PHOSPHORUS STUDIES WITH CATTLE AND SHEEP

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Submitted to the faculty of the Graduate School of
the Oklahoma State University in partial
fulfillment of the requirements
for the degree of
DOCTOR OF PHILOSOPHY
May, 1958

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ACKNOWLEDGMENT

The author wishes to express his appreciation to Dr. A. B. Nelson and Dr. A. D. Tillman of the Animal Husbandry Department for their assistance in planning and conducting these studies. Appreciation is also extended to Dr. W. D. Gallup of the Department of Biochemistry f the direction of the numerous chemical analyses and for his helpful suggestions.

Special recognition is due the author's wife, Dorothy, for assistance in the preparation and typing of this thesis.

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INTRODUCTION

Von Gohren (1861) observed that weak bones frequently appeared among cattle-grazing areas near the Rhine River. This abnormality was corrected by feeding small amounts of ground bone. Since this early report of mineral supplementation for cattle, large quantities of steamed bone meal have been used as a source of supplemental calcium and phosphorus.

It is recognized that the present supply of steamed bone meal can no longer meet the demand of an increasing livestock population. This demand has led to the use of other inorganic phosphate products as sources of supplemental phosphorus. At present a variety of such products are marketed. As examples, dicalcium phosphate, Curacao Island phosphate, defluorinated rock phosphate and soft phosphate with colloidal clay are used widely in livestock feeds.

In order to evaluate the effectiveness of phosphorus supplements they must be supplied in quantities that will furnish a level of phosphorus that is suboptimum for the test animal. Such a level could best be found by determining an area of linear response which would be below the actual requirement for the species studied.

Previous tests have indicated that dicalcium phosphate and defluorinated rock phosphate are satisfactory sources of supplemental phosphorus. It seemed desirable to compare these feed-grade supplements with purified sources of phosphorus for ruminants.

Recent research has indicated that the administration of stilbestrol to ruminants increases the retention of calcium and phosphorus. This

effect could result in an increased phosphorus requirement of the treated animal.

The experiments reported herein are concerned with the problems stated briefly above and have been designed with the following general objectives: (1) to determine the level of phosphorus intake at which certain tests of availability are most sensitive for evaluating sources of supplemental phosphorus; (2) to compare some common sources of supplemental phosphorus with relatively pure and reagent-grade sources of this element and (3) to observe the response of stilbestrol-implanted lambs to three levels of phosphorus supplementation.

REVIEW OF LITERATURE

Phosphorus Deficiency Symptoms

Characteristic phosphorus deficiency symptoms noted by Forbes and Johnson (1937) in cattle were as follows: Unthrifty appearance, poor growth, listless disposition, stiffness of gait, low plasma inorganic phosphorus, abnormal bone growth, swollen joints, depraved appetite and a marked reduction in feed intake.

The reduction in feed intake as related to efficiency of digestion and energy utilization had been studied earlier by Kleiber et al. (1936), who observed no significant reduction in digestibility of the smaller amount of food consumed by phosphorus-deficient beef cattle. The conclusion was that appetite is affected to a greater degree than digestion.

Stewart (1935) studied the effects of a phosphorus deficiency in sheep and noted that poor growth was accompanied by poor feed efficiency, a reduced plasma inorganic phosphorus level and an 8 percent reduction in the ash content of the long bones. In other bones the ash content was reduced as much as 25 percent. Beeson et al. (1944) reported that phosphorus-deficient lambs required 20 percent more feed per unit of gain than lambs receiving sufficient phosphorus.

Phosphorus Requirements

Deficiency symptoms such as those noted above can be corrected by the administration of phosphorus-containing materials to the affected animals. The correction and prevention of some of these symptoms have been

used by research workers to measure the adequacy of certain levels of dietary phosphorus.

Henderson and Weakly (1930) studied graded levels of phosphorus in dairy heifer rations ranging from 0.131 to 0.298 percent phosphorus. Levels less than 0.20 percent phosphorus caused a reduction in plasma inorganic phosphorus. They also noted that dietary changes in the amount of phosphorus ingested were detectable within one week by changes in plasma inorganic phosphorus values.

Van Landingham et al. (1935) reported 1.3 gm. of phosphorus daily per 100 lb. of body weight was inadequate for maintaining normal plasma inorganic phosphorus levels of dairy animals which were 6 to 25 months of age. A daily intake of 3.8 gm. per 100 lb. body weight, however, was found to be adequate.

Kleiber et al. (1936) reported that beef heifers placed on a diet containing 0.13 percent phosphorus stopped growing after 6 months on this treatment. Weight was, however, maintained on a ration containing only 0.09 percent phosphorus. Levels lower than 0.09 percent resulted in weight losses among the same animals.

Beeson et al. (1937a) observed phosphorus deficiency symptoms in beef steers fed a ration containing 0.12 percent phosphorus. A reduction in plasma inorganic phosphorus from 6.71 to 4.40 mg. percent was noted along with depraved appetite and unthrifty appearance. When steamed bone meal was added at the rate of 0.66 percent of the ration, the feed required per 100 lb. of gain was reduced 25.3 percent and daily gains increased from 1.37 to 1.90 lb. per day. Plasma inorganic phosphorus levels were increased, and the general appearance of the animals was improved. They concluded that approximately 2.0 gm. of phosphorus daily per 100 lb.

body weight was required for normal growth. Beeson et al. (1941) reported levels higher than 2.0 gm. of phosphorus per 100 lb. body weight daily failed to increase gains of steers and that levels of 1.63 gm. or less daily per 100 lb. body weight were too low to produce an optimum rate and efficiency of gain.

Nelson et al. (1955) reported that feeding 2.5 gm. of phosphorus per 100 lb. body weight to a group of beef heifers receiving a phosphorus-deficient forage resulted in an average weight that was 165 lb. greater than a control group receiving no supplemental phosphorus.

Beeson et al. (1937b) reported that growth was impaired and plasma inorganic phosphorus levels were reduced when lambs received 1.32 gm. or less of phosphorus per 100 lb. body weight daily. Also a ration containing 0.13 percent phosphorus was considered below the minimum requirement for optimum growth and efficiency. From 2.0 to 2.5 gm. of phosphorus per 100 lb. body weight daily was required to produce good gains and a thrifty appearance. DuToit et al. (1939) reported 1.1 gm. of phosphorus daily was sufficient for normal growth of lambs weighing approximately 60 lb.

In balance studies by Gallup and Briggs (1950) with 55 to 70 lb. lambs it was reported that the daily intake of 1.9 to 2.1 gm. of phosphorus per 100 lb. body weight was sufficient to maintain a positive balance in only part of the animals. From 2.4 to 2.9 gm. of phosphorus per 100 lb. body weight daily was required to produce a positive balance in all the experimental animals.

Beeson et al. (1944) indicated that no benefit was derived from feeding phosphorus above 0.15 percent of the total ration for lambs. At levels from 0.07 to 0.12 percent weight gain was in direct relationship

with phosphorus content of the ration. This work also indicated that the reduction in appetite due to a low phosphorus diet is not as great with sheep as with steers.

Inorganic Phosphorus Levels in Blood

One of the most common techniques for evaluating the phosphorus nutrition of animals has been the use of plasma inorganic phosphorus levels. Black et al. (1943) reported that a phosphorus deficiency could be diagnosed by low plasma phosphorus values long before external symptoms were apparent.

While it is difficult to pin point what would be a normal level of plasma phosphorus, the literature contains reports of average figures found for different classes of livestock under different conditions. Payne et al. (1946) reported that normal levels for plasma inorganic phosphorus for different ages and sexes of cattle in mg. percent were as follows: yearling beef bulls, 7.30; aged bulls, 4.76; two-year-old heifers, 5.07; and aged cows, 4.89. Based on the above work there seems to be a tendency for advancing age of animals to be accompanied by lower plasma inorganic phosphorus values. Haag and Jones (1935) reported little difference in plasma levels among dairy cattle at 6, 12, 18, 24, 36 and 48 months of age, but a steady trend downward was apparent. The respective levels were 7.74, 7.68, 7.05, 6.45, 5.69 and 5.69 mg. percent.

Palmer et al. (1930) studied the effect of age as well as other factors on plasma inorganic phosphorus levels. They reported a steady increase from 5.97 mg. percent at birth to 7.68 mg. percent at 6 months of age. This was followed by a steady decrease to 5.80 mg. percent at maturity. Other factors noted as having an influence on the plasma

inorganic phosphorus level were exercise and drinking which tended to reduce the blood level for a short time. Food consumption produced a significant rise in plasma inorganic phosphorus within 45 minutes. This was followed by a significant drop in plasma inorganic phosphorus 2 to 3 hours after feeding. Plasma inorganic phosphorus levels of these cattle varied slightly from day to day, but these values were highly correlated (0.93). Hour to hour variations were too slight to be considered of any consequence.

Beeson et al. (1944) indicated that fattening lambs on phosphorus-sufficient rations had plasma inorganic phosphorus levels ranging from 6.27 to 7.60 mg. percent. Long (1956) reported lambs from farm range conditions to have plasma inorganic phosphorus values ranging from 4.08 to 7.84 mg. percent.

On the basis of these data it seems that a normal range of plasma phosphorus must suffice rather than a normal value. The range appears to be from 4 to 8 mg. percent for both cattle and sheep under the observed conditions.

Sources of Supplemental Phosphorus

A very large number of sources of supplemental phosphorus for livestock is now available. Many of these compounds have been evaluated experimentally.

Von Gohren (1861) reported that ground bones were capable of correcting weak joints, when ingested by the affected animal.

While several factors must be considered in evaluating a supplement, price, availability, biological value and palatability are the most important ones. Theiler et al. (1924) fed four materials known to contain phosphorus in quantities large enough to make them of supplemental value.

Bone meal was found to be superior to sodium phosphate, phosphoric acid and rock phosphate for cattle. Aside from its superior ability to produce growth, bone meal was more palatable to the animals. Eckles et al. (1926) reported that cattle can utilize inorganic forms of phosphorus other than bone meal. This conclusion was based on the utilization of tricalcium phosphate and monosodium phosphate. Turner et al. (1934) reported monosodium phosphate and disodium phosphate to be satisfactory phosphorus supplements for dairy cattle rations. DuToit et al. (1940) reported that steamed bone meal and degelatinized bone flour were satisfactory sources of supplemental phosphorus for cattle. In addition to these two materials, dicalcium phosphate, disodium phosphate and monoammonium phosphate were effective supplemental sources of this element. Defluorinated superphosphate was satisfactory but noticeably unpalatable. Raw rock phosphate and superphosphate both proved to be unsatisfactory sources of phosphorus.

