PHOSPHORUS METABOLISM IN CATTLE FED SODIUM PHOSPHATE

By

BILL DAVIS

Bachelor of Science

Panhandle Agricultural and Mechanical College

Goodwell, Oklahoma

1953

Submitted to the faculty of the Graduate School of
the Oklahoma Agricultural and Mechanical College
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
May, 1956

PHOSPHORUS METABOLISM IN CATTLE FED SODIUM PHOSPHATE

Thesis Approved:

Thesis Adviser

Dean of the Graduate School

ACKNOWLEDGEMENT

The author wishes to express his sincere appreciation to Dr. Willis D. Gallup, under whose guidance this work was conducted. He also wishes to express his appreciation to Dr. Robert MacVicar and the Department of Agricultural Chemistry for the assistance and support extended throughout this work.

The cooperation of Dr. Allen Tillman and others of the Animal Husbandry Department is gratefully acknowledged.

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

Metabolism involves the chemical changes in living cells, by which energy is provided for vital processes and activities, and new material is assimulated to repair body tissues.

Phosphorus plays an important role in the metabolism of animals. It is found in every living cell and forms a large proportion of the bony structure. Phosphorus is a constituent of phospholipids, nucleoproteins, hexosephosphates, adenylic acid, creatine phosphate, lecithins and several other compounds of the body.

Since phosphorus functions in so many vital processes of the animal, there is little wonder that an adequate intake of this element is essential for optimal performance.

There are phosphorus deficient areas in parts of Oklahoma, and thus cattle grazing on forage in these areas tend to become phosphorus deficient. To prevent this deficiency, a phosphorus supplement is added to their ration. Steamed bonemeal or dicalcium phosphate are usually used.

In 1954, work was started to determine whether or not sodium phosphate could be used successfully as a phosphorus supplement for cattle and if so, to determine whether or not a linear relationship exists between phosphorus intake and weight gain of steers fed graded levels of phosphorus. The minimum phorphorus requirement and the possible toxicity of sodium phosphate were studied. A study with heifers, to determine the availability of phosphorus from dicalcium phosphate and colloidal clay phosphate, was also conducted.

REVIEW OF LITERATURE

Mitchell(1) states that of the elements needed by the animal phosphorus is foremost in importance. The bones contain 75 to 85 percent of the total phosphorus in the body, but according to Mitchell the stores of phosphorus in the skelton are difficult to tap when the need arises.

A deficiency of phosphorus is the most prevalent mineral deficiency of cattle in this country. Roughages that contain 0.12 percent or less will not provide adequate phosphorus to the animal.

Beeson(2) found that feeds containing 0.15 percent or less phosphorus were too low in phosphorus to satisfy the growth and fattening needs of steers. The symptoms of phosphorus deficiency that he observed were slow and inefficient gains, loss of appetite, lack of finish, rough hair coat, chewing boards and other foreign material, and eating dirt.

Beeson, Bolin and Hickman(3) showed that the minimum daily phosphorus requirement for fattening steer calves was about 2 gm. daily per 100 lb. of body weight. In a later report, Beeson et al.(4) set the minimum phosphorus requirement for fattening steers near 1.80 gm. per 100 lb. of body weight. They recommended, however, that under different conditions of feeding for optimum rate of gain and feed utilization, no less than 2.00 gm. daily per 100 lb. of body weight. These workers also reported that cottonseed meal was as effective as steamed bonemeal in preventing phosphorus deficiency.

Maynard, Greaves and Smith(5) in studying the effect of adding phosphorus supplements to sugar-beet rations, found that yearling steers showed definite aphosphorosis symptoms on a daily intake of 1.96 gm. phosphorus per 100 lb. of body weight, and that steer calves become phosphorus deficient when ingesting daily 1.62 gm. phosphorus per 100 lb. of body weight.

Hodgson et al.(6) found that steers consuming 2.11 gm. of phosphorus per 100 lb. of body weight from either steamed bonemeal or defluorinated superphosphate had better appetites, made larger and more economical gains, and had a more thrifty appearance than steers consuming 1.42 gm. The latter animals were unthrifty in appearance, exhibited wood chewing, made small gains in weight, had poor appetites, and were less efficient in the use of feed.

The National Research Council(7) recommends 15 gm. of phosphorus daily for normal growth of a 400-lb. steer, or a ration containing 0.21 percent phosphorus. Twenty gm. of calcium daily, or a ration containing 0.28 percent calcium is also recommended.

Knox, Benner and Watkins(8) reported that cattle grazing on forage of low phosphorus content, supplemented with sufficient dicalcium phosphate or steamed bonemeal to provide a daily consumption of about one gm. of phosphorus daily per 100 lb. of body weight, did not show phosphorus deficiency symptoms. Watkins and Knox(9) attributed this to the fact that New Mexico has a large number of days with sunshine, and thus cattle readily retain the phosphorus from materials eaten. This is supported by Wallis, Palmer and Gullickson(10) who state that phosphorus retention is markedly improved with adequate vitamin D in the ration. They found that phosphorus retention (3.25 gm. daily) was 11 times greater in animals on vitamin D therapy. Vitamin D was fed as viosterol, or the animals were exposed to sunshine.

Becker et al.(11) found that defluorinated superphosphate containing between 10.9 and 14.0 percent phosphorus and less than 0.20 percent fluorine could be substituted safely for steamed bonemeal in satisfying the phosphorus requirement of livestock; but, cattle performed better on the steamed bonemeal.

Mitchell(1) reported that the fluorine in rock phosphate and products made from them constitutes a hazard in the use of such supplements. Rock phosphate containing 3 or 4 percent fluorine is definitely unsafe. Defluorinated phosphate containing 0.1 percent or less is reasonably safe. The fluorine content of a cattle ration containing these supplements should not exceed 0.01 percent.

Hodgson et al.(6) have made extensive studies comparing steamed bonemeal and defluorinated superphosphate as supplements for steers. They reported that cattle consuming 1.96 gm. of phosphorus per 100 lb. of body weight performed normally and that either supplement was satisfactory when force-fed by mixing with the feed.

Ammerman et al.(12) using a balance technique observed no significant difference in phosphorus retention between steers fed dicalcium phosphate, steamed bonemeal, defluorinated rock phosphate, imported rock phosphate, or colloidal clay phosphate as sources of phosphorus. The level of phosphorus fed was not reported.

Meigs, Blatherwick and Cary(13) reported that the inorganic phosphorus in blood plasma of cattle would rise when sodium phosphate was added to the ration, and fall when the phosphate was withdrawn. Jones and Mullen(14) using supplements of bonemeal and raw phosphate rock made a similar observation; but, Robinson and Huffman(15) emphasize the fact that the variations observed were within the normal range of variation in blood plasma phosphorus values of animals on a constant diet.

