.0	20.760	2.651	22.478	2.871	0.92 : 1
17	806.0	21.166	2.626	22.467	2.871	0.91 : 1
18	828.0	21.642	2.614	22.988	2.776	0.94 : 1
19	852.7	22.250	2.609	23.348	2.738	0.95 : 1
20	884.0	22.490	2.544	23.766	2.688	0.95 : 1
21	918.2	24.236	2.640	24.243	2.640	1.00 : 1
22	952.8	26.310	2.761	25.030	2.627	1.05 : 1
23	995.2	28.192	2.833	26.901	2.703	1.05 : 1
24	1037.5	31.359	3.023	28.270	2.728	1.11 : 1

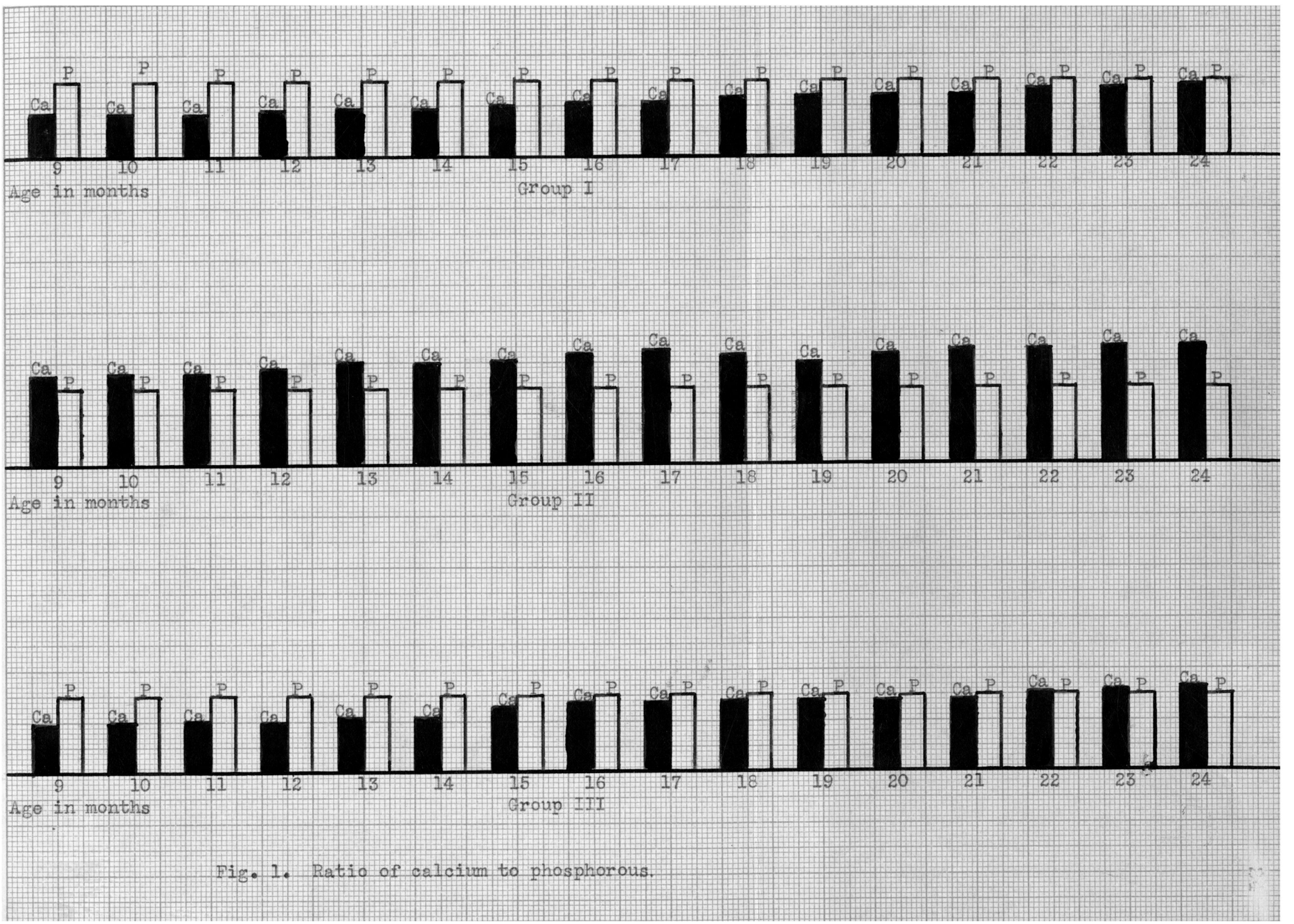

Fig. 1. Ratio of calcium to phosphorous.

the ration is essential for normal growth and body functions. Meigs and co-workers (31) working with lactating cows, concluded that phosphorous assimilation may be interfered with by an excess of calcium in the ration, and that two parts or more by weight to one part of phosphorous constituted an excess. On the other hand Gullickson and Eckles (16) noticed no ill effects from feeding rations to growing heifers in which the phosphorous content almost invariably exceeded the calcium content by nearly two to one. Theiler and associates (37) state, "When calcium is low it is probable that a relatively high proportion of phosphorous may facilitate the absorption of calcium and thus reduce the risk of calcium starvation. When phosphorous is low, a relatively high calcium intake may reduce the absorption of phosphorous and in this way increase the danger of aphosphorosis." From the foregoing work one would conclude that the large amounts of phosphorous in proportion to the calcium received by the heifers would have little detrimental effect.

