UNIVERSITY OF IDAHO
AGRICULTURAL EXPERIMENT STATION
Departments of Animal Husbandry and Agricultural Chemistry

The Phosphorus Requirement for Growing and Fattening Beef Steers

By

W. M. BEESON, D. W. BOLIN, C. W. HICKMAN,
and R. F. JOHNSON

BULLETIN No. 240 MAY 1941
Published by the University of Idaho, Moscow, Idaho

Figure 1.—Phosphorus-deficient steer. Fed on a low phosphorus ration containing 0.11 per cent phosphorus (Lot 5).

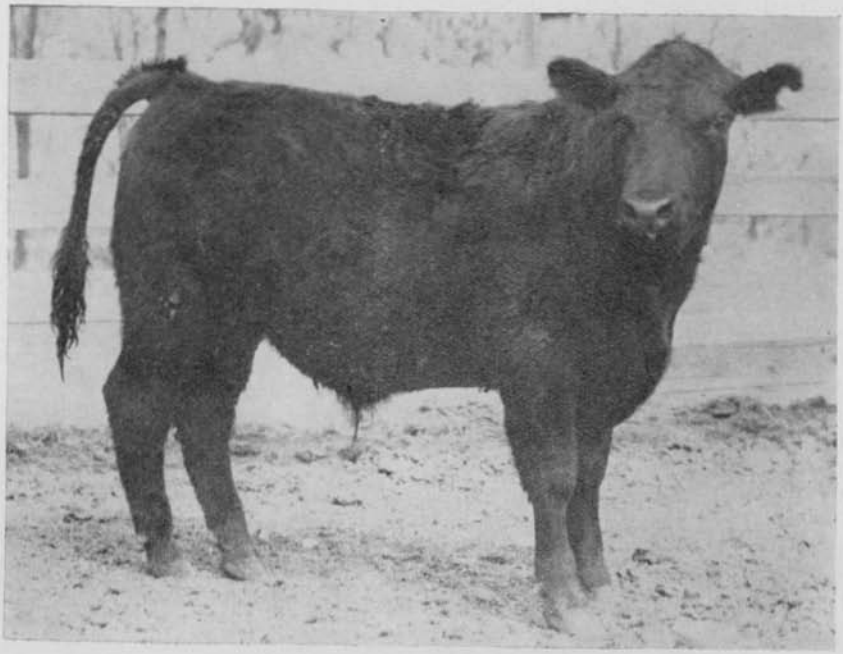

Figure 2.—Phosphorus-normal steer. Fed identically the same ration as the above steer excepting ample phosphorus was provided by adding bonemeal to the ration (0.18 per cent phosphorus in ration, Lot 6).

The Phosphorus Requirement for Growing and Fattening Beef Steers

By

W. M. BEESON[1], D. W. BOLIN[2], C. W. HICKMAN[3] and R. F. JOHNSON[4]

NUMEROUS experiments and observations have shown that beef cattle require phosphorus in their diet for normal processes of growth, fattening and reproduction. However, a majority of the studies have been of a qualitative nature and data submitted by most of the investigators have been insufficient to establish the optimum and minimum amounts of phosphorus required for fattening and growing beef cattle. The purpose of this present study was to determine quantitatively the phosphorus requirement for fattening and growing beef calves under feedlot conditions, and the effects of a low phosphorus intake upon the rate of gain and feed utilization.

Since an excellent review of the literature has recently been published by Theiler and Green *(10)* and Mitchell and McClure *(9)*, only the papers which have a specific bearing on the present studies will be discussed. Forbes, French and Lentonoff *(6)* conducted a balance study with 1,000-pound beef steers and showed that an intake of 10.84 grams daily was necessary to produce a positive phosphorus balance for maintenance. In contrast to this study, Watkins *(11)* showed that 500-pound steers ingesting 11.03 grams of feed phosphorus had a negative balance, but the steers receiving 14.7 grams of feed phosphorus, furnished either by natural feeds or disodium phosphate, showed uniformly positive phosphorus balances. He found also that growing steers of 18 months of age could not satisfy their phosphorus needs with a daily intake of 8.5 grams of phosphorus. Kleiber, Goss, and Guilbert *(7)*, conducting respiration trials on beef heifers, showed that they ceased to grow after 6 months on a diet containing 0.13 per cent phosphorus. They also reported that a phosphorus deficiency lowers the total efficiency of energy utilization. Maynard, Greaves, and Smith *(8)*, in studying the effect of adding phosphorus supplements to beet by-product rations, found that yearling steers showed definite symptoms of aphosphorosis with a daily intake of 1.96 grams of phosphorus per 100 pounds and that steer calves become phosphorus deficient when ingesting 1.62 grams per 100 pounds live weight daily. Their investigation also indicated that both calves and yearlings met their daily requirement by receiving, respectively, 18.0 and 24.0 grams of phosphorus per steer daily, but these values are not necessarily the minimum requirement. In a preliminary report Beeson, Bolin, and Hickman *(2)* showed that the minimum daily prosphorus requirement for fattening 600-pound steer calves is slightly less than 12 grams of phosphorus daily or an intake of about 2 grams daily per 100 pounds of live weight.