Davis et al. (1953) reported that 70 percent of the labeled phosphorus from defluorinated rock phosphate was absorbed and utilized by cattle. The balance trials of Ammerman et al. (1954) showed that phosphorus retention in steers did not differ when steamed bone meal, defluorinated rock phosphate, dicalcium phosphate, imported rock phosphate and colloidal clay were tested. However, the subsequent work of Long (1956) indicated that colloidal clay was not a satisfactory supplement when fed alone in a semi-purified diet to beef heifers or wethers.

Ammerman et al. (1955) reported dicalcium phosphate and Curacao Island phosphate to be more effective in increasing the plasma inorganic phosphorus levels of phosphorus-deficient lambs than were either defluorinated rock phosphate or colloidal clay. While this trend was

apparent, no significant difference existed in the blood values produced by the above supplements. Long (1956) reported that Curacao Island phosphate and dicalcium phosphate were fully as effective as steamed bone meal in promoting weight gains and normal plasma inorganic phosphorus levels in wether lambs. Ammerman (1957) reported that dicalcium phosphate and Curacao Island phosphate were more readily utilized than soft phosphate with colloidal clay by lambs.

Dicalcium phosphate and defluorinated rock phosphate were found to be satisfactory sources of phosphorus for cattle by Knox et al. (1941), Black et al. (1943), Becker et al. (1944), Gullickson and Olson (1946) and Hodgson et al. (1948). Beeson et al. (1945), however, suggested that the availability of the phosphorus in supplemental materials depends on its content of ortho phosphate. One sample of defluorinated rock phosphate that contained only 50 percent of the phosphorus in the ortho form was unsatisfactory for steers.

The Effect of Stilbestrol on Phosphorus Metabolism

Andrews et al. (1949), Jordan (1950), Pope et al. (1950) and Means et al. (1953) have reported increased rate and efficiency of gain in lambs with stilbestrol implants.

Bell et al. (1957), Shroder (1957) and Tillman (1957) reported that stilbestrol in the diet of lambs increased phosphorus retention. A similar response was noted by Whitehair et al. (1953) in stilbestrol-implanted lambs.

EXPERIMENT I

RESPONSE OF LAMBS FED DIFFERENT LEVELS OF PHOSPHORUS FROM MONOSODIUM PHOSPHATE AND REAGENT GRADE DICALCIUM PHOSPHATE

Two trials were conducted to test the response of lambs to graded levels of supplemental phosphorus from monosodium phosphate (Trial 1) and reagent-grade dicalcium phosphate (Trial 2).

The objective was to estimate the appropriate level at which phosphorus should be fed to lambs in experiments designed to evaluate phosphorus supplements. The response of lambs fed graded levels of phosphorus ranging from 0.07 to 0.16 percent of the total ration was observed.

Experimental Procedure

Trial 1

Twelve cross-bred ewe lambs weighing approximately 50 lb. each were given a phenothiazine drench and confined in individual pens for the duration of the trial.

All lambs were fed Ration 1 (Table 1) ad libitum during a 42-day depletion period. Following the depletion period the lambs were divided into 4 groups on the basis of weight and plasma inorganic phosphorus. Lot 1 received the basal ration (Ration 1) which contained 0.07 percent phosphorus while Lots 2, 3 and 4 received, respectively, Rations 2

(0.10% P), 3 (0.13% P) and 4 (0.16% P) during a 56-day repletion period. The supplemental phosphorus was supplied by monosodium phosphate. The Ca:P ratio of Ration 1 was 4.55:1 and this ratio was held constant among all rations by the addition of calcium carbonate. A micratized source of vitamin A and D was added to all rations.

Body weight, feed consumption and plasma inorganic phosphorus values were determined at approximately 14-day intervals. Plasma inorganic phosphorus determinations were made by the method of Fiske and Subbarow (1925). The data were analyzed by analysis of variance (Snedecor, 1956).

Table 1. Composition of Experimental Rations (lb.)

Ingredients	Ration 1	Ration 2	Ration 3	Ration 4
Cerelose	22.57	22.57	22.57	22.57
Cottonseed hulls	36.12	36.12	36.12	36.12
Dried beet pulp	27.06	27.06	27.06	27.06
Alfalfa meal	9.05	9.05	9.05	9.05
Urea 262	1.00	1.00	1.00	1.00
Corn gluten meal	3.65	3.65	3.65	3.65
A & D Supplement	0.06	0.06	0.06	0.06
Salt	0.50	0.50	0.50	0.50
Monosodium phosphate[1]	---	0.13	0.26	0.39
Calcium carbonate	---	0.36	0.73	1.10
P from basal ration	0.07	0.07	0.07	0.07
P from monosodium phosphate	---	0.03	0.06	0.09
Total P	0.07	0.10	0.13	0.16

[1]Contained 23.0 percent phosphorus.

Trial 2

Twelve cross-bred ewe lambs weighing approximately 45 lb. each were selected from the same flock as those used in Trial 1. All lambs were given a phenothiazine drench and confined in individual pens for the duration of the trial.

The experimental rations were essentially the same as those used in Trial 1 except reagent-grade dicalcium phosphate was added as a source of supplemental phosphorus at the levels shown in Table 2. All lambs received the low phosphorus basal ration (Ration 1, Table 2) during a 42-day depletion period. Following the depletion period the lambs were divided into 4 groups on the basis of weight and plasma inorganic phosphorus values. As in Trial 1, Lot 1 was continued on Ration 1, and Lots 2, 3 and 4 were given, respectively, Rations 2, 3 and 4 (Table 2) during the 112-day repletion period. Dicalcium phosphate was added in amounts to provide graded levels of phosphorus equal to those fed in Trial 1. The Ca:P ratios of Rations 3, 4 and 5 were adjusted to equal that of Ration 1 (4.55:1) by the addition of calcium carbonate. In Ration 2 the Ca:P ratio was 4.8:1. This resulted when the proper amount of dicalcium phosphate was added to provide a ration containing 0.10 percent phosphorus. The methods of collecting and analyzing data were the same as in Trial 1.

Results and Discussion

The individual observations for body weight, plasma inorganic phosphorus and feed consumption for Trial 1 appear in Appendix Tables 16, 17 and 18 and for Trial 2 in Appendix Tables 19, 20 and 21, respectively.

Table 2. Composition of Experimental Rations
(lb.)

Ingredients	Ration 1	Ration 2	Ration 3	Ration 4
Cerelose	22.57	22.57	22.57	22.57
Cottonseed hulls	36.12	36.12	36.12	36.12
Dried beet pulp	27.06	27.06	27.06	27.06
Alfalfa meal	9.05	9.05	9.05	9.05
Urea 262	1.00	1.00	1.00	1.00
Corn gluten meal	3.65	3.65	3.65	3.65
A & D Supplement	0.06	0.06	0.06	0.06
Salt	0.50	0.50	0.50	0.50
Reagent-grade dicalcium phosphate[1]	---	0.135	0.270	0.405
Calcium carbonate	---	---	0.23	0.48
P from basal ration	0.07	0.07	0.07	0.07
P from reagent-grade dicalcium phosphate	0.00	0.03	0.06	0.09
Total P	0.07	0.10	0.13	0.16

[1]Supplemental quantities based on chemically determined values which were 28.90 percent calcium and 22.25 percent phosphorus.

Trial 1

The results of Trial 1 are summarized in Table 3.

Table 3. Summary of Results
Experiment I. Trial 1

Ration	1	2	3	4
Level of P (%)	0.07	0.10	0.13	0.16
Number of animals	3	3	3	3
Initial weight (lb.)	53	51	48	47
Final weight (lb.)	50	55	60	71
Total gain (lb.)	-3	4	12	24
Daily feed (lb.)	1.16	1.46	1.93	2.72
Initial plasma inorganic phosphorus (mg. %)	3.02	3.00	2.95	2.90
Final plasma inorganic phosphorus (mg. %)	2.33	2.84	4.17	6.44
Change in plasma phosphorus (mg. %)	-0.69	-0.16	1.22	3.54
Average plasma inorganic phosphorus during repletion (mg. %)	2.63	2.94	3.66	6.89

Weight Gain

The animals fed Ration 1 (0.07% P) lost an average of 3 lb. during the 56-day repletion period. Lots 2, 3 and 4 which received 0.10, 0.13 and 0.16 percent phosphorus, respectively, gained 4, 12 and 24 lb. during the same period.

The gains produced by the four levels of phosphorus were significantly ($P < .01$) linear in nature. This linear response, which is in agreement with Beeson et al. (1944), accounted for 96.5 percent of the treatment variation. The periodic average gains of each lot are shown graphically in Figure 1. Rations 3 and 4 promoted definite gains during the first 2 weeks of the repletion period and at the end of this period had produced significantly ($P < .01$) greater gains than Rations 1 and 2. At the end of the second 14-day period, however, the lambs receiving Ration 2 had started to gain and continued to show a greater response than lambs on the basal ration. Thus, it appears that a level of 0.13 to 0.16 percent phosphorus produced a rather immediate response, as measured by weight gain; and the rations containing 0.10 percent phosphorus or less required a longer period to influence weight gain.

Plasma Inorganic Phosphorus

The average changes in plasma inorganic phosphorus values during the repletion period for Lots 1, 2, 3 and 4 were -0.69, -0.16, 1.22 and 3.54 mg. percent, respectively. This response was significantly ($P < .01$) linear. The periodic changes in plasma inorganic phosphorus are shown graphically in Figure 2. Ration 4 produced a significantly greater change in plasma inorganic phosphorus during the first 14-day period than did the other rations.