Influence of Vitamin A and D. That vitamin D plays a specific part in the assimilation of calcium and phosphorous has been shown by several workers. The work of Huffman (22) indicates that the vitamin D requirement of calves is greater than has been formerly believed. Results of this experiment show that calves fed a rachitic ration and kept away from the

sun develop rickets, while calves on the same ration but exposed to sunlight do not. Bechdel and co-workers (5) investigated the necessity of vitamin D in the ration of growing calves. They reported that calves kept in a dark stall develop rickets when fed a ration low in vitamin D. They noted that two and one-half pounds of sun-cured alfalfa prevented or cured rickets. Huffman (22) found that calves fed a rachitic ration grew normally when exposed to sunlight, and two pounds of timothy hay daily fed to calves in dark stalls prevented rickets.

Since the heifers in this experiment were allowed to run in an open corral, and received sun-cured hay, it was thought that they received sufficient vitamin D and no attempt to control this factor was made.

Since December 1935, the feeds have all been analyzed for carotene. An average daily ration was found to contain from 145 to 150 milligrams of beta carotene. This was considerable more carotene than other workers have found to be the minimum requirements for growing dairy heifers. Guilbert and Hart (15) found that the minimum carotene requirement of growing dairy heifers to be from 26 to 33 micrograms per killogram of body weight.

Table 8. Average gain in weight and height at withers of Group I, also given in per cent of the Kansas and the Morrison normal.

Age of Animals	Body Weight	Per cent of normal		Height at withers	Per cent of normal	
		Kansas	Morrison		Kansas	Morrison
mos.	lbs.			cms.		
9	502.8	100.8	97.5	110.6	99.4	99.9
10	558.5	102.3	98.3	113.0	100.2	99.8
11	598.8	101.6	98.1	117.0	101.7	101.4
12	632.0	100.5	96.8	118.2	101.2	100.8
13	669.0	99.7	97.1	120.0	100.9	100.7
14	697.7	98.8	96.2	122.0	101.1	101.0
15	719.3	96.4	94.6	124.0	101.0	101.3
16	741.8	94.7	93.3	125.0	100.8	100.8
17	776.5	95.1	93.8	126.7	101.4	101.2
18	798.5	93.7	92.7	126.5	100.6	100.4
19	818.2	91.5	91.4	128.0	100.4	100.8
20	840.7	90.9	90.6	128.5	100.1	100.0
21	868.5	90.7	90.2	129.0	99.7	99.7
22	910.2	91.7	91.1	130.0	99.8	99.8
23	944.7	92.0	92.9	131.0	100.0	99.5
24	979.0	90.9	91.0	131.5	99.8	99.8

Table 9. Average gain in weight and height at withers of Group II, also given in per cent of the Kansas and the Morrison normal.

Age of Animals	Body weight	Per cent of normal		Height at withers	Per cent of normal	
		Kansas	Morrison		Kansas	Morrison
mos.	lbs.			cms.		
9	501.8	100.6	96.3	110.0	100.0	99.2
10	546.0	100.0	96.1	113.7	100.9	100.4
11	592.7	100.5	97.1	116.0	100.8	100.5
12	612.5	97.4	93.8	118.5	101.5	101.0
13	661.3	98.5	95.9	119.0	100.1	100.0
14	693.2	98.1	95.6	121.0	100.2	100.1
15	727.7	97.5	95.8	123.0	100.2	100.5
16	753.7	96.2	94.7	124.5	100.6	100.6
17	780.5	95.6	94.3	125.6	100.6	100.4
18	804.6	94.5	93.4	126.3	100.2	100.0
19	829.8	92.8	92.6	127.5	100.0	100.2
20	860.0	93.0	92.7	128.0	99.7	99.6
21	905.3	94.5	94.0	129.0	99.7	99.7
22	937.3	94.4	93.8	130.0	99.8	99.8
23	995.2	96.9	97.8	130.5	99.5	99.2
24	1005.0	93.3	93.4	131.1	99.7	99.7

Table 10. Average gain in weight and height at withers of Group III, also given in per cent of the Kansas and the Morrison normal.

Age of Animals	Body weight	Per cent of normal		Height at withers	Per cent of normal	
		Kansas	Morrison		Kansas	Morrison
mos.	lbs.			cms.		
9	516.3	103.5	99.1	110.7	100.6	99.9
10	566.0	103.7	99.6	113.1	100.4	99.9
11	613.0	104.0	100.4	116.0	100.8	100.5
12	659.6	104.8	101.0	118.4	101.4	101.0
13	697.3	103.9	101.2	120.0	100.9	100.7
14	724.9	102.6	100.0	122.0	101.1	101.0
15	753.5	100.9	99.1	124.0	101.1	101.4
16	783.0	100.0	98.5	125.5	101.2	101.2
17	806.0	98.7	97.3	126.7	101.4	101.2
18	828.3	97.3	96.2	127.8	101.4	101.2
19	852.7	95.3	95.2	128.4	100.7	100.9
20	884.0	95.6	95.3	128.5	100.1	100.0
21	918.2	95.9	95.3	130.0	100.5	100.5
22	952.8	96.0	95.4	130.2	100.0	100.0
23	995.2	96.9	97.8	130.5	99.5	99.2
24	1037.5	96.3	96.5	132.2	100.5	100.5