Black et al.(16) state that it is possible to diagnose aphosphorosis by blood analysis before actual physical symptoms of this condition appear.

Payne et al.(17) reported that the normal levels for blood serum inorganic phosphorus in mg. percent were 7.3 for range Hereford yearlings and 5.07 for 2-year heifers.

Beeson et al.(4) considered steer calves with an inorganic blood phosphorus of 4 mg. percent to be deficient. Black et al.(16) states that phosphorus deficiency may exist in cows with plasma phosphorus levels of less than 4 mg. percent.

Maynard(18) stated that the blood phosphorus level of healthy cattle generally lies between 4 and 9 mg. percent, depending upon the age and species. However, Watkins and Knox (9) found that cattle with inorganic plasma phosphorus of 2.11 mg. percent in the winter, 5.37 mg. percent in the summer and fall, and a mean average of 3.53 mg. percent did not become phosphorus deficient.

Black et al.(16) found that range cattle weighing 600 lb. and given 6.5 gm. of phosphorus by hand dosing six times a week as bonemeal or disodium phosphate did not develope phosphorus deficiency.

Lewis et al.(19) found that giving phosphorus in a single dose at the rate of 7.5 gm. per 100 lb. of body weight produced slight incoordination and arched backs in five steers and convulsions in one. The plasma inorganic phosphorus rose from 2.8 mg. percent before drenching to 12.3 mg. percent after drenching. The calcium fell from 10.8 to 8.8 mg. percent. These values were for one steer that developed convulsions.

Since calcium is secondary to phosphorus in this report, the literature on the subject is not extensively covered. A deficiency of calcium in a ration will impair the utilization of phosphorus. The National

Research Council(7) states that the calcium to phosphorus ratio should be at least 1.33 to 1.

Determination of Plasma Phosphorus and Calcium.

The colorimetric determination of phosphorus by reduction of phosphomolybdate with stannous chloride to give a blue color was carried out in 1887 by Osmond(20). Denigès(21) and Truog and Meyer(22) made improvements on the method. Subsequent investigations have yielded a variety of data and opinions as to the nature of this so called "molybdenum blue". According to Schricker and Dawson(23) the name "molybdenum blue" properly applies only to that complex oxide or series of oxides of molybdenum lying between Mo_2O_5 and MoO_3. They also state that whether it is a single oxide or a series of oxides has not been fully established.

Many colorimetric procedures using a great variety of reducing agents have been proposed for the determination of phosphorus in biological material. Information concerning several of these methods is given in "Colorimetric Methods of Analysis" by Snell and Snell(24) and in "Photometric Chemical Analysis" by Yoe (25). Apparently the methods now in most general use in the United States are those proposed by Fiske and Subbarow(26) and the Briggs(27) modification of the Bell-Doisy(28) method. The method of Kuttnes and Cohen(29) has gained wide recognition in Europe. Fiske and Subbarow carried out the reduction in strong sulfuric acid(0.5N) and used a solution of 1-amino-2-naphthol-4-sulfonic acid as the reducing agent in a sulfite-bisulfite mixture. The principle advantages are (a) rapidity of color development, (b) proportionality between color density and the amount of phosphorus present over a wide range and (c) relative freedom of interference by such substances as ammonium and ferric salts, nitrates, silicates and chlorides.

Information concerning methods for determining calcium in blood serum is given in "Practical Physiological Chemistry" by Hawk, Oser and Summerson(30). In the Clark-Collip Modification(31) of the Kramer-Tisdall Method(32) calcium is precipitated directly from the serum as calcium oxalate. Excess sulfuric acid is added and the oxalic acid formed is titrated with standard potassium permanganate. Sendroy(33) has shown that direct precipitation as oxalate from diluted serum gives accurate results and that preliminary removal of protein is not necessary. Elliot and Pearson(34) reported that they obtained accurate serum calcium values by adding excess potassium permanganate to the oxalic acid solution and determining the calcium content by the color intensity of the unreduced permanganate.

EXPERIMENTAL

Steers.

Nine grade Hereford steers, which weighed approximately 410 pounds, were used to determine the response of cattle to graded levels of phosphorus in the ration. The basal ration that was formulated had to have a low phosphorus content and yet be adequate for growth and fattening when supplemented with phosphorus. The composition of the basal ration is given in Table I.

TABLE I

PERCENTAGE COMPOSITION OF EXPERIMENTAL RATIONS

Ingredients	Ration 1 (basal)	Ration 2 (0.14 percent P)	Ration 3 (0.19 percent P)
Cottonseed hulls	36.10	36.10	36.10
Dried beet pulp	27.20	27.20	27.20
Dehydrated alfalfa meal	9.10	9.10	9.10
Cerelose	18.00	18.00	18.00
Corn gluten meal	9.10	9.10	9.10
Urea (Two-Sixty-Two)	0.10	0.10	0.10
A and D supplement[1]	0.20	0.20	0.20
Salt (NaCl)	0.20	0.20	0.20
Sodium phosphate[2]	----	0.22	0.44
Calcium carbonate[3]	----	0.36	0.88
P from supplement	----	0.05	0.10
P from basal	0.09	0.09	0.09

1 Contributed vitamin A, 2724 I. U., and vitamin D, 340 I. U., per lb. of total ration.

2 $NaH_2PO_4 \cdot H_2O$. The compound used contained 23.25 percent P .

3 To keep calcium : phosphorus ratio about 5:1.

Analysis of this ration showed it to contain 0.094 percent phosphorus, 0.44 percent calcium and to have a calcium-phosphorus ratio of approximately 5:1.

The basal ration was fed for 66 days so that the steers would be in a relatively uniform state of phosphorus nutrition at the start of the test period. In fact, they were partially depleted of phosphorus, as evidenced by low plasma phosphorus values.

After this depletion period, the steers were divided according to plasma phosphorus levels, weight and general appearance into three lots, each lot having three steers. Lot 1 was continued on the basal ration. Lot 2 was fed the basal ration plus a supplement to give a total of 0.14 percent phosphorus and lot 3 was fed the basal ration plus a supplement to give a total of 0.19 percent phosphorus. The supplement was $NaH_2PO_4 \cdot H_2O$.[1] The composition of the two supplemental rations is given in Table I. The steers were continued on the rations for 105 days.

The experimental data collected, in addition to observations of general performance and appearance, were feed intake, weight gains and inorganic plasma phosphorus levels. The initial and final weights of the steers during this period, feed intake and the change in their plasma phosphorus levels are shown in Table V.

Blood samples were taken from the jugular vein at approximately two-week intervals. The samples were collected in heavy-wall pyrex test tubes containing lithium citrate as an anticoagulant. Slightly over 1 ml. of lithium citrate solution per 25 ml. of blood was added to each tube and the solution evaporated to dryness on a hot plate, leaving a fluffy residue that dissolved immediately when the blood came in contact with it. The lithium citrate solution contained 0.1 gm. per ml.