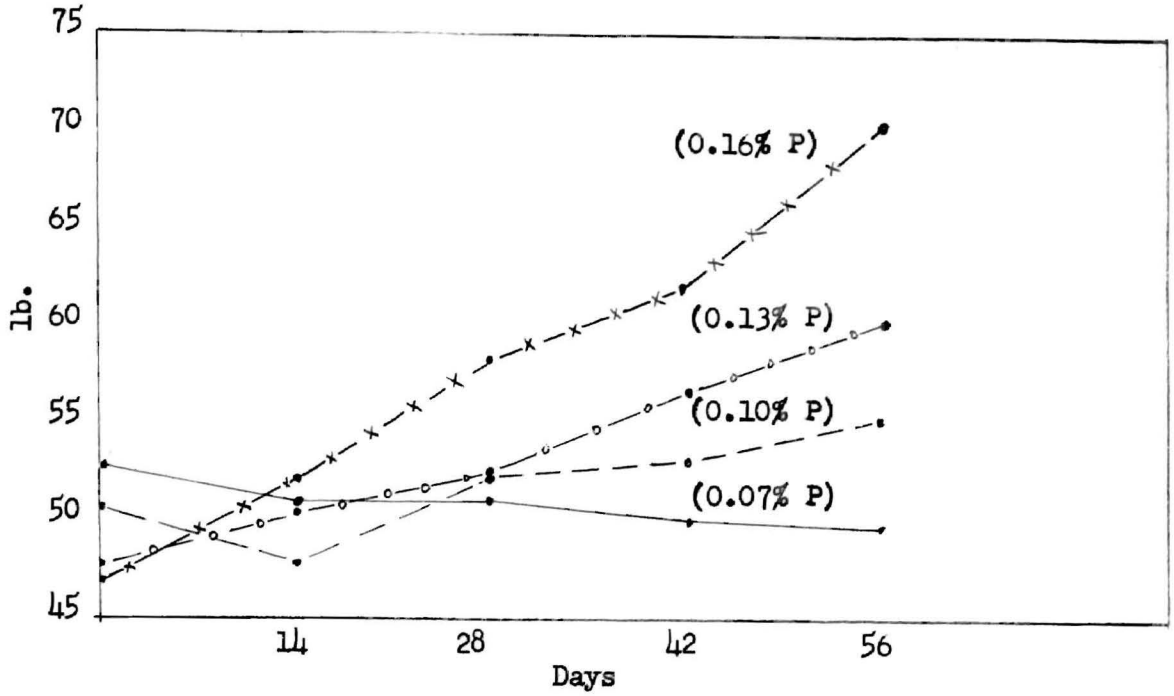

Figure 1. Weight Gain of Lambs
Experiment I. Trial 1

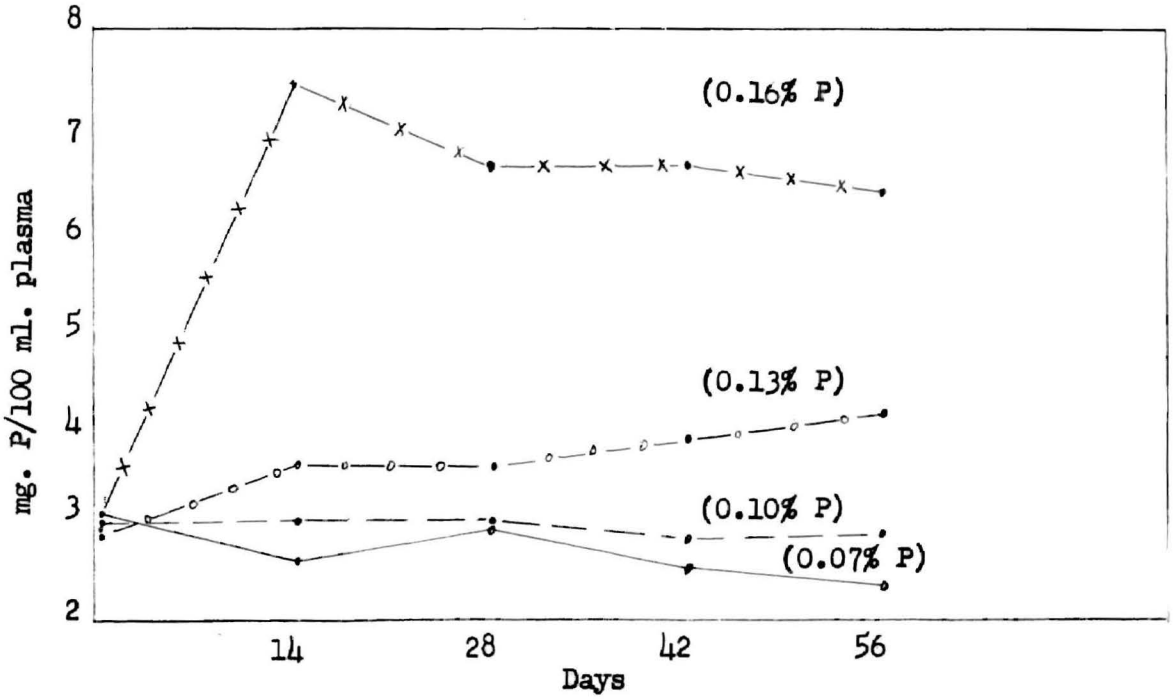

Figure 2. Plasma Inorganic Phosphorus of Lambs
Experiment I. Trial 1

The average plasma inorganic phosphorus values during repletion for Rations 1, 2, 3 and 4 were 2.62, 2.94, 3.66 and 6.89 mg. percent, respectively. According to the work of Beeson et al. (1944) only the value for Ration 4 could be considered a normal plasma inorganic phosphorus level for fattening lambs on a phosphorus-sufficient ration. The response noted here was significantly linear and accounted for 80.0 percent of the treatment variation.

The correlation between average plasma inorganic phosphorus level during repletion and weight gain was 0.90 ($P < .01$). The correlation between change in plasma inorganic phosphorus and weight gain during repletion was 0.91 ($P < .01$).

Feed Consumption

The average daily feed consumption for Lots 1, 2, 3 and 4 during the repletion period was 1.16, 1.46, 1.93 and 2.72 lb., respectively. This response was significantly ($P < .01$) linear with 96.0 percent of the treatment variation due to linearity. Based on feed consumption the lambs in Lots 1, 2, 3 and 4 consumed an average of 0.37, 0.66, 1.14 and 1.95 gm. of phosphorus per head daily during the repletion period. According to the work of Beeson et al. (1937b) only the lambs receiving Rations 3 and 4 consumed a minimum amount of phosphorus required for normal growth. The average daily feed consumption of each lot during the repletion period is graphically represented in Figure 3.

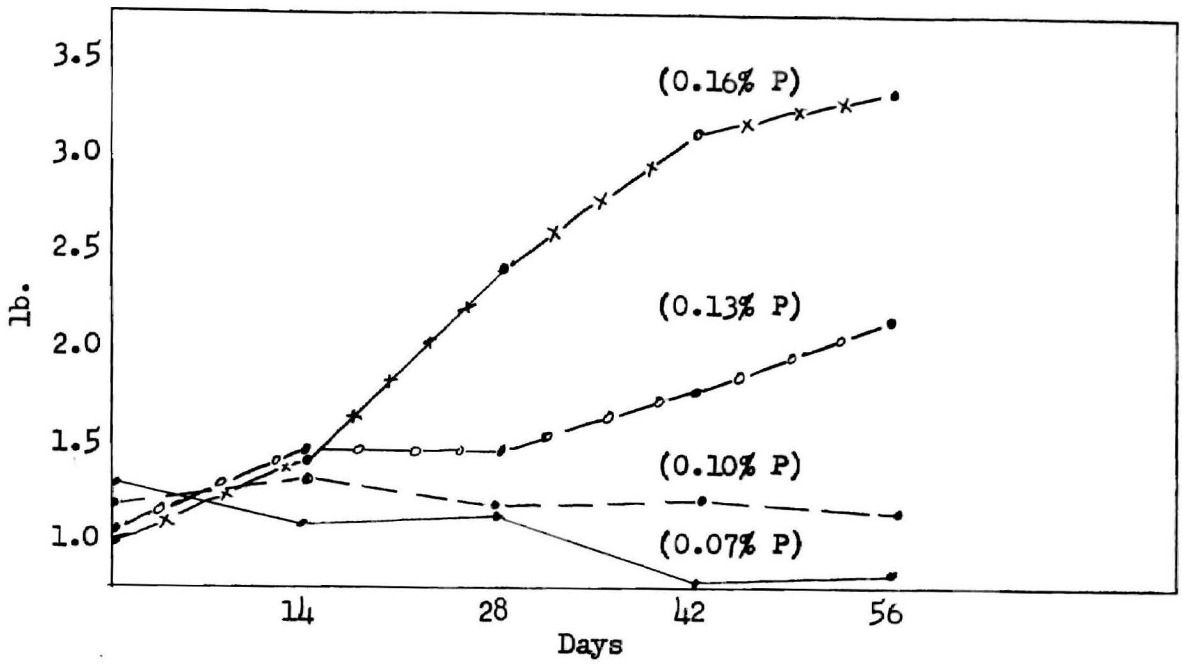

Figure 3. Daily Feed Consumption of Lambs
Experiment I. Trial 1

Trial 2

The results of Trial 2 are summarized in Table 4.

Weight Gain

The animals consuming Ration 1 gained an average of 5 lb. during the repletion period which indicates, as in Trial 1, that 0.07 percent phosphorus is not adequate to produce a satisfactory growth rate. Rations 2, 3 and 4 produced gains of 11, 22 and 29 lb., respectively. This response was significantly ($P<.01$) linear with linearity accounting for 99.6 percent of the total treatment variation.

Table 4. Summary of Results
Experiment I. Trial 2

Ration	1	2	3	4
Level of P (%)	0.07	0.10	0.13	0.16
Number of animals	2[1]	3	3	3
Initial weight (lb.)	45	49	46	47
Final weight (lb.)	50	60	68	76
Total gain (lb.)	5	11	22	29
Daily feed (lb.)	1.14	1.84	2.04	2.18
Initial plasma inorganic phosphorus (mg. %)	2.78	2.60	2.54	2.76
Final plasma inorganic phosphorus (mg. %)	2.82	3.09	3.74	6.14
Increase in plasma phosphorus (mg. %)	0.04	0.49	1.20	3.38
Average plasma inorganic phosphorus during repletion (mg. %)	2.56	3.11	3.87	4.49

[1]One lamb killed by dog.

The periodic changes in weight are graphically represented in Figure 4. A growth response due to phosphorus supplementation was apparent within 2 to 4 weeks after the repletion period was started. Six weeks were required for Ration 4 to produce greater gains than Rations 2 and 3. The gains produced by Rations 2 and 3 did not differ greatly until the final 14-day period.

Plasma Inorganic Phosphorus

The periodic plasma inorganic phosphorus values for each lot are graphically represented in Figure 5.

The average change in plasma inorganic phosphorus during the repletion period for Lots 1, 2, 3 and 4 were 0.04, 0.49, 1.20 and 3.38 mg. percent, respectively. This response was significantly linear ($P < .05$).