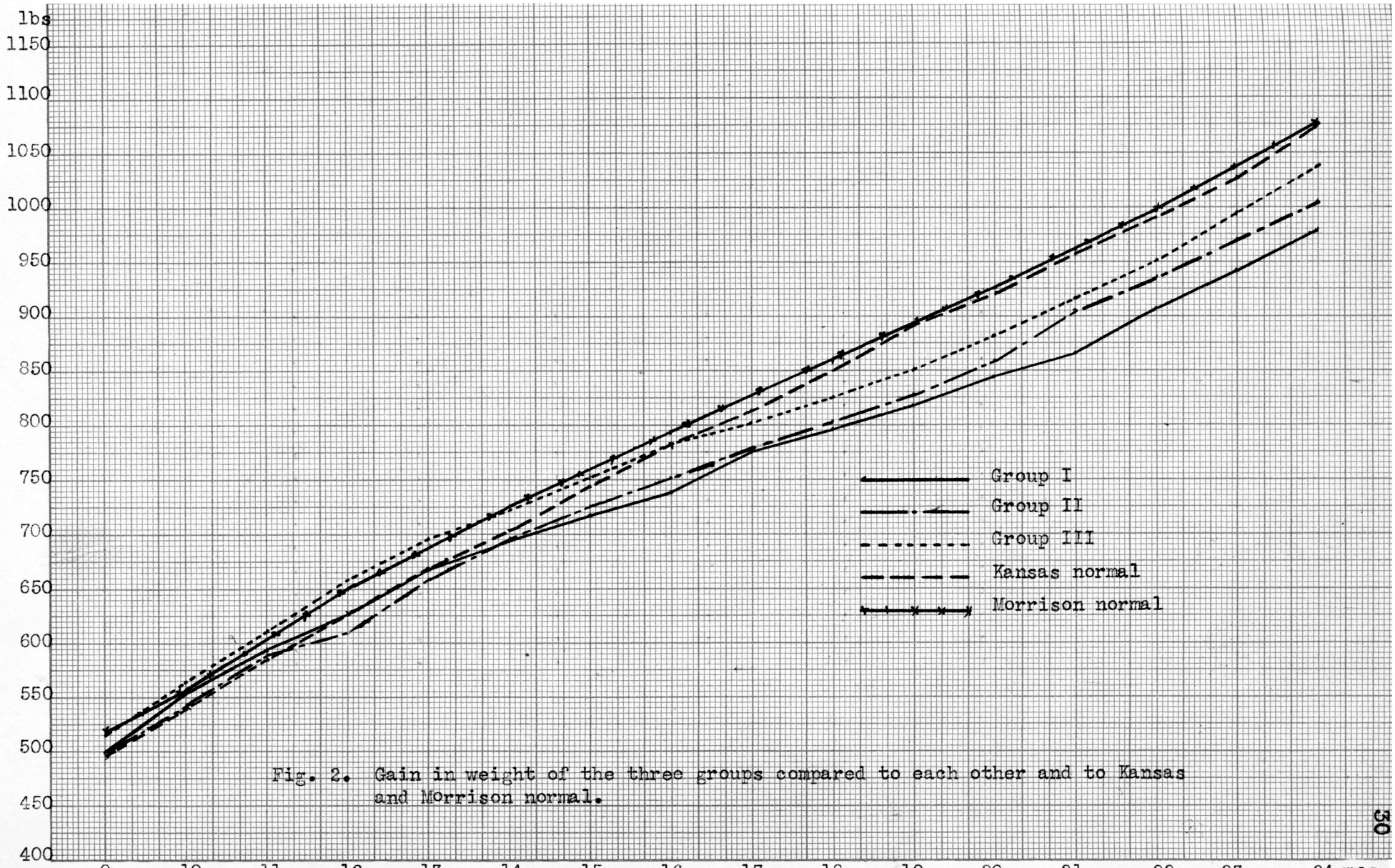

Fig. 2. Gain in weight of the three groups compared to each other and to Kansas and Morrison normal.