[1]Associate Animal Husbandman, Idaho Agricultural Experiment Station.
[2]Assistant Chemist, Idaho Agricultural Experiment Station.
[3]Animal Husbandman, Idaho Agricultural Experiment Station.
[4]Superintendent of Caldwell Branch Station, Idaho Agricultural Experiment Station.

Experimental Procedure

A uniform group of grade Angus steer calves was selected from the range for this study. Eight steers were allotted to each pen as equally as possible with respect to weight, type, and probable outcome. They were kept in open, straw-bedded feedlots with free access to water. All animals were weighed individually and blood samples were taken from the jugular vein and analyzed for calcium and phosphorus before the steers were placed on the experimental rations. All feed was weighed and fed twice daily to all lots. The mixture was fed ad libitum and the corn silage intake was limited. The steers were fed as a group and not individually. At the end of approximately 28-day feeding periods, the steers were re-weighed individually, and the amount of feed not consumed weighed back for each lot.

A ration consisting of alfalfa, dried molasses beet pulp, corn silage and blood meal was used as a phosphorus-deficient ration. The alfalfa was chopped finely and mixed with the dried beet pulp and blood meal. The intake of alfalfa hay was limited and the major portion of the ration was made up with dried molasses beet pulp in order to establish a low phosphorus diet. Blood meal, which is one of the few concentrates high in protein and low in phosphorus, was used to increase the protein content of the ration. This type of ration proved adequate in all nutritive essentials with the exception of phosphorus. Corn silage was weighed and fed separately. For calculation of total dry matter intake the corn silage was reduced to the moisture content of the basal ration.

Table 1.—Composition of rations.

Component	Basal ration	Basal + 0.30% bone meal	Basal + 0.66% bone meal	Basal + 1.0% bone meal	Basal + 10% C. S. M.	Control ration	Beet pulp + alfalfa hay
	%	%	%	%	%	%	%
Beet pulp, dried	67.70	67.60	67.58	67.50	62.65		40
Barley						52.50	
Alfalfa, chopped	26.00	26.00	26.00	26.00	26.00	54.25	60
Bloodmeal	5.00	5.00	5.00	5.00			
Cottonseed meal					10.00		
Meat meal						2.25	
Bone meal		0.30	0.66	1.00			
Oyster shell	0.80	0.60	0.26		0.85		
Salt	0.50	0.50	0.50	0.50	0.50		
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Corn silage—Fed at the rate of 1 to 2 lb. per 100 lb. live wt.

The composition of the rations used is shown in Table 1. Lots 1, 5, and 10 received the basal ration. The same proportion of ingredients was used in the basal ration for three successive years of experimental feeding. The basal ration varied in phosphorus content from one year to another, largely due to the variation in the phosphorus content of the alfalfa. This accounts for the difference in total intake of phosphorus for the various years. The per cent phosphorus for each lot is shown in Table 2.

Lot 11; Lots 2, 6, and 12; and Lots 3, 7, and 13 received 0.30, 0.66, and 1.0 per cent bonemeal, respectively, as a supplement to

the basal ration. Lots 4, 8, and 14 were fed 10 per cent cottonseed meal as a protein-phosphorus supplement in place of blood meal and bonemeal as a standard ration for the comparison of other lots. Steers in Lot 9 were fed beet pulp and alfalfa hay, a ration which is used in many sections of the western states. All feed analyses were made according to the methods of the Official Agricultural Chemists *(1)* with the exception of phosphorus, which was determined colorimetrically by a slight modification of the Fiske and Subbarow *(5)* method.

Blood samples were analyzed for phosphorus by the Fiske and Subbarow *(5)* method and for calcium by precipitating the calcium from the tri-chloracetic acid filtrate, at a pH of 4.0, and using bromcresol green as an indicator. The contents were filtered through a number 4 fritted cintered crucible, and washed with small portions of 2 per cent aqueous ammonia solution. The precipitate was dissolved from the crucible with hot, normal sulphuric acid into the flask in which the calcium was precipitated. The contents were titrated with 0.01 normal potassium permanganate from a microburette.