---

[1] The term sodium phosphate used throughout this paper refers to this compound.

The blood samples were chilled and brought to the laboratory for analysis. After centrifugation at 2000 rpm. for 30 minutes, the clear plasma was analysed for inorganic phosphorus by a modification of the Fiske and Subbarow method (26). The plasma proteins were precipitated by pipetting 0.5 ml. of clear plasma into 9.5 ml. of a 10 percent solution of trichloroacetic acid. The precipitated proteins were spun down (1500 rpm. for 15 minutes) and a 5-ml. aliqout of the clear supernatant liquid was placed in a colorimeter tube. One ml. of molybdate II reagent, made by dissolving 25 gm. of ammonium molybdate in 300 ml. of 10 N sulfuric acid and making to a liter with water, was added to form phosphomolybdic acid. This compound was then reduced with 0.4 ml. of aminonaphtholsulfonic acid solution. This latter reagent contains 0.25 gm. of 1-amino-2-naphthol-4-sulfonic acid, 0.5 gm. of sodium sulfite and 14.25 gm. of sodium bisulfite in 100 ml. of water. Reduction of the phosphomolybdic acid with the aminonaphtholsulfonic acid reagent produces a blue color. The volume in the colorimeter tube was made to 10 ml. with water and after standing 20 minutes the color intensity was determined with an Evelyn colorimeter at a wave length of 660 mμ. The concentration of phosphorus in the tube was determined from a standard curve. In the method described above, a dilution factor of 400 was necessary to convert the micrograms of phosphorus in the tube to milligrams phosphorus per 100 ml. of plasma.

Heifers.

Twelve grade Hereford heifers and 12 Angus x Hereford heifers were used to study the availability of phosphorus from different mineral supplements. They were fed the same basal ration as was described in the experiment with steers for 66 days and then divided into three lots.

Each lot contained four crossbred and four Hereford animals. Lot 1 continued to be fed the basal ration. Lot 2 was fed the basal ration plus a supplement of 0.05 percent phosphorus as colloidal clay phosphate[2] and lot 3 was fed the basal ration plus a supplement of 0.05 percent phosphorus as dicalcium phosphate. The rations are given in Table II.

TABLE II

PERCENTAGE COMPOSITION OF EXPERIMENTAL RATIONS

Ingredients	Ration 1 (Basal)	Ration 2 (Colloidal clay)	Ration 3 (Dicalcium phosphate)
Cottonseed hulls	36.10	36.10	36.10
Dried beet pulp	27.20	27.20	27.20
Dehydrated alfalfa meal	9.10	9.10	9.10
Cerelose	18.00	18.00	18.00
Corn gluten meal	9.10	9.10	9.10
Urea (Two-Sixty-Two)	0.10	0.10	0.10
A and D supplement[1]	0.20	0.20	0.20
Salt (NaCl)	0.20	0.20	0.20
Dicalcium phosphate[2]	----	----	0.27
Colloidal clay[3]	----	0.67	----
Calcium carbonate[4]	----	0.09	0.14
P from supplement	----	0.05	0.05
P from basal	0.09	0.09	0.09

1 Contributed vitamin A, 2724 I. U., and vitamin D, 340 I. U., per lb. of total ration.

2 Contained 18.50 percent phosphorus and 29.83 percent calcium.

3 Contained 8.6 percent phosphorus and 15.10 percent calcium and 0.97 percent fluorine.

4 To keep calcium : phosphorus ration about 5:1.

---

2 When rock phosphate is processed to superphosphate and dicalcium phosphate a product called soft phosphate with colloidal clay results. The term colloidal clay used in this writing refers to this product.

The animals were continued on these rations for 100 days. Observations were made as in the experiment with steers, and blood samples were taken at two-week intervals. Initial and final weights in the 100-day period, feed intake and plasma phosphorus values are shown in Table VI.

At the end of the 100-day period each lot was reduced to the four Hereford heifers. Lot 1 was used to study repletion and was given the same ration as lot 3 (0.05 percent supplemental phosphorus as dicalcium phosphate) for a period of 80 days. Lots 2 and 3 remained on their previous rations. Weights, feed intake and blood phosphorus values are shown in Table VI.

Oral Doses of Phosphorus.

To determine the effect of oral doses of phosphorus, at the end of these experiments two of the steers from lot 1 and two from lot 2 were given 7.5 gm. of phosphorus per 100 lb. of body weight, or twice the daily amount recommended by the National Research Council (7). The phosphorus was given in a single dose as sodium phosphate in gelatin capsules. Four days later three of these and one other steer were given the same amount of phosphorus by drench. In this method the sodium phosphate was dissolved in about a liter of water. A tube was forced down the esophagus into the animal's first stomach and the solution pumped in with a stomach pump. The amounts of sodium phosphate given are listed in Table III. Blood samples were taken over a 12-hour period and analysed for phosphorus. The results are in Tables VII and VIII.

In a similar manner four heifers, two from lot 2 and two from lot 3, were drenched with 7.5 gm. of phosphorus per 100 lb. body weight; and four heifers, two from lot 2 and two from lot 3, were drenched with

10.0 gm. of phosphorus per 100 lb. of body weight. The amounts given are shown in Table IV. Blood samples were taken for phosphorus determinations over a period of 12 hours. The results are shown in Table VIII.

TABLE III

AMOUNTS OF SODIUM PHOSPHATE GIVEN STEERS

Steer number	Weight (lb.)	Sodium phosphate		Previous ration (percent P)
		Capsule (gm.)	Drench (gm.)	
02	430	140.2	140.2	0.10
04	432	140.8	140.8	0.10
05	515	168.0	-----	0.20
07	562	183.0	183.0	0.20
08	440	-----	143.4	0.10

TABLE IV

AMOUNTS OF SODIUM PHOSPHATE GIVEN HEIFERS

Heifer[1] number	Weight (lb.)	Drench[2] (7.5 gm. P/100 lb. body weight)	Heifer[1] number	Weight (lb.)	Drench[2] (10.0 gm. P/100 lb. body weight)
53	440	143.5	57	430	187.0
50	535	174.0	47	630	274.0
46	690	225.0	48	610	265.0
49	605	197.0	54	745	322.0