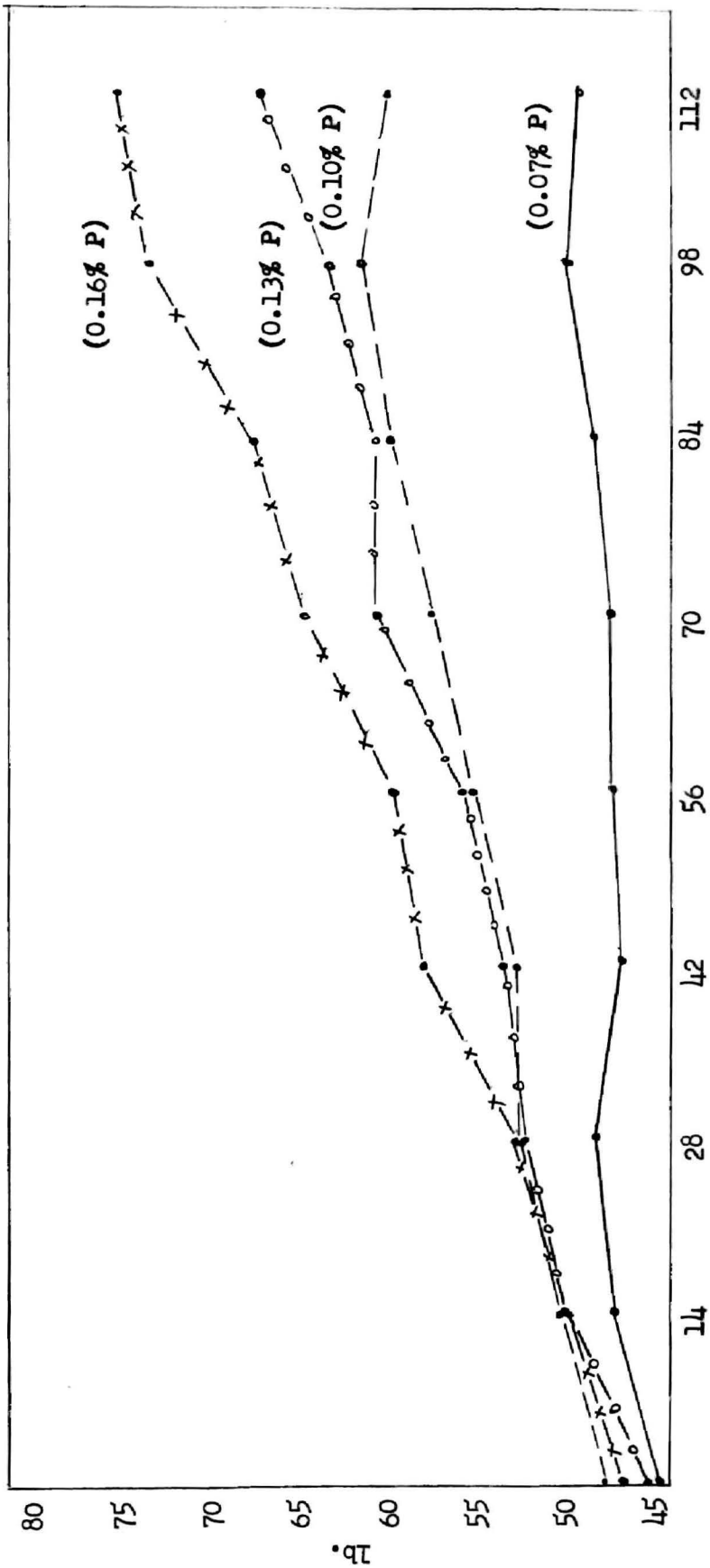

Figure 4. Weight Gain of Lambs
Experiment I. Trial 2

The average plasma inorganic phosphorus levels maintained by Rations 1, 2, 3 and 4 during repletion were 2.56, 3.11, 3.87 and 4.49 mg. percent, respectively. This response was significantly linear ($P < .025$) with linearity accounting for 99.0 percent of treatment variation.

The correlation between the average plasma inorganic phosphorus values during repletion and weight gain during the same period was 0.79 ($P < .01$). The correlation between change in plasma inorganic phosphorus and weight gain was 0.46 which was not significant.

Feed Consumption

The average daily feed consumption shown in Figure 6 for Lots 1, 2, 3 and 4 was 1.14, 1.84, 2.04 and 2.18 lb., respectively. The responses to the 4 levels of phosphorus were significantly linear with 85.5 percent of the treatment variation due to linearity. The animals in Lots 1, 2, 3 and 4 consumed, respectively, an average of 0.36, 0.83, 1.20 and 1.58 gm. of phosphorus per head daily.

Trials 1 and 2 Compared

Weight Gain

The terminal results of Trials 1 and 2 cannot be compared directly due to the difference in length of the repletion period of the two trials. It is of interest, however, to note the relationship of the weight gains at the end of 8 weeks in Trial 2 which is the point corresponding to the terminal observations in Trial 1. The important difference between the 2 trials at this time seems to be only the failure of Rations 2 and 3 to produce a difference in weight gain in Trial 2 as was noted in Trial 1. The weight gains at the end of 8 weeks were 3, 7, 10 and 13 lb.,

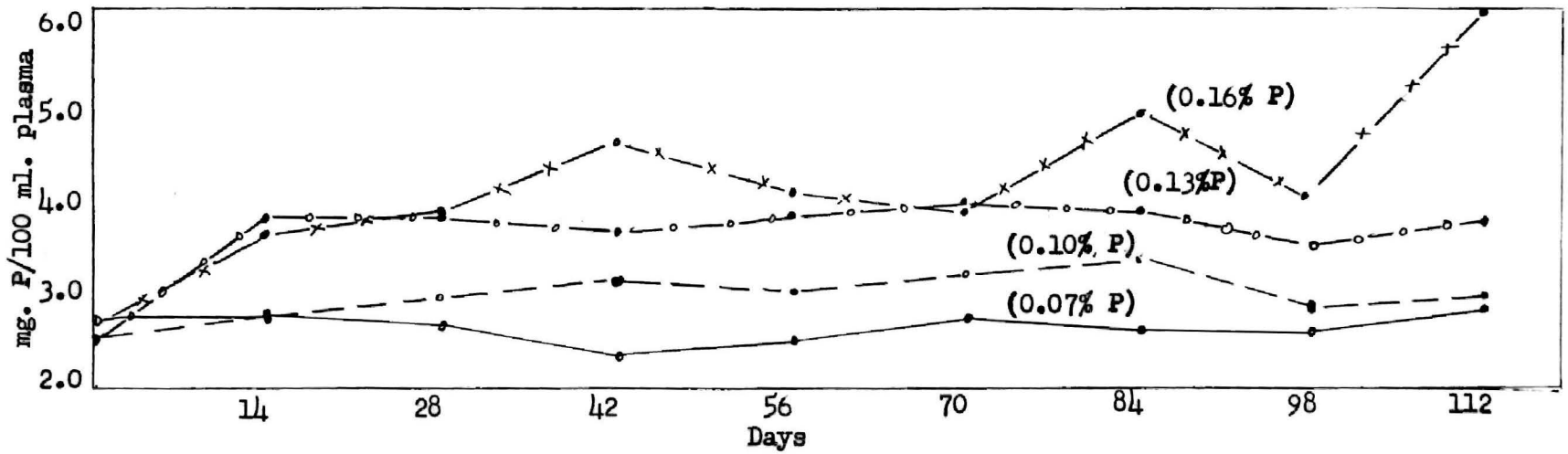

Figure 5. Change in Plasma Inorganic Phosphorus of Lambs
Experiment I. Trial 2

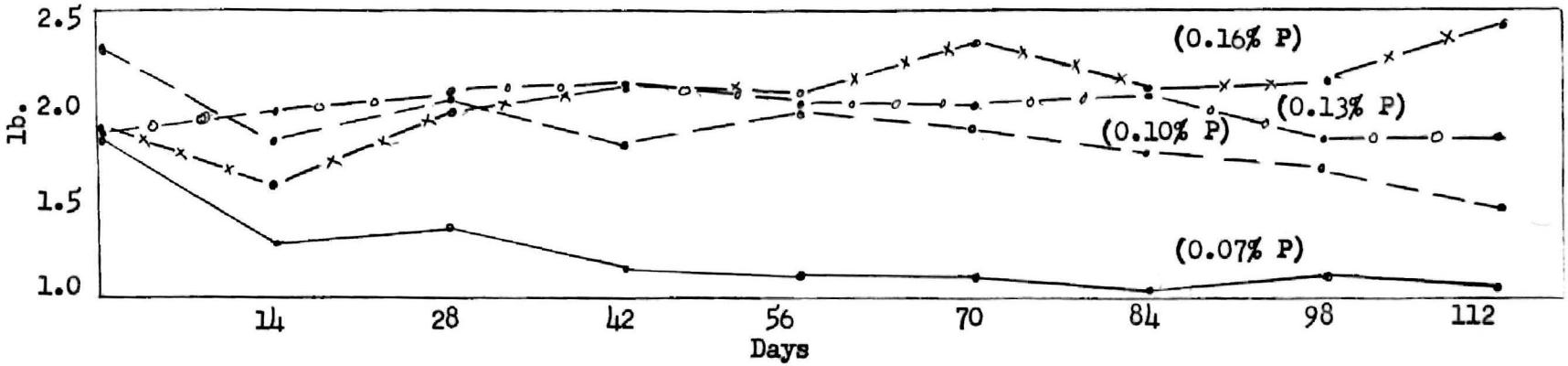

Figure 6. Daily Feed Consumption of Lambs
Experiment I. Trial 2

respectively, for Rations 1, 2, 3 and 4 in Trial 2 as compared with the respective gains of -3, 4, 12 and 24 lb. during Trial 1.

Plasma Inorganic Phosphorus

A comparison of average plasma inorganic phosphorus and phosphorus intake during the repletion period of Trials 1 and 2 is shown in Table 5. This comparison points out the relationship between phosphorus intake and plasma inorganic phosphorus values in both trials. The relatively small difference in phosphorus intake per 100 lb. body weight between lambs on Rations 3 and 4 during Trial 2 is reflected in a small difference in plasma inorganic phosphorus values.

Table 5. Average Plasma Inorganic Phosphorus Values and Daily Phosphorus Intake of Lambs Trials 1 and 2

Ration	1	2	3	4
	Plasma inorganic phosphorus (mg. %)			
Trial 1	2.63	2.94	3.66	6.89
Trial 2	2.54	3.04	3.90	4.18
	Daily phosphorus intake (gm.)			
Trial 1	0.37 (.71)[1]	0.66 (1.24)	1.14 (2.20)	1.95 (3.30)
Trial 2	0.38 (.82)	0.88 (1.69)	1.13 (2.21)	1.46 (2.81)

[1]Figure in parenthesis indicates average gm. phosphorus intake per 100 lb. body weight during repletion.