Results

The average weight of 8 steers and the average daily intake of feed per steer for three successive years from the different lots during the feeding trial are shown in Table 2, and a combined summary of the three experiments is presented in Table 3. From these results, the average daily feed consumed per 100 pounds of live weight, the amount of feed required to make 100 pounds of gain, and the total average daily intake of phosphorus in grams per steer, and the grams per 100 pounds of live weight, were determined as shown in Table 2. At the end of each year's experiment, the results are averaged and are shown for each lot. In the last column of Table 2, the average inorganic phosphorus content of the blood plasma of the 8 steers is shown for each lot at different time intervals during the experimental feeding trial, and the average calcium values are given in Table 3.

Influence of Phosphorus on the Rate of Gain and Food Utilization

Examination of the data in Table 2 shows that those lots receiving an excess of 2.00 grams daily intake of phosphorus per 100 pounds of live weight, did not make any more rapid or efficient gains than those receiving a 2.00 grams daily intake of phosphorus. Those lots which received 1.63 grams daily or less of phosphorus per hundredweight failed to make good gains and utilization of their feed. It is therefore assumed for the present that steers receiving 2.00 grams daily of phosphorus per 100 pounds live weight, are receiving sufficient phosphorus to meet the normal body requirement for growth and fattening.

Lots receiving 2.00 grams or more per hundredweight were compared to other lots receiving less than 2.00 grams daily intake for determining the influence of phosphorus on the rate of gain and feed utilization. To eliminate as many other factors as possible

Table 2.—The effect of phosphorus intake on the rate of gain, feed utilization and blood phosphorus of steers.

Feeding period Days	Weight lb.	Daily gain lb.	Feed consumed			Phosphorus intake		Blood phosphorus mg/100ml
			Daily lb.	per 100 lb. live wt. lb.	per 100 lb. gain lb.	Daily gm.	per 100 lb. live wt. gm.	
Experiment I—1936-37								
Lot — 1 Basal ration (0.14% phosphorus)								
0	446	——	——	——	——	——	——	6.71
28	483	1.32	11.40	2.46	861	7.73	1.67	
28	542	2.12	12.75	2.49	600	8.40	1.64	5.89
28	566	0.85	13.15	2.37	1550	8.66	1.59	6.04
28	593	0.96	12.14	2.09	1265	7.49	1.29	4.74
28	643	1.10	14.28	2.31	795	8.39	1.36	4.31
28	673	1.05	15.47	2.35	1475	8.55	1.30	4.40
Average	560	1.35	13.20	2.36	1091	8.20	1.46	
Lot — 2 Basal ration + 0.66% bonemeal (0.20% phosphorus)								
0	447	——	——	——	——	——	——	6.19
28	499	1.86	11.15	2.36	601	10.73	2.28	
28	558	2.10	12.64	2.39	603	12.08	2.44	7.10
28	594	1.29	14.37	2.49	1110	13.64	2.36	6.64
28	643	1.76	12.05	1.95	684	11.30	1.83	6.64
28	694	1.83	15.47	2.32	845	14.33	2.13	7.66
28	742	1.70	16.72	2.33	985	15.32	2.12	6.00
Average	594	1.76	13.73	2.31	805	12.90	2.19	
Lot — 3 Basal ration + 1.0% bonemeal (0.24% phosphorus)								
0	443	——	——	——	——	——	——	5.90
28	487	1.56	11.32	2.44	725	12.56	2.70	
28	531	1.56	13.14	2.59	841	14.60	2.87	7.32
28	576	1.61	13.82	2.50	861	15.39	2.78	7.11
28	605	1.27	12.83	2.19	1006	14.29	2.44	7.11
28	670	2.29	16.08	2.53	701	17.89	2.82	7.99
28	708	1.35	18.00	2.62	1448	20.05	2.92	7.79
Average	576	1.61	14.20	2.48	930	15.80	2.76	
Lot — 4 Basal ration + 10% cottonseed meal (0.22% phosphorus)								
0	448	——	——	——	——	——	——	7.06
28	498	1.77	11.38	2.40	641	11.36	2.40	
28	558	2.16	13.50	2.57	625	13.34	2.54	6.94
28	584	0.93	14.30	2.47	1533	14.13	2.44	7.27
28	619	1.25	11.70	1.95	936	11.51	1.92	6.39
28	675	1.98	15.96	2.48	804	15.52	2.42	6.39
28	720	1.61	16.22	2.33	1009	15.89	2.28	5.81
Average	634	1.62	13.84	2.37	925	13.63	2.33	
Experiment II—1937-38								
Lot — 5 Basal ration (0.11% phosphorus)								
0	430	——	——	——	——	——	——	6.30
28	474	1.58	11.8	2.61	750	6.08	1.35	4.62
28	517	1.54	12.9	2.60	835	6.29	1.26	
28	548	1.09	12.1	2.27	1109	5.94	1.11	4.15
28	577	1.05	12.5	2.22	1196	6.15	1.09	
28	568	0.32	10.2	1.78		5.16	0.90	3.20
Average	499	0.98	12.0	2.38	1209	5.91	1.18	
Lot — 6 Basal ration + 0.66% bonemeal (0.18% phosphorus)								
0	434	——	——	——	——	——	——	6.21
28	480	1.65	11.8	2.58	717	9.80	2.14	6.13
28	537	2.02	13.1	2.58	646	10.79	2.12	
28	588	1.38	13.9	2.48	762	11.52	2.05	7.00
28	649	2.16	14.1	2.28	652	11.60	1.88	
28	677	1.90	14.6	2.20	765	12.01	1.81	7.50
Average	556	1.74	13.5	2.43	779	11.12	2.00	
Lot — 7 Basal ration + 1.0% bonemeal (0.22% phosphorus)								
0	435	——	——	——	——	——	——	6.20
28	494	2.11	11.8	2.54	558	11.74	2.60	6.52
28	548	1.90	13.3	2.55	702	13.21	2.54	
28	589	1.47	14.0	2.46	948	13.92	2.45	6.90
28	651	2.14	12.8	2.38	690	14.73	2.37	
28	695	1.55	15.3	2.27	981	15.23	2.26	7.30
Average	565	1.53	13.8	2.44	775	13.81	2.44	