1 Heifers 53, 50, 57 and 47 had been on ration 2; the other heifers had been on ration 3.

2 Values are in grams of sodium phosphate.

The calcium values of the plasma of cattle after dosing with 7.5 or 10.0 gm. of phosphorus were determined by the Clark-Collip modification (31) of the Kramer-Tisdall method for determining blood serum calcium. In this method 2 ml. of distilled water, 2 ml. of plasma and 1 ml. of 4 percent ammonium oxalate were introduced into a 15 ml. centrifuge tube. The contents were throughly mixed by holding the tube at the mouth and giving the contents a circular motion by tapping the lower end. After standing for 30 minutes the tubes were centrifuged at 1500 rpm. for 5 minutes. The supernatant liquid was carefully poured off and the tube inverted and allowed to drain 5 minutes. The mouth of the tube was wiped dry with a soft cloth and the precipitate throughly washed with 3 ml. of dilute ammonium hydroxide (2 ml. of concentrate ammonium hydroxide in 100 ml. solution). The suspended precipitate was centrifuged and the tube drained as before. The precipitate was dissolved in 1 normal sulfuric acid with the aid of heat and a pointed stirring rod. The solution was brought to a temperature above 75°C by placing the tube in a boiling water bath and then titrated with 0.01 N potassium permanganate delivered from a microburette graduated in 0.02 ml. A blank was titrated and the value so obtained is subtracted for the burette reading for the sample. The corrected reading multiplied by 10 gives the mg. percent calcium in the sample. The Elliot-Pearson (34) method for serum calcium was investigated with a number of samples. The results are not reported, since the color of the excess potassium permanganate faded rapidly and constant galvanometer readings were not obtained. Apparently small, variable amounts of organic matter are separated with the calcium oxalate precipitate. Such material reduces the MnO_4^- to $Mn.^{++}$ An initial transmittance of 47 percent rose to 56 percent in 10 minutes.

RESULTS

Steers.

At the end of the 66-day depletion period all the steers had low plasma phosphorus; the average for each lot was less than 4 mg. percent. The average weight of the steers was about 412 lb. They were consuming about 7.4 lb. of feed per day. These values are shown in Table V. Detailed data are in the Appendix. Tables X - XIV.

TABLE V

AVERAGE WEIGHT, FEED INTAKE AND PLASMA PHOSPHORUS LEVEL OF STEERS

Lot number	Weight (lb.)		Daily feed intake[1] (lb.)		Plasma P (mg. percent)	
	66 days	171 days	66 days	171 days	66 days	171 days
1	413	434	7.2	4.7	3.87	2.87
2	411	539	7.4	10.0	3.81	5.43
3	411	551	7.4	10.0	3.64	6.09

1 Average daily values for last 30 days of periods.

At the end of the experimental period, lot 1 which received only the basal ration exhibited phosphorus deficiency symptoms such as unthriftiness, swollen joints, depressed appetite and poor feed utilization. Plasma phosphorus had dropped from 3.87 to 2.87 mg. percent. Feed intake dropped from 7.2 to 4.7 lb. per day and the steers gained only 21 lb. in weight during the 105-day period.

During the same period little difference was noted between the steers in lot 2 (0.14 percent P) and lot 3 (0.19 percent P). They started on the supplemented rations with plasma phosphorus values of 3.81 and 3.64

mg. percent, respectfully, and finished with values of 5.43 and 6.09 mg. percent. They exhibited no signs of phosphorus deficiency. Their feed intake increased from 7.4 to 10.0 lb. per day and they gained 128 and 140 lb. in weight, respectfully, in the 105-day period.

Heifers.

At the time the heifers were started on the supplemented rations they showed no signs of phosphorus deficiency. They had been fed the basal ration for 66 days. The plasma phosphorus for the three lots was 2.84, 2.66 and 3.06 mg. percent, respectfully. At the end of the 100-day experimental period these values were 2.04, 2.83 and 3.67 mg. percent, respectfully. Lots 1 and 2 became phosphorus deficient during this time, exhibiting pica, coprophagy, and enlarged joints; and, they walked with difficulty. Lot 3 was normal. Feed intake dropped from 12.3 lb. per day to 9.1 and 11.6 lb. per day (average for last 30 days of period) for lots 1 and 2, respectfully. Feed intake for lot 3 increased to 14.7 lb. per day. The weight gains were 39, 55 and 145 lb., for lots 1, 2 and 3, respectfully. The above values for feed intake, weight gain and plasma phosphorus are shown in Table VI. Detailed data are in the Appendix. Tables X - XV.

During the next 80-day period (repletion for lot 1), lot 1 showed a small gain in plasma phosphorus from 2.04 to 2.44 mg. percent. Feed intake increased from 9.1 to 12.0 lb. per day, and the heifers gained 49 lb. in weight. Phosphorus deficiency was less apparent, and the animals showed only occasional signs of pica and coprophagy. One animal, however, was creepy. During the same period, the heifers of lot 2 continued to show signs of phosphorus deficiency and their condition became progressively worse. Several had elongated hoofs. The plasma phosphorus dropped from 2.83 to 2.38 mg. percent; feed intake dropped from 11.6 to 8.3 lb. per day, and the heifers lost 15 lb. in weight. The heifers in lot 3, during this period, were normal. Their plasma phosphorus decreased slightly from 3.67 to 3.43 mg. percent; feed intake increased from 14.0 to 15.9 lb. per day and the heifers gained 48 lb. in weight.

TABLE VI

AVERAGE WEIGHT, FEED INTAKE AND PLASMA PHOSPHORUS LEVEL OF HEIFERS

Lot number	Weight (lb.)			Feed intake[1] (lb.)			Plasma P (mg. percent)		
	66 da.	166 da.	246 da.	66 da.	166 da.	246 da.	66 da.	166 da.	246 da.
1	464	503	552	12.3	9.1	12.0	2.84	2.04	2.44
2	469	524	509	12.3	11.6	8.3	2.66	2.83	2.38
3	469	614	662	12.3	14.7	15.9	3.06	3.67	3.43

1 Average daily values for last 30 days of periods.

Oral Doses of Phosphorus.

The effect on plasma phosphorus levels of dosing cattle with 7.5 gm. or 10.0 gm. of phosphorus per 100 lb. of body weight is shown in Tables VII and VIII.

Steers 02 and 04 had plasma phosphorus values of 2.32 mg. percent when given by capsule 7.5 gm. phosphorus per 100 lb. of body weight. Plasma phosphorus increased to 6.80 mg. percent in steer 02 and 5.80 mg. percent in steer 04. These peak values were reached 10 and 12 hours after the phosphorus administration. Four days later the plasma phosphorus of steer 02 was down to 4.08 mg. percent. It was then given phosphorus by drench. Plasma phosphorus increased to 8.52 mg. percent at the end of 12 hours. Steer 08, which had a low plasma phosphorus of only 2.24 mg. percent, was drenched in a similar manner. Plasma phosphorus almost tripled, reaching a peak of 6.46 mg. percent in 8 hours. All of these steers were from lot 1. They were similar in that they had low plasma phosphorus values before dosing and these values more than doubled after phosphorus administration by capsule or drench.