Feed Consumption

The average daily feed consumption of lambs on Rations 1, 2 and 3 was very similar during Trial 1 and the first 8 weeks of Trial 2. Consumption of Ration 4 was slightly less during this same period in Trial 2 and resulted in a reduced phosphorus intake during this trial.

Summary

Two feeding trials were conducted to determine the response of ewe lambs to graded levels of dietary phosphorus. At the levels of 0.07, 0.10, 0.13 and 0.16 percent of the total ration linear responses were noted with respect to weight gain, plasma inorganic phosphorus and feed consumption. In general, poor response was noted in lambs consuming rations containing less than 0.13 percent phosphorus. It appears that the most appropriate level of phosphorus for evaulating phosphorus supplements in repletion studies is around 0.14 or 0.15 percent of the total ration. In view of this it is necessary to use a basal ration that is as low in phosphorus as practicable to permit the phosphorus supplement being tested to provide a maximum amount of the total phosphorus.

EXPERIMENT II

RESPONSE OF STILBESTROL-IMPLANTED LAMBS FED GRADED LEVELS OF PHOSPHORUS

Recent work by Bell et al. (1957), Shroder (1957), Tillman and Brethour (1957) indicated that the feeding of stilbestrol increases calcium and phosphorus retention in growing lambs. A similar response was reported in stilbestrol-implanted lambs by Whitehair et al. (1953). The purpose of this study was to determine the effect of stilbestrol implantation upon the phosphorus requirements of fattening lambs.

Experimental Procedure

Forty-eight western wether lambs weighing approximately 70 lb. were given a phenothiazene drench and fed Ration 1 (Table 6) for a 10-day standardization period prior to being placed on the experimental rations. The lambs were then divided into 3 groups of 16 lambs each and allotted to individual pens in a 2 x 3 factorial design. One half of the lambs in each group received a 6.0 mg. stilbestrol implant immediately following the collection of an initial blood sample from all lambs.

All lambs were fed ad libitum for a period of 70 days. Rations 1, 2 and 3 contained 0.18, 0.25 and 0.33 percent phosphorus, respectively. Monosodium phosphate furnished the supplemental phosphorus, and a Ca:P ratio of 1.5:1 was maintained in all rations by the addition of calcium carbonate.

Plasma inorganic phosphorus, weight gain and feed consumption were observed as criteria for evaluating the results. These observations were made initially 7 days after the experiment was started and at approximately 21-day intervals thereafter. All animals were fasted 12 hours prior to weighing and collection of blood samples. Plasma inorganic phosphorus determinations were by the method of Fiske and Subbarow (1925).

Table 6. Composition of Experimental Rations (lb.)

Ingredients	Ration 1	Ration 2	Ration 3
Milo	45.00	45.00	45.00
Cottonseed hulls	30.00	30.00	30.00
Alfalfa meal	10.00	10.00	10.00
Soybean meal	5.00	5.00	5.00
Cerelose	5.00	5.00	5.00
Starch	5.00	5.00	5.00
Salt	0.50	0.50	0.50
A & D Supplement	0.10	0.10	0.10
Monosodium phosphate	---	0.32	0.64
Calcium carbonate	0.33	0.58	0.86
P from basal ration	0.18	0.18	0.18
P from monosodium phosphate	---	0.07	0.15
Total P	0.18	0.25	0.33

Results and Discussion

The results of Experiment II are summarized in Tables 7 and 8. Individual observations for body weight, plasma inorganic phosphorus and feed consumption appear in Appendix Tables 22, 23 and 24, respectively.

Weight Gain

The average daily gain of 0.36 lb. for the lambs receiving a 6.0 mg. stilbestrol implant was significantly ($P < .01$) greater than 0.29 lb. noted for the controls. This response due to stilbestrol implantation is in

Table 7. Summary of Results
(Response to Graded Levels of Phosphorus)

Ration	1	2	3
Level of P (%)	0.18	0.25	0.33
Number of animals	14[1]	16	15[1]
Initial weight (lb.)	70	70	70
Final weight (lb.)	94	92	92
Total gain (lb.)	24	22	22
Daily gain (lb.)	0.34	0.31	0.31
Feed/100# gain (lb.)	927	947	899
Feed/day (lb.)	2.93	2.96	2.85
Plasma inorganic phosphorus (mg. %) (Avg. 70-day period)	7.05	7.01	7.17
Average slaughter grade	Low Choice	Low Choice	Low Choice

[1]Three lambs removed due to urinary calculi.

Table 8. Summary of Results
(Response to Stilbestrol Implantation)

Treatment	Controls	6.0 mg. Stilbestrol Implant
Number of animals	24	21[1]
Initial weight (lb.)	70	70
Final weight (lb.)	90	95
Total gain (lb.)	20	25
Daily gain (lb.)	0.29	0.36
Feed/100# gain (lb.)	1016	833
Feed/day (lb.)	2.88	2.95
Plasma inorganic phosphorus (mg. %) (Avg. 70-day period)	7.15	7.12
Average slaughter grade	Low Choice	Low Choice

[1]Three lambs removed due to urinary calculi.

general agreement with the work of Andrews et al. (1949), Jordan (1950), Pope et al. (1950) and Means et al. (1953).

The daily gains of 0.34, 0.31 and 0.31 lb. produced by Rations 1, 2 and 3, respectively, did not differ significantly. This indicates that the lowest level of phosphorus fed was adequate to promote an optimum rate of gain. Beeson et al. (1944) reported that no benefit was obtained by additional phosphorus above a level of 0.15 percent of the total rations for lambs. Based on daily feed consumption and percent phosphorus in the ration, the lambs on Rations 1, 2 and 3, respectively, consumed 2.2, 3.2 and 4.1 gm. phosphorus daily. All these values are comparable to or above the published daily requirement of 2.0 to 2.5 gm. (Beeson et al. 1937) and 2.4 to 2.9 gm. (Gallup and Briggs, 1950) per 100 lb. body weight.

There was no significant interaction between level of phosphorus fed and stilbestrol implantation. This indicates that the administration of stilbestrol did not alter the phosphorus requirement of lambs in the experiment, although Bell et al. (1957), Shroder (1957), Tillman and Brethour (1957) have reported that an increased phosphorus deposition was noted in stilbestrol-fed lambs and Whitehair et al. (1953) observed a similar response in stilbestrol-implanted lambs.

Feed Consumption and Efficiency

The increased growth rate noted above in the stilbestrol-implanted group was accompanied by a significant ($P < .05$) increase in feed efficiency. Feed conversion rates for the implanted and control groups were, respectively, 833 and 1,016 lb. of feed per 100 lb. gain.

The respective daily feed consumption rates of 2.95 and 2.88 lb. for the implanted and control groups did not differ significantly. Also, the respective daily consumption rates of 2.93, 2.96 and 2.85 lb. noted

for Rations 1, 2 and 3 did not differ significantly. Apparently Ration 1 (0.18% P) was adequate for promoting a satisfactory rate of feed consumption as well as efficiency of gain in this experiment.

Plasma Inorganic Phosphorus

As shown in Tables 7 and 8, the average plasma inorganic phosphorus values for the various treatments were strikingly similar and did not differ significantly. This indicates that all levels of phosphorus were adequate for maintaining plasma inorganic phosphorus levels within a normal range. It would have been interesting to have observed the plasma inorganic phosphorus level of the lambs on the different rations prior to the 12-hour fasting period that preceded the collection of blood samples. The values taken at this time might reflect the ingestion of larger amounts of phosphorus.

Carcass Grade

The range in individual slaughter grade for all animals was from average good to high choice. The mean grades for each treatment did not differ significantly when the individual grades were coded and analyzed by analysis of variance.

Summary

Forty-eight western wether lambs were individually fed rations containing 0.18, 0.25 and 0.33 percent phosphorus during a 70-day fattening period. One half of the lambs on each level of phosphorus received a 6.0 mg. stilbestrol implant at the beginning of the experiment.

The stilbestrol implanted lambs gained significantly faster than unimplanted controls.

Neither rate and efficiency of gain nor feed consumption differed significantly among the 3 levels of phosphorus fed.

Stilbestrol implantation, apparently, did not increase the phosphorus requirements of the lambs above that supplied by the basal ration.

EXPERIMENT III

THE RESPONSE OF STEERS FED DIFFERENT LEVELS OF PHOSPHORUS FROM REAGENT-GRADE DICALCIUM PHOSPHATE

In previous tests at the Oklahoma station (Long et al.,1957) the response of steers to graded levels of feed-grade monosodium phosphate was studied. It seemed desirable to repeat the earlier work with reagent-grade dicalcium phosphate and to increase the number of steers on each treatment. The objective of the experiment was to determine the level at which supplemental phosphorus should be fed in experiment designed to evaluate phosphorus supplements.

Experimental Procedure

Twelve grade Hereford steers weighing approximately 400 lb. each were selected from the Lake Blackwell experimental herd. The calves were housed at the experimental steer shed during the 72-day depletion period and in the metabolism room pens during the 98-day repletion per At the end of the depletion period the animals were divided into 3 gro of 4 steers each as evenly as possible on the basis of weight and plas inorganic phosphorus level.

All animals were fed Ration 1 (Table 9) ad libitum during the depletion period. During the repletion period Lots 1, 2 and 3 receive Rations 1, 2 and 3 (Table 9), respectively. The animals were fed individually twice daily the amount of feed that they would consume in

one-hour period. Ration 1 contained 0.08 percent phosphorus and had a Ca:P ratio of 4.59:1. Reagent-grade dicalcium phosphate was added to Rations 2 and 3 to provide respective phosphorus levels of 0.12 and 0.16 percent of the total ration. The Ca:P ratios of Rations 2 and 3 were adjusted to equal that of Ration 1 by the addition of Ca CO_3. A micratized source of vitamins A and D was added to all rations.

Body weight, feed consumption and plasma inorganic phosphorus were determined at approximately 14-day intervals. Plasma inorganic phosphorus was determined by the method of Fiske and Subbarow (1925). Statistical treatment of results was by analysis of variance (Snedecor, 1956).

Table 9. Composition of Experimental Rations (lb.)