Feeding period Days	Weight lb.	Daily gain lb.	Feed consumed			Phosphorus intake		Blood phosphorus mg/100ml
			Daily lb.	per 100 lb. live wt. lb.	per 100 lb. gain lb.	Daily gm.	per 100 lb. live wt. gm.	
Experiment II—1937-38 (cont'd.)								
Lot — 8	Basal ration + 10% cottonseed meal (0.21% phosphorus)							
0	432	——	——	——	——	——	——	5.91
28	481	1.74	12.3	2.69	708	11.58	2.54	5.40
28	524	1.54	13.5	2.69	881	12.83	2.56	
28	578	1.90	14.4	2.61	759	13.59	2.47	6.49
28	638	2.14	14.7	2.42	686	13.88	2.28	
28	678	1.46	15.7	2.39	1073	14.83	2.25	6.10
Average	555	1.76	14.1	2.54	805	13.37	2.40	
Lot — 9	Beet pulp + alfalfa hay (0.14% phosphorus)							
0	435	——	——	——	——	——	——	5.50
28	474	1.42	11.9	2.62	836	7.66	1.69	4.34
28	523	1.74	13.1	2.62	727	8.17	1.64	
28	558	1.23	13.9	2.57	1132	8.63	1.60	5.21
28	601	1.54	14.7	2.53	952	9.09	1.57	
28	618	0.62	14.8	2.43	2371	9.15	1.50	4.50
Average	526	1.31	13.7	2.60	1046	8.57	1.63	
Experiment III—1938-39								
Lot — 10	Basal ration (0.11% phosphorus)							
0	452	——	——	——	——	——	——	6.39
29	496	1.51	9.51	2.05	633	4.81	1.02	
28	527	1.12	12.15	2.38	1090	6.07	1.19	4.34
28	548	0.74	11.71	2.18	1591	5.89	1.09	
28	565	0.60	10.56	2.08	1755	5.38	0.97	3.78
28	595	1.07	10.71	1.85	1001	5.44	0.94	
21	598	0.14	10.12	1.70	7404	5.19	0.87	3.18
Average	525	0.90	10.79	2.04	1207	5.48	1.04	
Lot — 11	Basal ration + .30% bonemeal (0.15% phosphorus)							
0	451	——	——	——	——	——	——	5.67
29	486	1.23	9.55	2.04	780	6.39	1.36	
28	532	1.63	12.06	2.37	741	8.11	1.60	4.24
28	546	0.51	12.37	2.30	2411	8.29	1.54	
28	582	1.29	12.29	2.13	949	8.22	1.45	4.94
28	631	1.72	12.43	2.05	723	8.30	1.37	
21	638	0.33	12.33	1.95	3767	8.24	1.30	3.96
Average	544	1.15	11.83	2.18	1024	7.90	1.45	
Lot — 12	Basal ration + 0.66% bonemeal (0.19% phosphorus)							
0	452	——	——	——	——	——	——	5.85
29	508	1.95	9.82	2.04	505	8.64	1.82	
28	542	1.20	12.30	2.34	1020	10.81	2.06	5.92
28	582	1.43	12.81	2.28	896	11.26	2.00	
28	615	1.18	13.10	2.29	1108	11.51	1.93	7.68
28	682	2.41	15.13	2.34	617	13.30	2.06	
21	705	1.09	15.61	2.26	1432	13.76	1.98	6.31
Average	578	1.57	13.02	2.26	831	11.45	1.98	
Lot — 13	Basal ration + 1.0% bonemeal (0.24% phosphorus)							
0	452	——	——	——	——	——	——	6.36
29	478	0.94	9.52	2.05	1016	10.32	2.22	
28	526	1.70	11.45	2.28	676	12.32	2.46	7.44
28	562	1.29	12.41	2.29	958	13.38	2.54	
28	604	1.50	13.20	2.26	887	14.25	2.26	6.54
28	659	1.96	14.66	2.32	746	15.87	2.44	
21	701	1.98	15.12	2.22	765	16.38	2.40	7.11
Average	576	1.54	12.64	2.20	821	13.62	2.36	
Lot — 14	Basal ration + 10% cottonseed meal (0.17% phosphorus)							
0	454	——	——	——	——	——	——	6.34
29	510	1.92	10.03	2.14	524	8.14	1.69	
28	567	2.03	13.70	2.55	674	11.10	2.07	6.30
28	604	1.32	13.10	2.24	995	10.61	1.83	
28	638	1.21	13.52	2.18	1121	10.91	1.76	6.10
28	692	1.96	13.72	2.06	698	11.11	1.70	
21	726	1.60	15.33	2.17	961	12.28	1.75	6.21
Average	590	1.68	13.15	2.23	784	10.62	1.80	