TABLE VII

PLASMA PHOSPHORUS LEVELS OF STEERS GIVEN SODIUM PHOSPHATE

Steer number	Previous ration	Plasma phosphorus levels (mg. percent)					
		0 hr.	4 hr.	6 hr.	8 hr.	10 hr.	12 hr.
		7.5 gm. P per 100 lb. body weight by capsule					
02	1	2.32	4.24	4.44	4.00	6.80	4.20
04	1	2.32	2.88	3.80	4.28	5.32	5.80
05	3	7.04	11.72	10.64	11.84	11.72	11.92
07	3	5.60	6.64	9.56	10.36	12.52	11.92
		7.5 gm. P per 100 lb. body weight by drench					
02	1	4.08	7.88	8.16	8.00	8.40	8.52
08	1	2.24	6.24	6.00	6.46	6.00	5.52
05	3	6.68	9.00	10.52	10.08	11.04	10.80
07	3	5.88	9.84	10.36	9.52	11.72	11.04

The steers treated from lot 3 were numbers 05 and 07. Both were given 7.5 gm. phosphorus per 100 lb. body weight by the two methods. They had plasma phosphorus values of 7.04 and 5.60 mg. percent, respectfully, when treated by capsule. Their plasma phosphorus values reached peaks of 11.92 and 12.52 mg. percent. Four days later their plasma phosphorus had gone down to 6.68 and 5.88 mg. percent. At this time they were drenched with 7.5 gm. phosphorus per 100 lb. of body weight.

Their plasma phosphorus rose to 11.04 and 11.72 mg. percent. Initial plasma phosphorus values were relatively high in both of these steers; treatment doubled the value in the case of only number 07.

The reaction of the heifers drenched with 7.5 gm. phosphorus per 100 lb. body weight was comparable to that of the steers. These results are found in the first part of Table VIII.

TABLE VIII

PLASMA PHOSPHORUS LEVELS OF HEIFERS DRENCHED WITH SODIUM PHOSPHATE

Heifer number	Previous ration	Plasma phosphorus levels (mg. percent)					
		0 hr.	4 hr.	6 hr.	8 hr.	10 hr.	12 hr.
		7.5 gm. P per 100 lb. body weight					
53	2	2.68	5.64	5.24	6.68	7.12	6.56
50	2	2.48	4.96	6.72	5.44	5.56	5.92
46	3	3.60	6.12	5.80	4.64	6.08	5.60
49	3	2.48	4.64	3.48	3.44	5.04	3.76
		10.0 gm. P per 100 lb. body weight					
57	2	1.68	3.04	2.56	2.48	3.04	3.60
47	2	3.28	8.60	8.40	7.52	9.40	8.52
48	3	3.28	9.24	10.24	10.60	9.04	7.84
54	3	5.08	14.28	13.76	12.12	11.04	12.40

Heifers 57 and 47 had previously been on the colloidal clay ration. They had low initial plasma phosphorus values of 1.68 and 3.28 mg. percent. These values increased after drenching with 10 gm. phosphorus per 100 lb. of body weight to 3.60 and 9.40 mg. percent, respectively. Heifers 48 and 54 had previously been on the dicalcium phosphate ration. They had plasma phosphorus values of 3.28 and 5.08 mg. percent respectfully. After drenching with 10 gm. phosphorus per 100 lb. of body weight, these values rose to 10.60 and 14.28 mg. percent, respectfully. In most cases the peak values were reached from 8 to 12 hours after drenching. In heifer 54, however, the peak value of over 14 mg. percent was reached within 4 hours. This heifer was the largest of the group and therefore was given the largest dose of sodium phosphate. She died from unknown causes, about 24 hours after treatment. All the other animals survived and appeared normal a few hours after treatment.

Changes in plasma calcium are of even greater interest, perhaps, than the changes in phosphorus. For that reason, plasma calcium values of heifers drenched with sodium phosphate are shown with the phosphorus values in Table IX.

TABLE IX

PLASMA CALCIUM AND PHOSPHORUS LEVELS (mg. percent) OF HEIFERS DRENCHED WITH SODIUM PHOSPHATE

Time (hr.)	No. 46		No. 49		No. 50		No. 53	
	Ca	P	Ca	P	Ca	P	Ca	P
7.5 gm. phosphorus per 100 lb. body weight								
0	12.2	3.60	13.8	2.48	13.9	2.48	----	2.68
4	10.1	6.12	13.4	4.64	11.2	4.96	12.1	5.64
6	8.4	5.80	13.5	3.48	11.1	6.72	9.6	5.24
8	9.7	4.64	11.7	3.44	9.7	5.44	----	6.68
10	8.3	6.08	10.6	5.04	8.8	5.56	9.7	7.12
12	8.0	5.60	7.4	3.76	7.3	5.92	7.7	6.56

Time (hr.)	No. 47		No. 48		No. 54		No. 57	
	Ca	P	Ca	P	Ca	P	Ca	P
10.0 gm. phosphorus per 100 lb. body weight								
0	11.1	3.28	11.7	3.28	10.3	5.08	11.7	1.68
4	10.6	8.60	11.2	9.24	9.6	14.28	11.0	3.04
6	10.0	8.40	8.4	10.24	7.9	13.76	11.7	2.56
8	8.4	7.52	8.3	10.60	8.1	12.12	11.4	2.48
10	8.0	9.40	7.3	9.04	7.3	11.04	9.9	3.04
12	7.9	8.52	7.3	7.84	7.3	12.40	9.4	3.60

It will be noted that plasma calcium values decreased after phosphorus administration, but this decrease was not generally apparent until 6 to 8 hours after drenching. In fact, calcium values reached the lowest level of about 7 mg. percent 12 hours after drenching.

DISCUSSION

In these feeding trials with steers fed rations containing 0.09, 0.14 and 0.19 percent phosphorus, the steers on the lowest level of phosphorus developed physical conditions characteristic of phosphorus deficiency. Their condition failed to improve after they were turned out to pasture. There was very little difference between the steers on the rations containing 0.14 and 0.19 percent phosphorus in the ration. Plasma phosphorus values were only slightly lower for the steers fed 0.14 percent phosphorus than for those fed 0.19 percent. In testing the availability of phosphorus in supplements, therefore, it would appear necessary to feed rations containing less than 0.14 percent phosphorus.

The heifers on the low phosphorus basal ration (no. 1) and those on the colloidal clay ration (no. 2) were in extremely poor physical condition at the end of the test period. Those that were changed from the basal to the dicalcium phosphate ration improved. However, one heifer from lot 1 and two from lot 2 had to be slaughtered at this time because of their condition. The remaining nine heifers were returned to grass. Two weeks later one of the remaining heifers from lot 2 was slaughtered when she became unable to walk. Forty-three days later the fourth and only remaining heifer from lot 2 was slaughtered. She had been on grass for 57 days in which time she had lost 123 lb. The fluorine content was 0.97 percent in the colloidal clay phosphate. There is a possibility that the cattle in this lot suffered from fluorine toxicity as well as phosphorus deficiency.