Ingredients	Ration 1	Ration 2	Ration 3
Cerelose	22.10	22.10	22.10
Cottonseed hulls	37.05	37.05	37.05
Beet pulp	27.10	27.10	27.10
Alfalfa meal	9.10	9.10	9.10
Corn gluten meal	3.70	3.70	3.70
Urea 262	0.35	0.35	0.35
A & D Supplement	0.10	0.10	0.10
Salt	0.50	0.50	0.50
Calcium carbonate	---	0.47	0.95
Reagent-grade dicalcium phosphate	---	0.18	0.36
P from basal ration	0.08	0.08	0.08
P from dicalcium phosphate	---	0.04	0.08
Total P	0.08	0.12	0.16

Results and Discussion

The results of Experiment III are summarized in Table 10. Observations of individual weight gains, plasma inorganic phosphorus levels and feed consumption appear in Appendix Tables 25, 26 and 27, respectively.

Table 10. Summary of Results

Lot Number Level of P (%)	1 0.08	2 0.12	3 0.16
Number of animals	4	4	4
Initial weight (lb.)	427	425	418
Final weight (lb.)	393	488	516
Total gain (lb.)	-34	63	98
Daily feed consumption during repletion period (lb.)	3.56	6.40	7.61
Initial plasma inorganic phosphorus (mg. %)	3.31	3.27	3.18
Final plasma inorganic phosphorus (mg. %)	2.49	3.42	4.44
Change in plasma phosphorus	-0.82	0.15	1.26
Average plasma phosphorus during repletion period (mg. %)	2.69	3.53	3.84

Weight Gain

The weight gains of each lot are graphically represented in Figure 7. The average weight gains for Lots 1, 2 and 3 during the repletion period were -34, 63 and 98 lb., respectively. The response to the 3 levels of phosphorus was significantly linear ($P < .01$) and accounted for 93.0 percent of the treatment variation. The gains produced by Rations 2 and 3 were lower than those reported by Long *et al.* (1957) in a similar experiment, but the same characteristic trend was apparent. Part of this reduced response could have been due to an overcrowded condition.

On the basis of weight gain it appears that a level between 0.12 and 0.16 percent phosphorus might be the most appropriate level at which to test sources of supplemental phosphorus. Based on the observation of gross deficiency symptoms reported later (Experiment IV), a level above 0.12 percent is required. As a result of the above, the most appropriate level seems to be around 0.15 percent phosphorus.

These results are in general agreement with the work of Beeson et al. (1938) and Kleiber et al. (1936).

Plasma Inorganic Phosphorus

The periodic response with respect to plasma inorganic phosphorus is shown graphically in Figure 8. The change in plasma inorganic phosphorus for Lots 1, 2 and 3 during repletion was -0.82, 0.15 and 1.26 mg. percent, respectively. This response was significantly ($P < .01$) linear and accounted for 99.8 percent of the treatment variation. Beeson et al. (1938) reported that 0.12 percent phosphorus was inadequate to maintain the plasma inorganic phosphorus levels of heifers. The plasma inorganic phosphorus levels of steers in the current experiment receiving this same level held remarkably constant (Table 10, Figure 8).

The average plasma inorganic phosphorus values during the entire repletion period for Lots 1, 2 and 3 were 2.69, 3.53 and 3.84 mg. percent, respectively. This response was significantly linear ($P < .01$) and accounted for 93.0 percent of the treatment variation. The difference between the average values for Lots 2 and 3 did not differ as greatly as the change in plasma inorganic phosphorus between the same lots. Part of this could be explained by the failure of one steer in Lot 3 to show an increase in plasma inorganic phosphorus until the latter part of the repletion period.

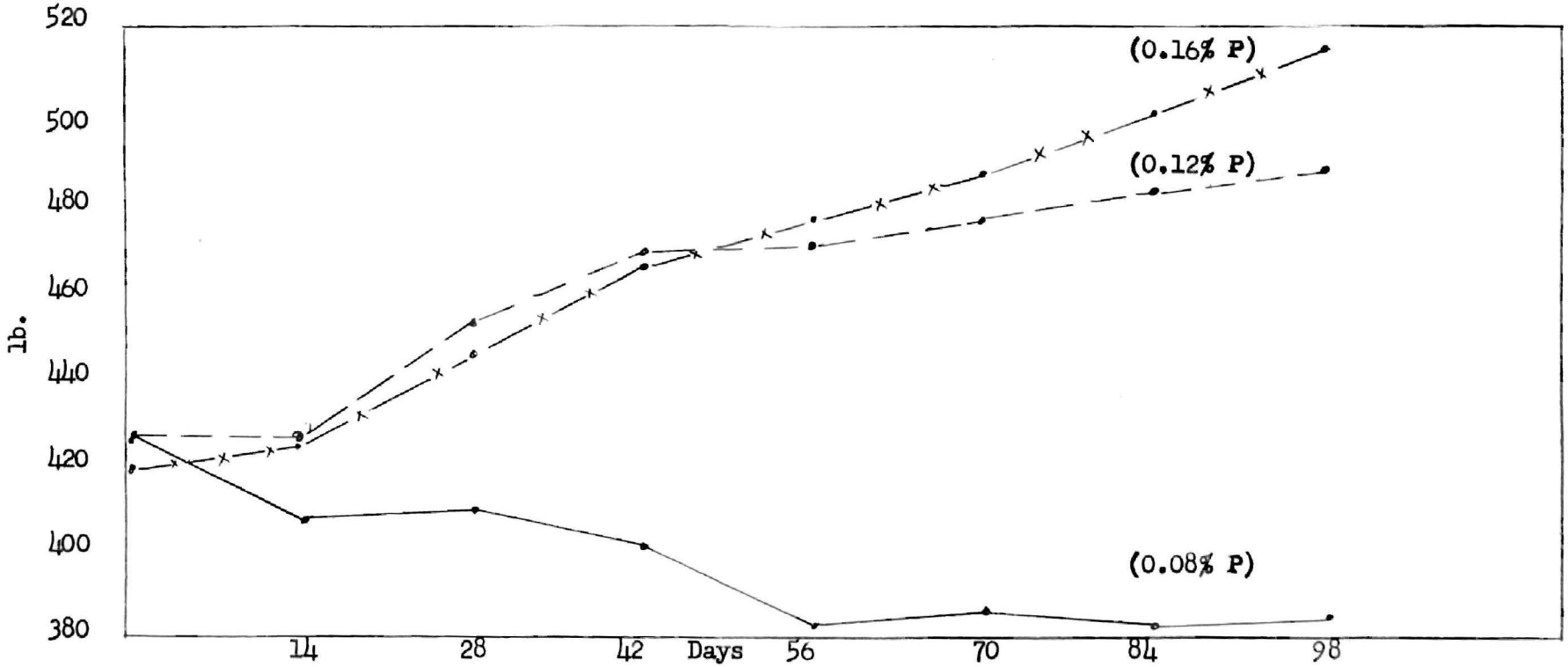

Figure 7. Weight Changes of Steers
Experiment III

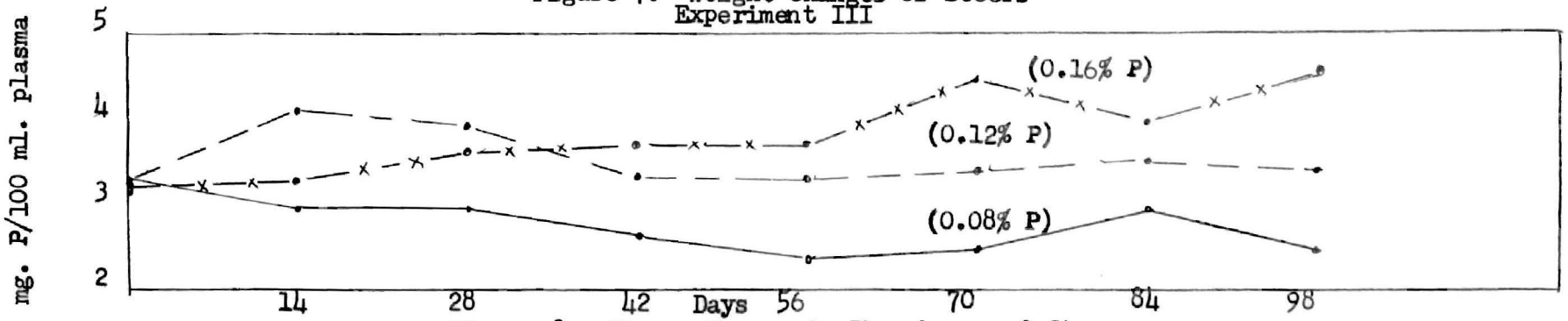

Figure 8. Plasma Inorganic Phosphorus of Steers
Experiment III

The correlation between change in plasma inorganic phosphorus and weight gain during repletion was 0.76 ($P<.05$). The correlation between the average plasma inorganic phosphorus level and weight gain during the same period was 0.89 ($P< .01$). This relationship was also pointed out in Experiment I with sheep and indicates the possibility that the average value may be a better measure of response than change in plasma inorganic phosphorus. The former measure at least takes into account all data collected during the experiment rather than the initial and final plasma inorganic phosphorus values only.

Feed Consumption

The average daily feed consumption for Lots 1, 2 and 3 during repletion was 3.56, 6.40 and 7.61 lb., respectively. This response was significantly linear ($P<.025$) with 94.8 percent of the treatment variation being due to linearity. The periodic measurements of feed consumption are graphically represented in Figure 9.

As pointed out above the difference in weight gains between Rations 2 and 3 was not so large as the difference between Rations 1 and 2. This trend can be accounted for in part, perhaps, by the small difference in feed consumption between Lots 2 and 3 as noted here. Also, as pointed out above, gains were not as large as had been obtained previously (Long, 1956).