which may have an influence on the rate of gain and feed utilization, lots were compared which consumed about the same amounts of the basal ration but with different phosphorus content, and in the same year's experiment. Steers in Lots 2 and 3 receiving ample phosphorus and an average consumption of 2.31 pounds of feed daily per 100 pounds of live weight, showed an average percentage increase in weight of 32.5 per cent over the steers in Lot 1, which consumed the same amount of feed daily but had only 0.14 per cent phosphorus in the ration. The steers in Lots 6 and 7 ingesting, respectively, 11.12 and 13.81 grams of phosphorus daily showed an increase in gains of 54 per cent over steers in Lot 5 receiving only 5.91 grams of phosphorus daily for the first 112 days on the experiment. The animals in Lots 12 and 13 showed a 40 per cent increase in live weight over Lot 10, which was phosphorus deficient. The per cent increase in daily gains was not considered for the entire feeding period because of the decrease in consumption of feed for Lots 5 and 10 in the latter part of the feeding period. Steers receiving 2.00 grams or more of phosphorus daily per 100 pounds live weight showed an average increase in weight, for the three years, of 37 per cent over the phosphorus-deficient lots.

These data clearly indicate that animals given ample phosphorus utilize their feed better and gain more per unit of feed consumed than do steers on a phosphorus-low diet. The fact that on the same food intake the phosphorus-low steers make less gains per unit of food eaten indicates that a low phosphorus regime interferes with the utilization of the food, even before the appetite has decreased.

In Lot 10, at the beginning of the feeding period, steers on the low-phosphorus diet made a pound of gain on 6.33 pounds of feed, but the feed requirements increased as the phosphorus deficiency progressed and at the end of the period the feed requirement rose to 74.04 pounds per pound of gain. The steers on the phosphorus deficient rations required on the average about 12 pounds of feed to produce 1 pound of gain, while steers on a phosphorus sufficient ration required only 8 pounds of feed per pound of gain.

These results confirm the findings of Theiler *(10)*, who concluded that animals given sufficient phosphorus utilized their feed better and gained more per unit of feed consumed than do animals on the phosphorus-low diet. Eckles and Gullickson *(3)* report that cows on a low phosphorus diet need at least 20 per cent more digestible nutrients to maintain live weight. Kleiber, Goss and Guilbert *(7)* have reported that animals 14 to 15 months of age on a low phosphorus ration consumed the same amount of feed and gained the same as animals on a phosphorus sufficient diet for the first 6 months. These results show that the rate of gain decreased within the first 2 months, and in several cases, the loss of appetite occurred at the end of 4 months. The explanation of the difference between our results and those of Kleiber, et al., *(7)* is that younger animals were used in our studies. Younger animals are expected to make a greater demand for phosphorus than older animals. Therefore, the symptoms of phosphorus deficiency should appear sooner with younger animals than with the older animals.

In 1937-38 a positive check lot (Lot 6, Table 3) was included to determine whether the gains of the steers on the basal ration plus phosphorus were as good as would be expected from steers on an excellent fattening ration. Steers on the control ration gained 1.76 pounds daily, and the steers on the basal ration with a phosphorus supplement gained 1.74 pounds per steer daily, which is not significantly different. These results substantiate the first assumption that the basal ration is ample in all known dietary essentials except phosphorus.