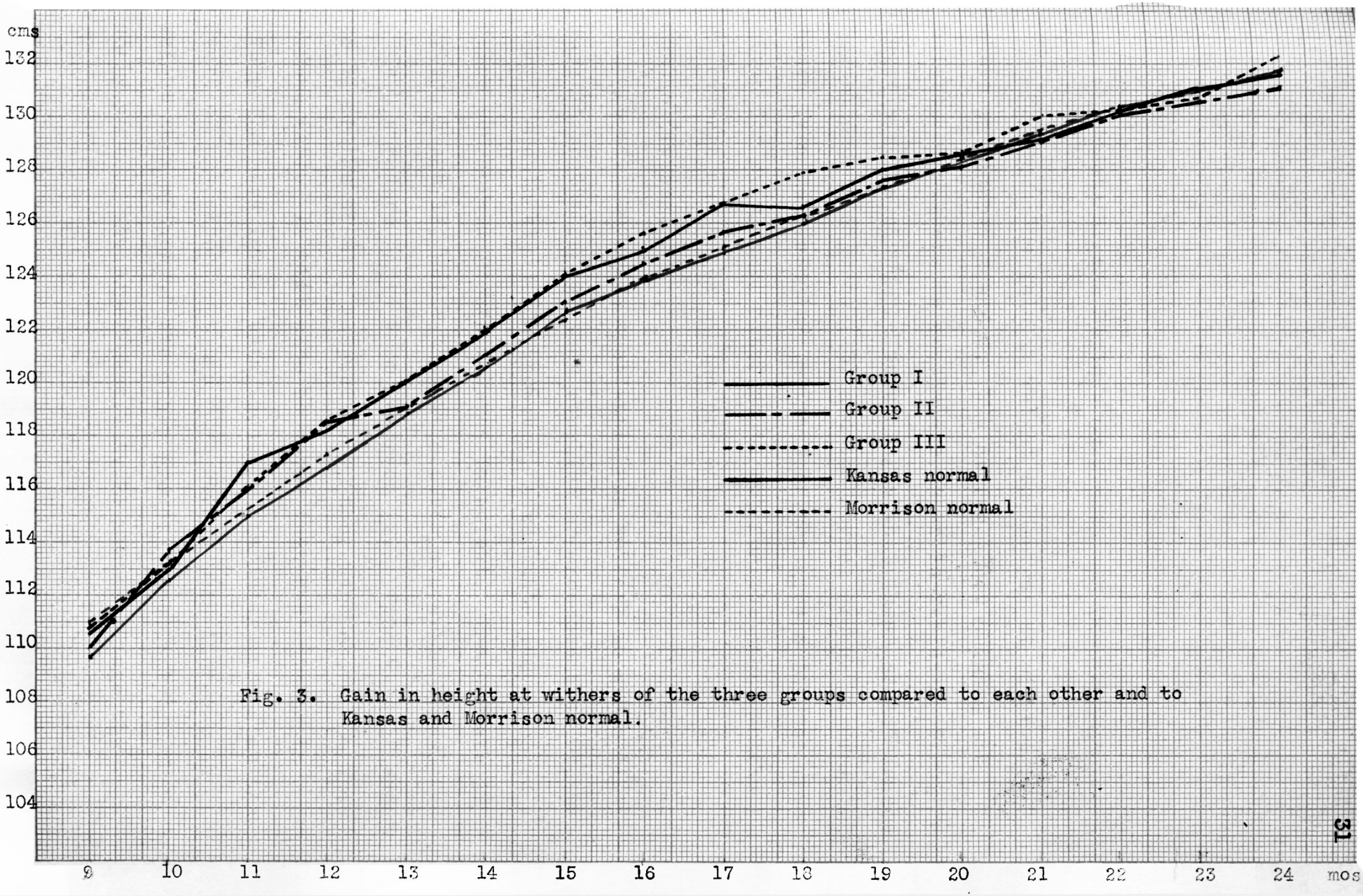

Fig. 3. Gain in height at withers of the three groups compared to each other and to Kansas and Morrison normal.

Effects of the Rations on Growth and Development

Growth. The gain in weight and height at withers is shown in figures 2 and 3. The average body weights and heights at withers by months are shown in tables 8, 9 and 10. There also is shown the percentages that these are of Kansas Normal Growth figures (13) and the normal growth figures taken from Morrison (29). The Morrison growth figures were given for only every other month but for the other months, an average was taken of the preceding and the following months figures.

It will be noted that until the heifers in group III were 14 months of age they equalled or exceeded both of the normal growth standards; however, after this they dropped below the normal growth figures in weight. The heifers in groups I and II, while they were never above the normal growth standard taken from Morrison (29), from 9 to 12 and 9 to 11 months of age, respectively, they were above the Kansas normal (13). It will also be noted that the animals in group III were larger than those in the other groups at the start of the experiment and also showed more increase in weight than either of the other groups, especially in the early part of the experiment. At 24 months of age the animals in group III were 58 pounds heavier than those in group I, and 32 pounds heavier than those in group II.

The animals in group I failed by nearly a hundred pounds to reach the weight of either the Kansas normal or the normal given by Morrison (29). After 20 months of age, they were also slightly below these normals in height at withers.

Discussion of Growth. Since the animals in group I received the same ration except for calcium supplement as those in group II, it would seem that the faster growth in group II might have been due to the higher calcium content of their ration. However, the difference in average gain is so slight that it has very little significance. Although groups I and II were of the same average weight at 9 months, there was a 26 pounds spread at 24 months of age.

The animals in group III were about 58 pounds heavier than group I at 24 months of age, but all of this difference cannot be accounted for by growth as they were larger at 9 months of age when the experiment started. The larger gains of group III over group I must be due to the fact that part of the prairie hay was replaced by silage. It was probably due to the variety, and to the succulence of the ration.

Since the intake of calcium by the different groups was not in proportion to the gains made by the animals in these groups, the intake of these minerals probably does not account for the differences in gains in weight. There was very little difference in the gain made by groups I and II,

From indications of previous work (3) (26) (38) there appeared to be enough phosphorous in all rations.

As the heifers in group III more nearly reached normal weight than groups I or II, it would seem that the addition of silage to the ration of prairie hay improved its value. However, the fact that they failed to maintain entirely normal growth although they started out above the normal growth figures, it would seem that even when the silage was added there was still some deficiency in the ration.

The fact that most of the animals were about normal in height at withers may be accounted for by the fact that several workers have found that animals will still gain in height at withers under adverse conditions of nutrition. Eckles (10) found that deficient rations fed to growing heifers restricted gain in weight more than height at withers. This same result was obtained by Davis and co-workers (9).

Physical Abnormalities. All animals developed normally as far as physical appearance was concerned. While there were differences in appearance, they were no more than could be attributed to individuality.

Abnormal Cravings. The heifers were observed chewing wood from time to time, but there was no noted difference in this respect among the three groups. This abnormal craving was only slight and no nutritional significance could be attached to it.

Effects of the Rations on the Calcium and Phosphorous Content of the Blood

Since many workers report changes in the chemical composition of cow's blood, especially in phosphorous, analyses of the bolld for inorganic phosphorous and calcium content were made from time to time as a check on the utilization of the minerals. The hemoglobin of the blood was also run as an indication of the health and thrift of the animals.

Henderson and Weakley (17) show that when the phosphorous in the feed is lowered, a decrease in the inorganic phosphorous content of the blood shows up in a relatively short time. Meigs and co-workers (31) report the concentration of calcium in the plasma of cow's blood to be fairly constant. Palmer and Eckles (32) obtained normal calcium values when the inorganic phosphorous was low.