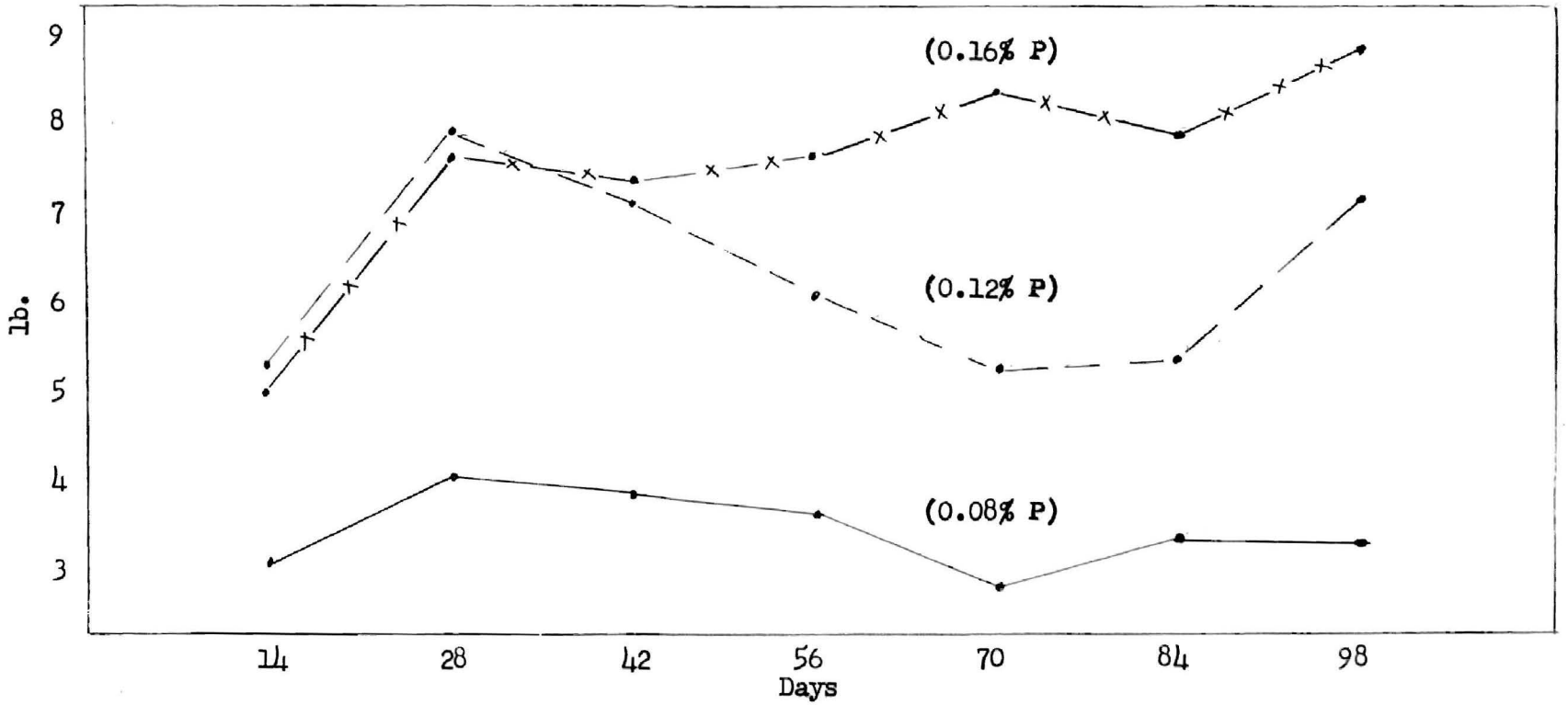

Figure 9. Daily Feed Consumption of Steers
Experiment III

Summary

One feeding trial involving 12 grade Hereford steers was conducted to establish a linear range of response to graded levels of dietary phosphorus. Criteria of response were plasma inorganic phosphorus, body weight and feed consumption. By all criteria, response was significantly linear in the dietary range between 0.08 and 0.16 percent phosphorus.

Plasma inorganic phosphorus did not reflect dietary phosphorus any more rapidly than did weight gain in this experiment.

The correlation between the average plasma inorganic phosphorus level and weight gain during repletion was 0.89 as compared to a correlation of 0.76 between change in final plasma inorganic phosphorus and weight gain during the same period.

Apparently, a level of phosphorus around 0.15 percent of the total ration would be appropriate for evaluating sources of supplement phosphorus. In view of this it is necessary to use a basal ration as low in phosphorus as practicable in order for the supplement being tested to provide a maximum amount of the total phosphorus.

EXPERIMENT IV

A COMPARISON OF PURIFIED AND FEED-GRADE SOURCES OF PHOSPHORUS FOR BEEF CATTLE

Several sources of inorganic phosphorus are available for use in livestock feeds. Of these, feed-grade dicalcium phosphate and defluorinated rock phosphate are used extensively. Since these materials are not refined to a high degree of purity, it seemed desirable to compare them with highly purified sources of supplemental phosphorus in beef cattle rations. This experiment was designed with the following objectives: (1) to compare defluorinated rock phosphate with feed-grade dicalcium phosphate as sources of supplemental phosphorus for growing beef cattle and (2) to compare these feed-grade materials with two purified sources of phosphorus and chemical reagent-grade dicalcium phosphate.

Experimental Procedure

Fifteen grade Hereford steers and 25 grade Hereford heifers were selected from the Lake Blackwell experimental herd. The average initial weight of the animals was approximately 465 lb.

All animals were fed Ration 1 (Table 11) ad libitum for a 56-day depletion period (Period 1). The animals were then divided, on the basis of sex and weight into 5 lots and given the following treatments during Period 2 (56 days): Lot 1 received the basal ration (Ration 1, 0.08% P) while Lots 2, 3, 4 and 5 received 0.04 percent supplemental phosphorus

supplied by reagent-grade dicalcium phosphate, defluorinated rock phosphate, feed-grade dicalcium phosphate and monosodium phosphate, respectively. During Period 3 (56 days) the level of supplemental phosphorus from all supplements was increased to 0.07 percent.

All animals were weighed initially and at 14-day intervals for the duration of the experiment. Blood samples were collected and feed consumption was determined at the end of each 14-day period. Plasma inorganic phosphorus determinations were made by the method of Fiske and Subbarow (1925). The data were treated statistically by analysis of variance (Snedecor, 1956).

Table 11. Composition of Experimental Rations (lb.)

Ingredients[1]	Ration 1	Ration 2	Ration 3	Ration 4	Ration 5
Cerelose	22.10	22.10	22.10	22.10	22.10
Cottonseed hulls	37.48	37.48	37.48	37.48	37.48
Beet pulp	27.10	27.10	27.10	27.10	27.10
Alfalfa meal	9.10	9.10	9.10	9.10	9.10
Corn gluten meal	3.70	3.70	3.70	3.70	3.70
Urea	0.35	0.35	0.35	0.35	0.35
A & D Supplement[2]	0.17	0.17	0.17	0.17	0.17
Reagent dicalcium phosphate	---	0.18(.32)[3]	---	---	---
Defluorinated rock phosphate	---	---	0.25(.44)	---	---
Feed grade dicalcium phosphate	---	---	---	0.21(.36)	---
Monosodium phosphate	---	---	---	---	0.17(.31)
Calcium carbonate	---	0.34(.56)	0.25(.41)	0.31(.50)	0.47(.79)
P from basal ration	0.08	0.08	0.08	0.08	0.08
P from supplement	---	0.04(.07)	0.04(.07)	0.04(.07)	0.04(.07)

[1]In addition, salt was fed free choice.
[2]Supplied 2724 I.U. of vitamin A and 340 I.U. of vitamin D per lb. of ration. Trade name is "Quadrex"--supplied gratis by Nopco Chemical Co., Harrison, N. J.
[3]Figures in parenthesis indicate quantities of the phosphorus supplement added during Period 3.

Results and Discussion

The observations of individual weight gain, plasma inorganic phosphorus and feed consumption, respectively, appear in Appendix Tables 28, 29 and 30.

Weight Gain

As shown in Table 12 the average total gains of 29, 60, 44 and 28 lb., respectively, for Lots 2, 3, 4 and 5 during Period 2 were significantly ($P < .01$) greater than the average gain of 23 lb. for Lot 1 when the treatment means were compared orthogonally. Rations 3 and 4 produced significantly ($P < .01$) faster gains during Period 2 than did Rations 2 and 5 which contained the purified sources of phosphorus.

In Period 3 the animals receiving Rations 2, 3, 4 and 5 again gained significantly ($P < .01$) faster than the animals consuming the basal ration. During this same period the animals receiving the feed-grade supplements (Lots 3 and 4) did not gain significantly faster than those receiving the purified supplements (Lots 2 and 5) as was noted in Period 2. The gains of animals consuming Rations 3 and 4 did not differ significantly at any time during the experiment. This observation is in agreement with the work of Ammerman et al. (1954) and Davis et al. (1953) in which defluorinated rock phosphate was found to be a satisfactory source of phosphorus for ruminants. The poor response produced by Rations 2 and 5 cannot be explained since Eckles et al. (1926), Long (1956) and Turner et al. (1934) have reported satisfactory results from monosodium phosphate for beef cattle. It is interesting to note that Scott et al. (1956) found a higher percentage ash content in the bones of poults fed feed-grade dicalcium phosphate than those fed reagent-grade dicalcium phosphate. These authors

have suggested the possibility of an unknown nutrient required in bone formation that perhaps is absent from highly purified phosphate containing materials.

Table 12. Weight Gain of Cattle
(lb.)

Ration	1 Basal	2 Reagent-Grade Dicalcium Phosphate	3 Defluorinated Rock Phosphate	4 Feed-Grade Dicalcium Phosphate	5 Monosodium Phosphate
Period 2 (56 days)					
Initial weight	455	475	469	467	465
Final weight	478	504	529	511	493
Gain	23	29	60	44	28
Period 3 (56 days)					
Initial weight	478	504	529	511	493
Final weight	478	568	579	606	572
Gain	0	64	50	95	79
Periods 2 & 3 (112 days)					
Initial weight	455	475	469	467	465
Final weight	478	568	579	606	572
Gain	23	93	110	139	107

When Periods 2 and 3 were combined, the differences noted during Period 2 were not apparent. This indicates that the gains during Period 3 tended to compensate for the slower gaining lots during the first period. Orthogonal comparison of the treatment means for Periods 1 and 2 combined indicates that the only significant difference among treatments existed between the supplemented and unsupplemented lots. No significant differences existed among the supplements tested.

Period 2 should have provided the most sensitive evaluation of the supplements tested; however, the failure of the relatively purified

sources to produce gains comparable to those produced by the feed-grade materials is apparent during that period. Apparently no data are available to either support or disagree with this observation; and, since the performance of all supplements during Period 3 failed to differ significantly, it is doubtful if the differences as large as those shown during Period 2 are real. Individual weights taken during the experiment are shown in Appendix Table 27.

Plasma Inorganic Phosphorus

The average plasma inorganic phosphorus values during repletion are shown in Table 13.

Table 13. Average Plasma Inorganic Phosphorus Values During Repletion

Ration	1 Basal	2 Reagent-Grade Dicalcium Phosphate	3 Defluorinated Rock Phosphate	4 Feed-Grade Dicalcium Phosphate	5 Monosodium Phosphate
Period 2 (56 days)	2.45	3.16	3.16	3.21	2.54
Period 3 (56 days)	2.09	3.89	4.63	4.63	4.27

During Period 2 the average plasma inorganic phosphorus values noted for Rations 2, 3, 4 and 5 as a group were significantly ($P < .05$) greater than for Ration 1. During this same period the average values for Rations 3 and 4 were significantly higher than those for Rations 2 and 5. The only significant differences with respect to average plasma inorganic phosphorus during Period 3 were between the supplemented rations and the basal ration.