Appetite of Steers

The lack of appetite was usually evident in the steers after 112 days on the phosphorus-low ration. This was associated with a depraved appetite which was manifested by wood chewing and eating dirt. The steers on inadequate phosphorus diets became very emaciated, thin, and listless (compare Figures 1 and 2). Table 2 shows by 28-day periods the average daily intake of feed of steers fed on phosphorus-deficient and sufficient rations. After 4 months on the phosphorus-deficient rations, the daily feed consumption of the steers decreased until the end of the feeding period, while the steers receiving enough phosphorus ate more feed as their weight increased. The feed consumption of the steers receiving ample phosphorus increased from about 9.5 to 15.0 pounds per steer daily during the course of the experiments, whereas the consumption of the steers on the phosphorus-low ration showed no increase. These studies show that it takes considerable time for the appetite of steers to be depressed by low phosphorus diets. Therefore, the first effects of a phosphorus-low diet is the poor utilization of feed, slow gain, and depraved appetites. The inefficient utilization of feed in the first stages of aphosphorosis is due to some disturbed metabolic process and not to low food intake. However, after the appetite is affected the feed requirements per unit gain increase, because a larger percentage of the nutrients is used for maintenance, thus leaving less food for building new tissues.

The exact physiological action associated with the loss of appetite is not known, but this phenomenon is common to most nutritional deficiencies.

Blood Phosphorus and Calcium

The data on the inorganic phosphorus and calcium content of the blood plasma are presented in Tables 2 and 3. These data are based upon an average of 8 analyses of the blood samples from the individual steers. Steers fed on rations containing 0.15 per cent or less phosphorus showed a definite lowering of the blood phosphorus to deficient levels. The average phosphorus level for steers on the phosphorus-low ration was lowered from a normal of 6.47 mg. per 100 ml. of plasma to an abnormal level of 3.59 mg. It required from 51 to 69 days for the inorganic blood phosphorus to drop below normal when the steers were fed on a ration with 0.11 per cent phosphorus and a period of 100 days was required when the steers received 0.15 per cent phosphorus in the ration. A phosphorus

intake of 1.46 grams or less per 100 pounds of live weight did not support normal phosphorus levels in the blood plasma.

The blood phosphorus values for the steers on the rations containing 0.18 per cent or more phosphorus *(Table 2)*, corresponding to an intake of 2.00 grams or more of phosphorus per 100 pounds of live weight, were all within the normal range. There was no evidence of a calcium deficiency among any of the steers *(Table 3)*.

Individual variations were found among the steers in regard to their response to low phosphorus rations. This was indicated by the variation in time required to reduce the blood phosphorus to an abnormal level. Furthermore, the feeding prior to starting the experiment has a definite influence on the time required to deplete the animal's phosphorus reserve.

Table 3.—Summary of results for three experiments on the phosphorus requirement for fattening steers.

Experimental days—161[1]	Lot 1. Basal ration	Lot 2.[1] Basal ration + 0.30% bonemeal	Lot 3. Basal ration + 0.66% bonemeal	Lot 4. Basal ration + 1% bonemeal	Lot 5. Basal ration + 10% C. S. M.	Lot 6.[2] Check ration barley, meat meal, alf. hay
Steers per lot	8	8	8	8	8	8
Av. initial weight, lb.	443	451	444	444	445	422
Av. final weight, lb.	620	638	724	711	721	669
Total gain per steer, lb.	177	187	280	267	276	247
Av. daily gain, lb.	1.10	1.16	1.74	1.66	1.71	1.76
Av. daily ration, lb.	12.0	11.8	13.5	13.6	13.8	15.1
Feed per 100 lb. gain, lb.	1129	1025	794	832	800	856
Phosphorus in ration, per cent	0.12	0.15	0.19	0.23	0.20	0.33
Daily phosphorus intake, grams	6.54	7.90	11.87	14.38	12.57	22.86
Phosphorus intake per 100 lb. live wt. grams	1.23	1.45	2.03	2.49	2.15	4.19
Daily calcium intake, grams	44.7	44.8	52.0	52.7	52.4	51.6
Ca/P ratio	6.8	5.7	4.4	3.7	4.2	2.2
Blood phosphorus, mg/100 ml. plasma.						
Initial	6.47	5.67	6.08	6.15	6.44	5.22
Final	3.59	3.96	6.60	7.40	6.04	7.10
Blood calcium, mg/100 ml. plasma						
Initial	9.50	9.05	8.37	9.19	9.70	9.37
Final	11.20	11.40	10.30	10.60	10.60	10.70

[1]The data presented in Lots 2 and 6 represent only one experiment.
[2]Steers in lot 6 fed 141 days.