If the difference in plasma phosphorus, at the end of the test period, between lots 1 and 3 is ascribed to dicalcium phosphate and assigned a value of 100 the relative value of colloidal clay is 48.

Dosing with 7.5 or 10.0 gm. of phosphorus per 100 lb. of body weight affected the animals only slightly, except for animal 54. This animal had been on the dicalcium phosphate ration, had gained weight and performed normally throughout the trial. She had gained 380 lb., or more than doubled her weight (from 365 to 745 lb.) in the 180 days. She had shown no signs of sickness during the trial and no signs of phosphorus toxicity during the first 12 hours after drenching with 322 gm. of sodium phosphate. Yet, 24 hours after the drench she was found dead. The autopsy revealed little information as to what happened to her. There was slight congestion of the lungs, hemorrhaging from the treachea and from 6 to 8 feet of the small intestion. The cause of death was not determined.

CONCLUSIONS

Sodium phosphate can be used successfully as a phosphorus supplement for growth and fattening of steers.

The phosphorus requirement for growth and fattening of steers as determined by this experiment is about 0.14 percent phosphorus in the ration. Steers fed this amount of phosphorus from a cottenseed hull ration and sodium phosphate supplement performed satisfactorily.

Growth, feed intake and plasma phosphorus are closely related to the phosphorus intake at levels of 0.09 and 0.14 percent phosphorus in the ration. Little advantage is gained by feeding more than 0.14 percent in the ration.

Colloidal clay phosphate containing 0.97 percent fluorine is a poor source of supplemental phosphorus. Heifers on a ration containing 0.14 percent phosphorus, of which about one-third is from such a supplement, will be in poor physical condition. They exhibit slow growth, low feed intake and poor feed utilization, and have low plasma phosphorus. Heifers on the same basal ration supplemented with an equivalent amount of dicalcium phosphate will perform satisfactorily.

Supplemental phosphorus added to rations ample in other nutrients will not cure injuries due to prolonged phosphorus deficiency.

Cattle with plasma phosphorus of 3 to 4 mg. percent are borderline deficient; below this amount they frequently show phosphorus deficiency symptoms.

Dosing with 7.5 or 10.0 gm. of phosphorus per 100 lb. of body weight increases the plasma phosphorus level within 4 hours. The amount of increase is related to the plasma phosphorus value before dosing. Peak values are reached about 10 hours after dosing. Calcium values drop as phosphorus values rise.

A plasma phosphorus level of 14.0 mg. percent may be fatal to cattle.

BIBLIOGRAPHY

1. Mitchell, H. H.
The mineral requirement of farm animals.
J. Animal Sci., 6, 365-77 (1947).

2. Beeson, W. M.
Phosphorus needs for fattening steers.
Idaho Agr. Exp. Sta. Circ. No. 83, 6 pp. (1941).

3. Beeson, W. M., D. W. Bolin and C. W. Hickman.
The phosphorus requirement of beef cattle.
Proc. Am. Soc. Animal Production, 92-5 (1937).

4. Beeson, W. M., D. W. Bolin, C. W. Hickman and R. F. Johnson.
The phosphorus requirement for growing and fattening beef steers.
Idaho Agr. Exp. Sta. Bull., 240, 14 pp. (1941).

5. Maynard, E. J., J. E. Greaves and H. H. Smith.
Phosphorus supplements improve sugar-beet by-product rations for cattle.
Utah Agr. Exp. Sta. Bull., 265, 29 pp. (1936).

6. Hodgson, C. W., R. F. Johnson, A. C. Wiese and C. W. Hickman.
A comparison of steamed bonemeal and defluorinated superphosphate as phosphorus supplements for fattening cattle.
J. Animal Sci., 7, 273-8 (1948).

7. National Research Council, Committee on Animal Nutrition.
Recommended Nutrient Allowances for Beef Cattle, No. 4, (1950).

8. Knox, J. H., J. W. Benner and W. E. Watkins.
Seasonal calcium and phosphorus requirements of range cattle, as shown by blood analysis.
New Mexico Agr. Exp. Sta. Bull., 282, 28 pp. (1941).

9. Watkins, W. E. and J. H. Knox.
Inorganic blood phosphorus levels necessary for satisfactory production of range cattle in the southwest.
J. Animal Sci., 7, 263-72 (1948).

10. Wallis, G. C., L. S. Palmer and T. W. Gullickson.
The relation of vitamin D to calcium and phosphorus retention in cattle as shown by balance trials.
J. Dairy Sci., 18, 213-28 (1935).

11. Becker, R. B., G. K. Davis, W. G. Kirk, R. S. Glasscock, P. T. Dix Arnold and J. E. Pace.
Defluorinated superphosphate for livestock.
Florida Agr. Exp. Sta. Bull., 401, 15 pp. (1944).

12. Ammerman, C. B., A. L. Neumann, R. M. Forbes and H. W. Norton. Utilization of phosphorus from various inorganic sources. J. Animal Sci., 13, 974 (1954).

13. Meigs, E. B., N. R. Blatherwick and C. A. Cary. Contribution to the physiology of phosphorus and calcium metabolism as related to milk secretion. J. Biol. Chem., 37, 1-75 (1919).

14. Jones, W. B. and J. H. Mullen. M.S. Thesis, Michigan State College. (1926). (Cited by Eckles, Gullickson and Palmer, Minn. Agr. Exp. Sta. Tech. Bull., 91, 1932)

15. Robinson, C. S. and C. F. Huffman. Studies on the chemical composition of beef blood. J. Biol. Chem., 67, 245-55 (1926).

16. Black, W. H., L. H. Tash, J. M. Jones and R. J. Kleberg, Jr. Effects of phosphorus supplements on cattle grazing on range deficient in this mineral. U. S. Dep. Agr. Tech. Bull., 856, 23 pp. (1943).

17. Payne, M. G., A. G. Clark, H. E. Kingman and W. M. Stansbury. Blood levels of calcium and inorganic phosphorus in hereford cattle. J. Agr. Research, 72, 353-63 (1946).

18. Maynard, L. A. "Animal Nutrition," 2nd Ed. pp. 120-1, McGraw-Hill Book Co. Inc., New York, 1947.

19. Lewis, J. K., W. H. Burkett, L. Seghetti and F. B. Wilson. Toxicity in steers from drenching with excess phosphorus. North Am. Veterinarian, 32, 830-1 (1951).

20. Osmond, F. Colorimetric estimation of phosphorus. J. Chem. Soc., 52, 999 (1887).

21. Denigès, G. Sensitive colour reaction of phosphates and arsenates. Analyst, 46, 24 (1921).

22. Truog, E. and A. H. Meyer. Improvements in the Denigès colorimetric method of phosphorus and arsenic. Ind. Eng. Chem., Anal. Ed., 1, 136-9 (1929).