Henderson and Weakley (17) reported a heifer on a calcium and phosphorous deficient diet as having shown a low calcium content in her blood shortly before showing signs of nervousness, convulsions and bent legs. However, they found that as a rule rations low in calcium had very little effect on the calcium content of the blood. Greaves et al (14) say that with sufficient information on the optimum inorganic phosphorous content of the blood under varying conditions it

appears probable that the blood analysis may be used to discover those animals which are on a phosphorous deficient diet.

Samples of blood were taken from the jugular vein of the animals the first month of the experiment and again the fifth month, after which they were taken at monthly intervals until the twenty-first month and every three months thereafter. Due to this fact and to the fact that there was quite a variation in the ages of the animals the data are not, in every instance, complete for each month.

Table 11, 12 and 13 show the calcium and inorganic phosphorous content of the blood of each animal, also the average for each group by monthly periods, whenever possible.

Meigs et al (31) found the calcium in the serum of normal calves to be about 10 milligrams per 100 cubic centimeters with variations from 9.1 milligrams to 13.7 milligrams. The inorganic phosphorous in the serum was found to average 6.5 to 7 milligrams per 100 c.c., with variations from 5.6 to 9.2 milligrams. Van Landingham and Harrison (38) report as low as 6.31 milligrams of calcium and 6.2 milligrams of inorganic phosphorous per 100 cubic centimeters of whole blood in normally fed animals. The blood from a group of six normally fed heifers in the Kansas State college dairy herd, receiving the herd ration, varied from 6.3 to 8.9 milligrams of phosphorous and from 9.4 to 11.9 milligrams of calcium

Table 11. Calcium and inorganic phosphorous content of the blood from heifers in Group I.

Age	E 35		E 36		E 37		E 38		E 39		E 40		Average	
	Ca.	Phos.	Ca.	Phos.	Ca.	Phos.	Ca.	Phos.	Ca.	Phos.	Ca.	Phos.	Ca.	Phos.
mos.														
9	10.6	8.2							10.8	9.5	10.1	8.8	10.2	8.8
10							8.9	7.2	10.6	8.5	11.0	8.3	10.2	8.0
11			9.3	8.4	9.0	7.8	11.0	8.7	11.5	8.3	11.3	7.9	10.0	8.2
12			11.0	8.1	10.4	9.7	11.4	8.3	11.2	7.1	11.0	8.7	10.1	8.4
13	9.5	7.5	10.8	6.9	10.7	7.9	11.8	7.8	11.1	7.2	10.4	8.5	10.7	7.6
14	10.4	7.6	11.1	7.1	10.6	7.9	10.7	7.4	11.2	6.9	11.0	8.4	10.8	7.6
15	11.3	8.3	10.8	7.1	10.3	7.8	10.7	8.1	11.5	6.7	11.3	8.6	11.0	7.8
16	11.9	6.2	10.0	7.4	9.7	8.8	11.2	8.3	11.1	6.7	10.7	7.5	10.8	7.5
17	11.3	6.4	10.5	7.9	10.9	6.7	10.9	7.5	9.9	7.8	9.8	9.0	10.6	7.6
18	11.2	6.3	10.6	7.4	6.7	6.0	10.8	7.2	10.8	6.8	10.4	7.4	10.1	6.9
19	11.6	7.3	10.8	6.8	10.2	8.0	9.7	8.8	10.5	7.2	10.5	8.5	10.6	7.8
20	11.5	6.9	9.8	8.3	9.8	9.0	10.0	7.7	10.9	6.4	10.4	7.9	10.2	7.7
21	11.3	6.6	10.4	7.5	10.0	8.3	10.2	8.8	10.6	8.1	10.1	8.4	10.4	7.9
22	10.0	7.0	10.7	7.0	9.7	8.4	9.7	8.4					10.0	7.7
23	10.7	5.8	10.6	6.8	9.6	8.8	10.3	8.5					10.3	7.5
24	10.7	7.1	10.6	9.4	9.3	9.0			8.9	7.4	8.5	7.1	9.6	8.0

Table 12. Calcium and inorganic phosphorous content of the blood from heifers in Group II.

Age	E 41		E 42		E 43		E 44		E 45		E 46		Average	
mos.	Ca.	Phos.	Ca.	Phos.	Ca.	Phos.	Ca.	Phos.	Ca.	Phos.	Ca.	Phos.	Ca.	Phos.
9	9.1	8.1							9.6	9.3	10.1	8.1	9.6	8.2
10							10.6	7.5	10.3	8.6	10.9	9.3	10.6	8.2
11					9.1	7.3	10.1	8.5	11.3	8.8	11.2	9.0	10.4	8.2
12			9.2	7.3	10.3	9.2	10.7	7.5	10.1	9.1	10.7	8.4	10.2	8.3
13	8.9	7.3	10.5	8.9	10.5	7.7	11.7	7.5	10.6	8.8	10.0	9.7	10.4	8.3
14	10.2	9.5	10.5	8.3	11.4	7.6	10.8	7.6	11.2	7.5	10.2	7.9	10.7	8.2
15	10.3	7.6	11.1	7.0	10.3	7.8	10.4	9.1	11.0	7.5	10.3	7.7	10.6	7.8
16	10.9	7.5	10.0	8.5	10.0	7.5	10.4	8.1	11.1	7.1	10.4	7.3	10.5	7.7
17	10.2	7.7	10.0	8.4	10.5	7.9	10.7	7.7	10.4	7.4	9.2	7.7	10.2	7.8
18	9.8	8.7	10.0	7.4	10.7	6.6	10.7	7.9	10.8	7.3	9.6	7.1	10.3	7.5
19	9.9	8.0	10.6	8.1	10.2	6.4	10.2	7.3	10.9	7.5	10.8	7.7	10.4	7.5
20	10.6	6.8	10.2	7.8	10.0	8.4	10.9	7.8	11.0	6.6	10.4	6.9	10.5	7.4
21	9.9	7.7	9.9	8.6	10.6	7.4	10.9	7.9	10.3	7.4	10.1	9.3	10.3	8.0
22	9.8	8.4	10.2	7.1	9.8	7.6	10.6	6.8					10.1	7.5
23	9.8	6.3	10.1	8.3	9.7	7.8	10.4	8.5					10.0	7.7
24	9.7	7.5	10.2	7.5	9.4	7.1			9.0	5.0	9.4	6.7	9.6	6.6