Calcium-Phosphorus Ratio

The calcium intake was maintained at approximately the same level in all lots by the addition of ground oyster shell. This caused a variation in the calcium-phosphorus ratio, ranging from 6.8:1 to 2.2:1 *(Table 3)*. If a more favorable calcium-phosphorus ratio had been maintained in the low phosphorus lots, this might have lowered the minimum requirement for phosphorus. However, under practical feed conditions, aphosphorosis occurs under less favorable calcium-phosphorus ratios than used in this experiment. For example, alfalfa hay has a calcium-phosphorus ratio of 6.8:1, which is the same as the ratio in the deficient lot. Since alfalfa hay is fed as the sole roughage and many times the only feed for cattle, we are led to conclude that requirement for phosphorus determined

with a wide ratio is more applicable to conditions as they exist, than if the ratio was optimum in all lots. Analyses of a large number of range plants in Idaho have shown that cattle feed in the late summer and fall on plants having calcium-phosphorus ratios ranging from 20:1 to 6:1, which further substantiates the fact that optimum relations between calcium and phosphorus seldom exist under natural feeding conditions. A recent review of the importance of calcium-phosphorus ratio in animal nutrition by Fairbanks *(4)* has pointed out that an optimum calcium-phosphorus ratio has greater importance when the vitamin D of the ration is inadequate. Since the steers on the experiment were fed in open lots and on good quality sun-cured alfalfa hay, the vitamin D intake should have been ample.

Cottonseed Meal vs. Bonemeal as a Phosphorus Supplement

Lots 4, 8, and 14 were designed to compare the effectiveness of an organic form of phosphorus such as found in cottonseed meal with an inorganic phosphorus, when fed at approximately the same level. The close agreement of the results in the three experiments shows that cottonseed meal is a very good source of phosphorus and therefore is useful in preventing aphosphorosis. These data indicate that an organic form of phosphorus is just as effective in preventing aphosphorosis as the inorganic form *(Table 2)*. The steers fed the basal ration plus cottonseed meal made gains comparable to the lots supplemented with bonemeal, and the blood phosphorus levels were normal. Thus cottonseed meal lends itself to serve not only as an excellent protein supplement but also as a suitable phosphorus supplement.

Phosphorus Requirement for Growing and Fattening Steers

The optimum phosphorus requirement as determined by the rate of gain, feed utilization, appetite and inorganic blood phosphorus level is shown to be 2.00 grams daily intake per 100 pounds of live weight or about 10 grams daily for a 500 pound steer calf. This is not necessarily the minimum physiological phosphorus requirement necessary to support normal nutrition and health of the animal, but is as low a level as should be fed under practical feeding conditions.

The minimum physiological phosphorus requirement is possibly nearer 1.80 grams per 100 pounds of live weight than 2.00 grams. In Lot 1 it is definitely shown that 1.67 grams of phosphorus daily per hundredweight during the first part of the feeding period is insufficient. The steers in this lot became phosphorus deficient in the latter part of the feeding period as shown by small gains and the lowering of the inorganic blood phosphorus. This conclusion is also substantiated by Lot 9. In Lot 14 the average daily intake for the feeding period was 1.80 grams per 100 pounds. These animals maintained normal gains, feed consumption, and blood phosphorus levels. This lot would indicate the minimum physiological phosphorus requirement to be 1.80 grams daily intake per 100 pounds

in comparison to the data presented from other lots. In Lots 2, 6, and 12, during some of the feeding period, the phosphorus intake dropped to 1.80 grams daily intake of phosphorus. All these lots maintained normal food consumption, optimum blood phosphorus levels, and made good gains.

It is, therefore, suggested that rations of the type fed must contain 0.18 per cent phosphorus to supply a daily intake of phosphorus of 2.00 grams per 100 pounds live weight. To meet the requirement of 1.80 grams of phosphorus daily a ration must contain 0.17 per cent phosphorus under normal consumption. The 0.17 per cent phosphorus ration is too low for safety because other unknown factors could lower consumption of feed and thus lower the intake of phosphorus below the minimum requirement.

These results are somewhat lower than reported by Mitchell and McClure *(9)* in which they state that a 500-pound growing steer requires a daily intake of 12.4 grams; a fattening steer of the same weight 16.7 grams; and a growing Holstein-Friesian (female) weighing 500 pounds required 10.4 grams of phosphorus. These variations in phosphorus requirement of different type animals are wide. It is not likely that a growing beef steer should require more phosphorus than a growing dairy calf at the same weight.