23. Schricker, J. A. and P. R. Dawson. Improved molybdenum blue reagents for determination of phosphorus and arsenic. J. Assoc. Offic. Agr. Chemists, 22, 167-79 (1939).

24. Snell, F. D. and C. T. Snell.
"Colorimetric Methods of Analysis," 3rd Ed. pp. 630-81, D. Van Nostrand Co. Inc., New York, 1949.

25. Yoe, J. H.
"Photometric Chemical Analysis," Vol. 1, pp. 336-54, John Wiley and Sons, New York, 1928.

26. Fiske, C. H. and Y. Subbarow.
The colorimetric determination of phosphorus.
J. Biol. Chem., 66, 375-400 (1925).

27. Briggs, A. F.
A modification of the Bell-Doisy phosphate method.
J. Biol. Chem., 53, 13-16 (1922).

28. Bell, R. D. and E. A. Doisy.
Rapid colorimetric methods for the determination of phosphorus in urine and blood.
J. Biol. Chem., 44, 55-67 (1920).

29. Kuttner, T. and H. R. Cohen.
Micro-colormetric studies.
J. Biol. Chem., 75, 517-31 (1927)

30. Hawk, P. B., B. L. Oser and W. H. Summerson.
"Practical Physiological Chemistry," 13th Ed. pp. 644-8, Philadelphia, 1954.

31. Clark, E. P. and J. B. Collip.
A study of the Tisdall method for the determination of blood serum calcium with a suggested modification.
J. Biol. Chem., 63, 461-4 (1925).

32. Kramer, B. and F. F. Tisdall.
A simple technique for the determination of calcium and magnesium in small amounts of serum.
J. Biol. Chem., 47, 475-81 (1921).

33. Sendroy, J. Jr.
Determination of serum calcium by precipitation with oxalate.
J. Biol. Chem., 152, 539-56 (1944).

34. Elliot, J. E. and P. B. Pearson.
A direct photoelectric method for the determination of serum calcium.
J. Lab. Clin. Med., 31, 1262-6 (1946).

APPENDIX

TABLE X

STEER WEIGHTS IN POUNDS AT DIFFERENT DATES (1954-55)

Animal number	12-27	12-28	1-15	1-29	2-17	3-3	3-17	3-31	4-5	4-14	4-28	5-12	5-26	6-15
Ration 1														
02	400	400	425	380	403	420	433	429	440	443	447	437	437	430
04	395	400	420	375	396	404	420	415	432	430	440	435	437	432
08	390	405	425	395	417	415	435	447	459	432	450	443	455	440
Average						413	429	430	444	435	446	438	443	434
Ration 2														
09	410	420	435	390	410	424	450	463	480	483	498	512	548	547
01	365	375	425	375	394	410	421	440	455	455	480	490	520	530
06	395	400	410	380	408	399	430	444	451	465	485	505	545	540
Average						411	434	449	462	468	488	502	538	530
Ration 3														
07	400	400	420	380	412	431	455	465	490	488	501	530	555	562
03	395	400	435	385	420	431	458	470	482	498	512	540	577	575
05	365	380	410	360	385	370	421	433	445	430	472	490	491	515
Average						410	445	456	472	472	495	520	541	551

TABLE XI

HEIFER WEIGHT IN POUNDS AT DIFFERENT DATES (1954-55)

Animal number	12-27	12-28	1-15	1-29	3-3	3-5	3-20	4-2	4-17	4-30	5-14	5-28	6-11[1]	7-3	7-15	7-29	8-16	8-30
Ration 1 Basal																		
4	415	430	470	470	500	475	485	490	495	500	500	510	500					
6	400	405	420	440	460	450	470	475	470	475	475	480	475					
10	475	480	515	515	535	510	545	520	545	545	565	565	560					
12	470	495	520	535	550	520	525	545	550	545	545	550	560					
51	395	400	425	440	500	475	490	500	520	525	520	520	525	510	495	510	520	520
52	375	385	410	410	435	410	425	415	435	430	430	440	430	455	455	485	500	500
55	370	380	400	410	455	425	435	445	480	475	520	495	485	515	520	550	565	585
56	365	390	435	430	475	450	465	465	490	490	480	485	495	520	540	565	585	605
Average						464	480	482	498	498	504	506	503	500	503	515	542	552
Ration 2 Colloidal Clay																		
3	385	400	445	445	475	450	465	475	495	485	500	505	515					
5	355	375	380	405	435	410	430	450	470	465	470	495	460					
8	510	530	575	580	635	609	615	640	665	660	680	670	680					
11	400	400	430	470	525	500	515	540	555	570	575	585	570					
47	390	395	430	450	495	470	495	530	540	555	565	585	570	585	580	605	630	630
50	390	395	420	425	485	460	485	480	510	500	485	505	505	510	495	515	510	535
53	385	405	420	415	425	415	450	455	460	460	470	455	440	430	450	430	450	440
57	410	415	405	430	460	435	470	470	475	475	465	465	450	440	430	420	425	430
Average						469	491	505	520	521	526	533	524	491	489	492	504	509

Ration 3 Dicalcium Phosphate

1	470	480	520	540	530	515	560	580	600	595	605	610	600					
2	370	380	410	425	465	445	490	510	540	560	585	620	640					
7	435	450	500	515	575	530	590	615	665	680	700	690	725					
9	425	440	445	460	490	465	505	520	550	560	585	600	600					
46	400	405	435	445	470	465	510	525	560	585	605	620	620	635	655	670	700	690
48	465	390	410	375	400	390	420	430	480	470	460	495	490	525	530	570	590	610
49	435	450	465	475	495	465	515	520	540	550	580	575	580	580	580	595	605	605
54	365	375	425	440	500	475	520	550	585	600	620	650	655	640	645	690	725	745
Average						469	514	531	565	575	592	607	614	595	602	631	655	662

1 Four heifers from each lot were slaughtered after June 11; the heifers remaining in the lot fed the basal ration were fed ration 3 after this date.