Table 13. Calcium and inorganic phosphorous content of the blood from heifers in Group III.

Age	E 47		E 48		E 49		E 50		E 51		E 52		Average	
	Ca.	Phos.	Ca.	Phos.	Ca.	Phos.	Ca.	Phos.	Ca.	Phos.	Ca.	Phos.	Ca.	Phos.
mos.														
9									10.1	8.2	9.6	7.2	9.9	7.7
10							9.7	8.8	10.7	8.4	9.8	9.1	10.1	8.8
11	10.2	8.5	10.0	7.5			9.6	9.2	11.2	7.9	10.3	9.8	10.2	8.6
12	10.0	9.4	10.0	9.0	10.4	7.8	10.5	9.3	10.2	8.0	10.9	8.9	10.3	8.7
13	10.7	7.9	10.0	8.0	9.9	9.2	11.1	8.5	10.0	9.2	9.8	9.3	10.3	8.7
14	10.9	7.5	11.4	5.6	9.9	8.5	10.1	9.2	10.3	7.6	9.9	10.2	10.4	8.1
15	10.3	8.0	10.3	8.4	10.9	7.9	10.1	10.0	10.6	7.6	10.3	8.6	10.4	8.4
16	10.3	8.7	10.6	8.4	10.6	8.1	10.0	8.8	10.4	6.9	10.7	9.8	10.4	8.4
17	10.3	8.1	10.1	7.6	10.2	8.2	10.1	8.1	10.2	8.0	10.4	8.1	10.2	8.0
18	10.7	6.5	10.3	8.4	10.0	7.6	10.0	7.8	10.2	7.1	9.7	9.2	10.2	7.8
19	10.0	7.3	9.8	7.4	10.8	7.9	9.4	9.1	9.8	7.6	10.2	8.6	10.0	8.0
20	9.3	7.5	9.7	7.7	10.5	6.9	9.5	8.4	11.3	7.8	9.6	8.6	10.0	7.8
21	9.8	6.9	10.1	6.7	9.9	8.2	9.9	8.9	10.8	6.1	10.4	8.9	10.1	7.6
22	10.5	7.1	10.0	9.1	9.4	8.1	9.7	8.9			10.6	8.6	10.0	8.4
23	10.0	6.9	9.9	8.4	10.3	7.5	10.1	8.9					10.1	7.9
24	10.1	8.4	10.4	7.8	10.1	7.5			9.9	6.3			10.1	7.5

per 100 c.c. of blood serum. From these results it will be noted that the blood from the heifers on this experiment seemed normal in all cases.

Effects of the Ration on Reproduction

The record of reproduction in the animals is shown in table 14. This table includes the age at which the first oestrum period was noticed, the number of days the calf was carried, abortions, retained placentas, and the weight and condition of the calf.

A little difference in the age of the animals at which the first oestrum period was observed will be noted. The heifers in group I averaged 381 days of age, group II, 423 days of age, and group III, 404 days of age. Group I exhibited symptoms of oestrum at an earlier age than either of the other groups, which would indicate that from this standpoint their ration was more satisfactory than the rations fed the other groups. Group II showed the greatest age at first oestrum and all heifers in the group were uniformily older at first oestrum than those in the other two groups. The high average age in group III is due partly to heifer E 50 who was 516 days of age before any signs of oestrum were observed.

In average number of services per conception there was very little difference among the three groups -- 2.7 services

Table 14. Reproduction records

	Heifer number	Age at first observed oestrum	Services per conception	Calf carried	Weight of calf at birth	Condition of calf at birth	Remarks
		days		days	pounds		
Group I	E 35	352	2	273	87	normal	retained placenta
	E 36	321	3	273	87	normal	retained placenta
	E 37	324	5	283	76	normal	retained placenta
	E 38	415	1	283	71	normal	normal calving
	E 39	440	3	266	90	normal	normal calving
	E 40	424	2	272	81	normal	normal calving
	Average	381	2.7	275	81.5		
Group II	E 41	452	3	276	90	normal	normal calving
	E 42	458	5	279	90	normal	retained placenta
	E 43	440	5	278	83	normal	normal calving
	E 44	456	1	278	55	dead	normal calving
	E 45	376	1	209*		dead	aborted, retained placenta
	E 46	359	1	286	81	normal	normal calving
	Average	423	2.7	279.4	80		
Group III	E 47	346	1	280	80	normal	normal calving
	E 48	323	1	283	82	normal	retained placenta
	E 49	316	5	280	88	normal	normal calving
	E 50	516	4				sold-Bang's reactor 8-16-36
	E 51	456	3	277	95	normal	retained placenta
	E 52	470	3				due to calve 8-30-36
	Average	404	2.8	280	84		

being required for group I and II and 2.8 for group III.