Maynard, Greaves, and Smith *(8)* produced a phosphorus deficiency by feeding 1.96 grams of phosphorus per 100 pounds of live weight, while our studies indicate that this amount of phosphorus was ample for fattening steers. Reports for the phosphorus requirement of beef steers vary widely and the differences are greater than can be accounted for by experimental error. In a recent report by Williams, MacLeod, and Morrell *(12)* in studies with rats, it has been shown that the availability of phosphorus varies within the same forage. It is quite possible that this fact may account for the discrepancies between the various reports.

Summary

A three-year study using 112 head of steer calves ranging in initial and final weights, respectively, from 422 to 724 pounds and fed on different levels of phosphorus for an average of 161 days has given consistent enough results to permit the following interpretations and conclusions:

1. A definite phosphorus deficiency was produced with steer calves fed on rations containing from 0.11 to 0.15 per cent phosphorus with an average daily phosphorus intake ranging from 1.04 to 1.63 grams per 100 pounds of live weight.

2. Steer calves manifesting aphosphorosis required 30 per cent more feed to make a pound of gain and gained 37 per cent slower than calves receiving ample phosphorus.

3. An average of 60 days was required for the steers to show signs of aphosphorosis as indicated by low blood phosphorus, efficiency of feed utilization, and depraved appetite. However, the appetite of the steers was not retarded in most cases until after 112 days.

4. The fact that on the same feed intake the low phosphorus steers made less gain per unit of feed eaten, shows that a low phosphorus ration interferes with the utilization of the feed even before the appetite has decreased.

5. Fed at the same phosphorus level, the organic phosphorus of cottonseed meal was as effective in preventing a phosphorus deficiency as the inorganic phosphorus in bonemeal.

6. The phosphorus requirement for fattening steers was met by feeding rations containing 0.18 per cent or more phosphorus or by supplying a daily intake of 2.00 grams of feed phosphorus per 100 pounds of live weight.

Literature Cited

1. Association of Official Agricultural Chemists.
   1935. OFFICIAL AND TENTATIVE METHODS OF ANALYSIS.
2. Beeson, W. M., D. W. Bolin, and C. W. Hickman.
   1937. THE PHOSPHORUS REQUIREMENT OF BEEF CATTLE. Am. Soc. An. Prod. Proc., pp. 92-95.
3. Eckles, C. H., and T. W. Gullickson.
   1927. THE RELATION OF PHOSPHORUS DEFICIENCY TO THE UTILIZATION OF FEED. Am. Soc. An. Prod. Proc., pp. 16-21.
4. Fairbanks, B. W.
   1939. THE CALCIUM-PHOSPHORUS RATIO. North Am. Vet., vol. 20, No. 1.
5. Fiske, C. H., and Y. Subbarow.
   1925. THE COLORIMETRIC DETERMINATION OF PHOSPHORUS. J. Biol. Chem., vol. 66, pp. 375-400.
6. Forbes, E. B., R. B. French, and T. V. Letonoff.
   1929. THE MINERAL METABOLISM OF THE BEEF STEER. J. Nutrition, vol. 1, p. 201.
7. Kleiber, Max, Harold Goss, and H. R. Guilbert.
   1936. PHOSPHORUS DEFICIENCY METABOLISM AND FOOD UTILIZATION IN BEEF HEIFERS. J. Nutrition, vol. 12, p. 121.
8. Maynard, E. J., J. E. Greaves, and H. H. Smith.
   1936. PHOSPHORUS SUPPLEMENTS IMPROVE SUGAR-BEET BY-PRODUCT RATIONS FOR CATTLE. Utah Agr. Exp. Sta. Bul. 265, pp. 1-29.
9. Mitchell, H. H., and F. J. McClure.
   1937. MINERAL NUTRITION OF FARM ANIMALS. National Research Council Bulletin No. 99.
10. Theiler, Sir A., and H. H. Green.
    1932. APHOSPHOROSIS IN RUMINANTS. Nutr. Abst. and Rev., vol. 1, p. 359.
11. Watkins, W. E.
    1933. DIGESTION AND MINERAL BALANCE TRIALS ON RANGE CATTLE WITH NATIVE NEW MEXICO RANGE HAY, COTTONSEED MEAL, AND MINERAL SUPPLEMENTS. New Mexico Agr. Exp. Sta. Tech. Bul. No. 212.
12. Williams, Dorothy E., Florence L. MacLeod, and Elsie Morrell.
    1940. AVAILABILITY TO WHITE RATS OF PHOSPHORUS IN LESPEDEZA SERICEA AND ALFALFA HAYS. J. Nutrition, vol. 19, p. 251.