TABLE XII

DAILY FEED CONSUMPTION IN POUNDS AT DIFFERENT DATES (STEERS 1955)

	Date								
Animal number	1-15 2-15	2-15 3-8	3-8 3-17	3-17 3-31	3-31 4-14	4-14 4-28	4-28 5-12	5-12 5-28	5-28 6-15
				Ration 1 Basal					
02	6.99	7.71	8.74	7.41	9.14	5.79	5.07	5.21	4.84
04	6.99	6.34	8.74	6.44	8.36	6.14	5.07	5.21	4.61
08	6.99	7.56	8.74	8.07	9.21	6.86	4.68	5.50	4.72
Average	6.99	7.20	8.74	7.31	8.90	6.26	4.94	5.31	4.72
				Ration 2 (0.144% P)					
05	6.99	7.76	8.63	8.00	9.93	9.43	10.0	10.21	10.00
01	6.99	7.95	8.74	7.78	9.93	9.43	10.0	9.75	10.00
06	6.99	6.56	8.74	8.37	9.93	9.43	10.0	10.10	10.00
Average	6.99	7.42	8.70	8.05	9.93	9.43	10.0	10.02	10.00
				Ration 3 (0.194% P)					
07	6.99	7.95	8.74	8.37	9.93	9.43	10.0	10.07	10.00
03	6.99	7.80	8.74	8.07	9.93	9.43	10.0	10.07	10.00
05	6.99	6.44	8.74	8.07	9.93	9.43	10.0	10.07	10.00
Average	6.99	7.40	8.74	8.07	9.93	9.43	10.0	10.07	10.00

TABLE XIII

DAILY FEED CONSUMPTION IN POUNDS AT DIFFERENT DATES (HEIFERS 1955)

Ration number	Date 1-15 3-3	3-3 3-20	3-20 4-17	4-17 4-30	4-30 5-14	5-14 6-11	6-11[1] 7-2	7-2 7-29	7-29 8-30
1	12.27	10.83	9.54	8.21	9.86	9.12	10.27	11.86	12.05
2	12.27	11.88	12.10	11.84	12.49	11.57	11.77	7.92	8.28
3	12.27	13.97	14.85	13.79	14.65	14.71	13.61	16.01	15.88

1 Four heifers from each lot were slaughtered after June 11; the heifers remaining in the lot fed the basal ration were fed ration 3 after this date.

TABLE XIV

PLASMA INORGANIC PHOSPHORUS OF STEERS IN MG. PERCENT AT DIFFERENT DATES (1955)

Animal number	Date 1-20	2-5	2-19	3-3	3-17	3-31	4-5	4-14	4-28	5-11	5-26	6-16
					Ration 1							
2	3.72	4.88	4.84	4.88	3.96	3.60	3.72	3.32	3.40	2.92	3.36	2.88
4	2.68	3.28	2.92	3.28	2.92	3.36	3.00	2.84	2.92	2.64	3.00	3.08
8	3.28	4.24	3.52	3.44	2.92	2.76	2.76	2.48	2.80	2.56	2.76	2.64
Average	3.23	4.13	3.76	3.87	3.27	3.24	3.16	2.88	3.04	2.70	3.04	2.87
					Ration 2							
1	6.12	4.88	5.32	4.88	4.32	5.40[1] 7.68	5.76	5.80	7.28	6.44	7.32	6.60
6	3.28	3.28	2.96	3.20	3.72	5.12[1] 5.12	4.88	4.28	5.60	4.88	5.64	5.56
9	2.64	3.28	3.00	3.36	3.72	4.48[1] 6.20	4.48	4.60	5.44	5.32	5.48	4.12
Average	4.00	4.13	3.76	3.81	3.92	5.00[1] 6.33	5.04	4.89	6.10	5.55	6.15	5.43
					Ration 3							
3	3.35	4.08	4.16	3.68	6.32	7.68[1] 5.40	5.84	8.68	8.88	6.64	6.64	5.80
5	3.36	3.88	3.12	3.60	4.60	5.12[1] 4.48	5.16	6.92	8.42	7.12	8.00	6.28
7	3.28	3.84	3.68	3.64	4.92	6.20[1] 5.12	4.88	7.84	8.76	5.92	7.84	6.20
Average	3.33	3.93	3.65	3.64	5.28	6.33[1] 5.00	5.29	7.81	8.69	6.56	7.49	6.09

1 Values if feed or samples reversed.

TABLE XV

PLASMA INORGANIC PHOSPHORUS OF HEIFERS IN MG. PERCENT AT DIFFERENT DATES (1955)

Animal number	Date 3-3	4-17	5-14	6-11[1]	6-20[2]	7-5[2]	7-15	7-29	8-16	8-30
				Ration 1 Basal						
4	2.40	3.96	2.56	2.44						
6	2.52	2.28	1.88	1.72						
10	3.68	3.08	2.84	2.12						
12	3.04	3.36	2.36	2.24						
51	2.60	2.24	2.00	1.52	2.64	2.24	2.64	2.64	3.36	2.64
52	2.64	2.64	2.16	2.12	2.08	2.56	2.36	3.20	3.28	2.04
55	2.68	2.84	2.28	2.20	2.92	2.80	2.84	3.80	2.52	2.68
56	3.20	3.40	2.36	1.96	2.80	3.08	3.68	3.80	2.64	3.48
Average	2.84	2.98	2.30	2.04	2.61	2.67	2.88	3.36	2.95	2.44
				Ration 2 Colloidal Clay Phosphate						
3	2.76	4.28	3.48	3.68						
5	2.72	3.28	3.24	2.92						
8	2.48	3.60	3.28	3.08						
11	3.20	3.96	3.72	3.36						
47	2.60	3.44	3.04	2.56	3.28	3.20	3.04	3.32	2.56	2.30
50	3.28	4.36	3.32	2.92	3.28	3.28	2.92	2.40	3.60	2.30
53	2.48	2.68	3.04	2.56	2.24	2.68	2.52	2.28	2.08	3.16
57	1.76	2.60	2.24	1.56	2.28	2.40	2.64	2.36	2.28	1.76
Average	2.66	3.52	3.17	2.83	2.77	2.89	2.78	2.59	2.63	2.38

Ration 3 Dicalcium Phosphate

1	2.64	3.16	2.84	2.40				
2	3.44	4.16	4.60	3.80				
7	3.64	6.28	5.32	4.48				
9	3.40	4.40	4.60	4.36				
46	2.84	4.80	4.44	3.68	4.56	3.68	3.36	2.80
48	2.52	4.40	2.28	2.32	3.40	3.96	3.28	3.24
49	2.24	3.20	3.28	2.80	2.24	3.16	2.76	2.48
54	3.76	6.40	6.04	5.52	5.20	5.20	4.80	5.20
Average	3.06	4.60	4.18	3.67	3.85	4.00	3.55	3.43

1 Four heifers from each lot were slaughtered after June 11; the heifers remaining in the lot fed the basal ration were fed ration 3 after this date.

2 Samples were not collected for heifers on ration 3 on these dates.

VITA

Bill Davis
canidate for the degree of
Master of Science

Thesis: PHOSPHORUS METABOLISM IN CATTLE FED SODIUM PHOSPHATE

Major: Chemistry

Biographical:

Personal data: Born in Spearman, Texas, August 21, 1931, the son of James W. and Mattie Davis.

Education: Attended grade school in Spearman, Texas; graduated from Spearman High School in 1948; attended the University of Texas 1949-50; received the Bachelor of Science degree from Panhandle Agricultural and Mechanical College, with a major in Chemistry in May, 1953; graduate study at Oklahoma Agricultural and Mechanical College 1954-56.

Member of American Chemical Society and Phi Lambda Upsilon.

Date of final examination: May, 1956