All three groups showed early calving, with only three animals out of the sixteen carrying their calves for a normal gestation period. The animals in group I carried their calves an average of only 275 days. Group II, 279.4 days, and group III, the most nearly normal group in this respect, 281 days. One animal, E 45, aborted after 209 days.

The blood of each animal was tested from time to time for Bang's disease, and in February 1936, E 50 reacted in a dilution of one to fifty. Heifer E 45 aborted January 1, 1936 but was found to be negative to the blood test shortly after the abortion occurred.

In calving behavior the results are distinctly abnormal. One animal E 45 aborted and another, E 44, had a dead calf carried 278 days; also two animals in each of groups II and III and three animals in group I retained their placentas. As there is little difference among the three groups in this respect, no conclusions can be drawn in favor of any one of the rations.

In this experiment all indications of a mineral deficiency are lacking. The work of Palmer and co-workers (32) show normal reproduction for three years with cows receiving a ration very low in calcium. It therefore seems reasonable to conclude that the abnormal conditions shown here are

probably not due to a deficiency of minerals. Whether this can be due to a vitamin or other deficiency has not yet been determined.

Calcium and Phosphorous Balance Trial

Three heifers from each of the three groups were used in nine metabolism trials before they had freshened, and one heifer from group II and one from group III were used in mineral balance trials about two months after they had freshened.

Three heifers were run on balance trials at one time. Each trial included a five day preliminary period and a ten day collection period. During the trials the heifers were housed in a portion of the main barn, which is equipped with metabolism stalls. These stalls were provided with deep steel mangers which were entirely enclosed to the height of the stanchions with a heavy canvas curtain. This facilitated individual feeding and prevented the animals from wasting their feed. To avoid constant watch, in the collection of the excreta, large hoppers which delivered into receptical cans, were placed directly behind each heifer. The stall floors were covered with a canvas which was underlaid with heavy linoleum.

Feeding. At the beginning of each balance trial suf-

ficient individual feedings of hay and grain to last for the fifteen day period were weighed in grams and sealed in paper bags. For the group that received ground limestone, the individual feedings of limestone were weighed and sealed in envelopes. For the group that received silage, each feeding of silage was weighed at feeding time.

Collection of Samples. When weighing the individual feedings of hay and of grain, every tenth feeding was dumped on a large convas. This large sample was reduced by the quartering method, to a sample of convenient size for analysis. From each feeding of silage a small portion was saved for analysis. Due to daily variation in the calcium content of the water supply, at each time the heifers were watered, a small amount was added to a composite for analysis.

Feeding and Watering. During the trials each animal was fed the same amount of the ration as it had been receiving previously. All animals were fed at approximately six o'clock morning and evening. With group II animals the limestone was thoroughly mixed with the rest of the feed at time of feeding. Before each feeding water was offered to each animal, and the amount consumed was weighed and recorded.

Collection of Excreta Samples. Every 24 hours, during the collection period, the total excreta from each animal was weighed in grams, thoroughly mixed and a 5 per cent

aliquot sample taken. The composite samples were stored in tightly covered cans, and each days sample was added to the composite for the ten day period.

At the end of the collection period the composite samples were weighed, thoroughly mixed, and a representative sample secured for analysis.

Analytical Methods. The method used for the determination of the calcium and phosphorous in the feed and excreta samples was taken directly from the methods of analysis of the Association of Official Agricultural Chemists.

Discussion of Results. Tables 15 and 16 summarize the nine balance trials before freshening and the two after freshening. It will be noted that the balances for the three heifers from each group previous to calving were all positive for both calcium and phosphorous but the two trials during lactation were both negative. In the balances before calving there was little variation in groups I and II, although heifer E 37 did show a slightly lower phosphorous balance. The balances for the heifers in group III, however, showed more variation. Heifer E 52 showed a lower balance in both calcium and phosphorous, and heifer E 51 showed a lower phosphorous balance than did the other heifers. These variations seem to have no particular significance since animals vary from time to time in the amounts of these elements stored.

Archibald and Lindsey (2) in 86 calcium and phosphorous balance trials found that considerable fluctuation occurred in the amounts stored. Oftentimes these variations were much greater in different trials with the same animal than between animals in the same group. This indicates that a small number of trials is less significant than a large number, and that averages are more reliable than individual balances.

In the two balance trials during lactation, a cow from group II and one from group III were used. A wide difference in the calcium balance of the two cows will be noted. This might be due to two different factors. The greater negative balance of cow E 52 was possibly due to the fact that she was producing much more milk, which caused a heavier drain on the minerals in the system. On the other hand, the better relative showing of heifer E 46 might have been due to the fact that she was receiving a calcium carbonate supplement and thus had more calcium available.

In the balances before calving the animals in group II showed a 44.3 per cent higher intake of calcium than group I and a 70 per cent higher intake than group III. However, they stored only 1.7 and 1.0 per cent, respectively, more calcium than the heifers in groups I and III. Although group II actually stored more calcium than either group I or III, the percentage of retention was less. The per cent of re-

Table 15. Calcium and phosphorous balance before calving.

Heifer number	Daily intake		Daily output		Balance		Balance per 100 pounds		Percentage of Utilization	
	Ca.	Phos.	Ca.	Phos.	Ca.	Phos.	Ca.	Phos.	Ca.	Phos.
	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams
Group I										
E 36	37.25	29.80	30.28	24.51	6.97	5.29	.587	.446	18.71	17.75
E 37	37.85	30.09	30.22	26.34	7.63	3.75	.642	.315	20.16	12.47
E 40	37.17	28.21	29.96	22.56	7.21	5.56	.666	.513	19.40	19.71
Average	37.42	29.37	30.15	24.47	7.27	4.87	.632	.425	19.42	16.64
Group II										
E 42	54.27	30.56	45.51	24.07	8.76	6.49	.744	.551	16.14	21.24
E 43	53.80	30.56	45.78	24.10	8.02	6.46	.686	.553	14.91	21.14
E 46	53.89	30.56	44.96	24.21	8.73	6.35	.791	.576	16.20	20.78
Average	53.99	30.56	45.42	24.13	8.50	6.43	.740	.560	15.42	21.05
Group III										
E 49	32.46	29.31	22.49	23.86	9.97	5.45	.819	.447	30.16	18.59
E 51	33.53	27.59	24.02	24.43	9.51	3.16	.853	.283	28.36	11.45
E 52	29.00	26.68	24.10	24.10	4.90	2.58	.529	.279	16.90	9.67
Average	31.66	27.86	23.54	24.13	8.13	3.73	.734	.336	25.14	13.24

Table 16. Calcium and phosphorous balance during lactation.

Daily output - Group II - Heifer E 46							
Average daily excreta	Average daily Milk Production	Excreta		Milk		Total	
		Ca.	Phos.	Ca.	Phos.	Ca.	Phos.
grams	grams	grams	grams	grams	grams	grams	grams
33507	11823	60.98	36.19	11.82	11.47	72.80	47.66
Daily output - Group III - Heifer E 49							
39261	16509	44.76	38.08	17.33	16.18	62.09	54.26

Intake and balance utilization - Group II - Heifer E 46							
Daily intake		Balance		Balance per 100 pounds		Percentage of utilization	
Ca.	Phos.	Ca.	Phos.	Ca.	Phos.	Ca.	Phos.
grams	grams	grams	grams	grams	grams	grams	grams
68.86	40.59	-3.94	-7.07	-.376	-.675	11.44	10.84
Intake and balance utilization - Group III - Heifer E 49							
51.98	46.93	-10.11	-7.33	-.938	-.680	13.89	18.86

tention of calcium in group II was 15.42 per cent as compared with 19.42 and 25.14 per cent, respectively, in group I and III. These differences are small and thought to have little significance. With an intake of phosphorous per unit of weight averaging nearly the same for all three groups, group II stored an average of 30 and 67 per cent, respectively, more than groups I and III. These results are in accord with the work of Archibald and Lindsey (2). They found that as the retention of calcium increased the phosphorous retention also increased, and that there was also a higher per cent of the phosphorous retained. However, they do not agree with their work in respect to the ratio of calcium-phosphorous retention. They found that the ratio of calcium-phosphorous retention was usually about two to one. It will be noted that the results of this experiment show a ratio of calcium-phosphorous retention of about one and one-half to one for groups I and II and about two to one for group III.

GENERAL DISCUSSION

From the results of the experiment, it is evident that the heifers did not make normal growth. At 24 months of age the heifers in group I was 90.9 per cent of normal weight; group II, 93.3 per cent normal and group III, 96.3 per cent normal, when compared with Kansas normal growth figures.

The failure of the animals in this experiment to reach normal weight, however, can probably not be attributed to the lack of minerals. The balance trials before calving were all positive, and very little of the extra calcium received by group II was assimilated. Also the work of previous workers (2) (17) (26) indicates that the heifers were receiving enough calcium and phosphorous. The heifers in group I made the least gains and received 19.93 grams of calcium and 25.46 grams of phosphorous daily. In calcium this was above the 13 gram intake on which Theiler and Green (35) report good growth, and in phosphorous, it is above the 16.6 to 24.0 grams, which Kellner (26) stated that the ration for growing dairy heifers should contain.

The fact that the heifers did not receive enough total digestible nutrients according to Henry and Morrison's (18) growth requirements may have been responsible for some of the smaller size in the animals, but when we compare the nutrients received with Morrison's (29) growth requirements, we find a very close correlation. Consequently, the intake of nutrients is thought to have had little effect on the growth of the heifers.

Whether the extra calcium intake of group II will have a beneficial effect on milk production has not yet been determined.

The cause of the breeding difficulties and abnormal calving, also, has not been determined by this experiment. With the exception of the aborted foetus of E 45 and the dead calf of E 44, all calves were normal in appearance and vigorous at birth.

One of the most interesting things shown by the metabolism trials is the fact that the heifers assimilated but very little of the calcium carbonate. However, with the increased intake of calcium and the slight increase in calcium retention, there was a higher retention of phosphorous.

SUMMARY AND CONCLUSIONS

The dairy heifers used in this experiment failed to make normal growth when dry lot fed on a ration where prairie hay was the principal roughage.

Supplementing a prairie hay ration with calcium carbonate seemed to have little beneficial effect on the growth and development of the animal.

The use of silage in the ration resulted in a slightly better growth, indicating that the addition of a succulent feed was of some value.

The calcium and phosphorous balances before calving were all positive, but when the heifers were in full milk flow they were negative.

The lower calcium intake of the heifers not receiving the calcium supplement tended to be offset by the higher percentage of retention.

With an intake of 44.3 per cent more calcium than the group receiving the basal ration and 70 per cent more than the group receiving silage, the heifers receiving the calcium carbonate retained only 1.7 and 1.0 per cent, respectively, more calcium.

The experiment indicated that there was some deficiency in the prairie hay rations used, but that this deficiency was not one of calcium or phosphorous.

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