The correlation coefficients between average plasma inorganic phosphorus value and weight gains during Periods 2 and 3 were 0.46 and 0.55, respectively. These coefficients are significant and indicate a positive relationship between plasma inorganic phosphorus and weight gain.

In previous tests of this nature, results have been evaluated partly on the basis of increase in plasma inorganic phosphorus; however, the average plasma inorganic phosphorus values during the entire repletion or treatment period, such as discussed above, should also be of value. Such average values should be indicative of the ability of a ration or supplement to rebuild and maintain the plasma inorganic phosphorus levels of depleted animals. Such an observation will also tend to eliminate the misleading effects of erratic variations which, for some unexplained reason, do occur.

The changes in plasma inorganic phosphorus during Periods 2 and 3 are shown in Table 14.

In Period 2 monosodium phosphate was the only source of supplemental phosphorus that failed to increase the plasma inorganic phosphorus level. The failure of this supplement can be partially explained by a lower feed consumption (Table 15) in Lot 5 as compared to the lots receiving the other sources of supplemental phosphorus. During Period 2 the change in plasma inorganic phosphorus of calves receiving Rations 2, 3 and 4 did not differ significantly. This observation does not support the work of Ammerman et al. (1955) in which it was reported that dicalcium phosphate was more effective in increasing the plasma inorganic phosphorus values of depleted lambs.

The increase in plasma inorganic phosphorus during Period 3 was undoubtedly influenced by the change effected in Period 2. Apparently

Table 14. Average Change in Plasma Inorganic Phosphorus of Cattle

Ration	1 Basal	2 Reagent-Grade Dicalcium Phosphate	3 Defluorinated Rock Phosphate	4 Feed-Grade Dicalcium Phosphate	5 Monosodium Phosphate
Period 2 (56 days)					
Initial phosphorus	2.70	2.74	2.83	2.89	2.75
Final phosphorus	2.05	3.28	3.36	3.40	2.39
Change	-0.65	0.54	0.53	0.51	-0.36
Period 3 (56 days)					
Initial phosphorus	2.05	3.28	3.36	3.40	2.39
Final phosphorus	1.96	3.62	4.26	4.64	4.49
Change	-0.09	0.34	0.90	1.24	2.10
Periods 2 & 3 (112 days)					
Initial phosphorus	2.70	2.74	2.83	2.89	2.75
Final phosphorus	1.96	3.62	4.26	4.64	4.49
Change	-0.84	0.88	1.43	1.75	1.74

Table 15. Average Daily Feed Consumption (lb.)

Ration	1 Basal	2 Reagent-Grade Dicalcium Phosphate	3 Defluorinated Rock Phosphate	4 Feed-Grade Dicalcium Phosphate	5 Monosodium Phosphate
Period 2 (56 days)	9.12	9.18	9.63	9.39	7.79
Period 3 (56 days)	8.50	14.37	14.85	14.96	13.78

those lots doing poorly in Period 2 were compensated during Period 3. The different sources of supplemental phosphorus did not differ significantly in Period 3, with respect to their effect on plasma inorganic phosphorus.

When Periods 2 and 3 were combined no one supplement was superior to any other in its ability to effect a change in plasma inorganic phosphorus.

Feed Consumption

Average feed consumption for the various lots is shown in Table 15. During Period 2 feed consumption was approximately equal in Lots 1, 2, 3 and 4 but was considerably less in Lot 5. A part of the reduced feed consumption in Lot 5 might be attributed to the difficulty the animals had eating out of the feeder; however, to what extent this influenced the results cannot be estimated. Adjustments were made as soon as the difficulty was suspected as causing a lower rate of consumption in that lot.

In Period 3 feed consumption improved rapidly in all the supplemented lots and decreased slightly in the lot receiving the basal ration. Feed consumption in Lot 5 remained slightly lower than Lots 2, 3 and 4 during Period 3, but the rate of consumption was apparently sufficient to promote an increased plasma inorganic phosphorus level during the period.

It is quite evident from these results that feed consumption was greatly enhanced by increasing the level of phosphorus in the ration from 0.12 to 0.15 percent.

It was apparent that the rations containing 0.12 percent phosphorus were too low with respect to this element to prevent gross deficiency symptoms and that 0.15 percent phosphorus was sufficient to cure the affected animals rapidly. This is in agreement with Beeson et al. (1938) in which gross deficiency symptoms developed in steers receiving a 0.12 percent phosphorus ration. Also, Kleiber et al. (1936) noted that heifers fed a 0.13 percent phosphorus ration ceased to grow after 6 months.

Summary

Fifteen grade Hereford steers and 25 grade Hereford heifers were self-fed a low phosphorus ration for a 56-day depletion period. The animals were then divided into 5 lots and the basal ration was supplemented at the rate of 0.04 percent phosphorus for a 56-day period and at the rate of 0.07 percent phosphorus for another 56-day period. The supplemental phosphorus was supplied by reagent-grade dicalcium phosphate, defluorinated rock phosphate, feed-grade dicalcium phosphate and monosodium phosphate.

Reagent-grade dicalcium phosphate and monosodium phosphate produce gains that were significantly lower than the other supplements during the period in which 0.04 percent supplemental phosphorus was supplied. This difference was not apparent when the rations were supplemented at the rate of 0.07 percent phosphorus. A combination of the results of both repletion periods indicated no significant difference in the response produced by the supplements tested.

All supplements tested produced more rapid gains, greater feed consumption and a higher plasma inorganic phosphorus level over the entire repletion period than the basal ration.

Gross deficiency symptoms developed in some animals while being fed rations containing 0.12 percent phosphorus. These symptoms were rapidly corrected by raising the phosphorus level to 0.15 percent of the total ration.

SUMMARY

Two feeding trials were conducted to determine the response of ewe lambs to graded levels of dietary phosphorus. A basal ration containing 0.07 percent phosphorus was supplemented with monosodium phosphate (Trial 1) and reagent-grade dicalcium phosphate (Trial 2) to provide rations containing 0.10, 0.13 and 0.16 percent phosphorus. Within the range from 0.07 to 0.16 percent dietary phosphorus, the response with respect to weight gain, plasma inorganic phosphorus levels and feed consumption was significantly linear.

A similar study was conducted to determine the response of grade Hereford steers to graded levels of dietary phosphorus. A basal ration containing 0.08 percent phosphorus was supplemented with reagent-grade dicalcium phosphate to provide rations containing 0.12 and 0.16 percent phosphorus. Within the range from 0.08 to 0.16 percent dietary phosphorus, the response with respect to weight gain, plasma inorganic phosphorus and feed consumption was significantly linear.

One experiment was conducted to observe the response of stilbestrol-implanted lambs to graded levels of dietary phosphorus. A basal ration containing 0.18 percent phosphorus was supplemented with monosodium phosphate to provide rations containing 0.25 and 0.33 percent phosphorus. Stilbestrol implantation significantly increased rate and efficiency of gain but apparently did not increase the phosphorus requirement of lambs above that provided by the basal ration. Rate and efficiency of gain, feed consumption and plasma inorganic phosphorus values did not differ significantly within the dietary levels of 0.18, 0.25 and 0.33 percent

phosphorus.

An experiment with grade Hereford steers and heifers was conducted to compare reagent-grade dicalcium phosphate, defluorinated rock phosphate, feed-grade dicalcium phosphate and monosodium phosphate as sources of phosphorus for beef cattle. When the basal ration containing 0.08 percent phosphorus was supplemented with the above materials at the rate of 0.04 percent phosphorus, feed-grade dicalcium phosphate and defluorinated rock phosphate produced more rapid gains than did monosodium phosphate and reagent-grade dicalcium phosphate. When the supplemental level was raised to 0.07 percent phosphorus, the responses noted for the supplements tested did not differ significantly.

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APPENDIX

Table 16. Body Weight of Lambs
Experiment I. Trial 1
(lb.)

Lamb No.	Period Ending 3/17	3/31	4/14	4/28	5/12	5/26	6/9	6/23
				Ration 1 (0.07% P)				
21	52	55	52	48	45	44	44	43
6	52	56	58	56	55	55	55	55
9	52	56	59	55	53	55	51	51
Av.	52	56	56	53	51	51	50	50
				Ration 2 (0.10% P)				
19	51	57	52	50	49	52	53	56
18	53	57	57	53	55	56	57	60
10	49	55	51	49	48	49	50	50
Av.	51	57	53	51	51	52	53	55
				Ration 3 (0.13% P)				
3	48	49	48	46	51	52	57	60
1	52	54	52	48	48	50	53	54
8	52	54	51	50	53	56	60	67
Av.	51	52	50	48	51	52	57	60
				Ration 4 (0.16% P)				
2	48	50	50	47	53	61	67	72
20	53	53	52	49	54	61	68	75
16	51	49	48	46	51	54	59	65
Av.	51	51	50	47	53	59	63	71

Table 17. Plasma Inorganic Phosphorus Levels of Lambs
Experiment I. Trial 1
(mg. P/100 ml. plasma)

Lamb No.	Initial	Period Ending 3/31	4/14	4/28	5/12	5/26	6/9	6/23
				Ration 1 (0.07% P)				
21	6.48	3.28	2.40	2.36	2.40	2.48	2.36	2.24
6	8.88	3.68	3.08	2.64	2.48	2.72	2.64	1.84
9	8.44	4.40	4.36	4.08	3.16	3.72	2.68	2.92
Av.	7.92	3.78	3.28	3.02	2.68	2.97	2.56	2.33
				Ration 2 (0.10% P)				
19	5.64	3.76	2.84	2.72	2.56	2.88	2.16	2.36
18	5.76	3.64	2.64	3.08	3.40	3.64	3.36	3.52
10	9.52	3.76	3.36	3.20	3.12	2.60	3.12	2.64
Av.	6.97	3.72	2.95	3.00	3.02	3.04	2.88	2.84
				Ration 3 (0.13% P)				
3	6.24	3.76	2.72	3.24	3.16	4.08	4.08	4.72
1	6.48	3.88	2.72	2.72	3.28	3.16	3.12	2.92
8	6.88	4.00	3.04	2.88	2.54	3.52	4.48	4.88
Av.	6.53	3.88	2.83	2.95	3.62	3.59	3.89	4.17
				Ration 4 (0.16% P)				
2	7.37	3.32	2.56	2.24	8.24	6.84	6.84	5.96
20	6.44	3.36	3.28	2.84	7.76	6.84	7.16	6.84
16	5.64	4.11	2.92	3.60	6.88	6.48	6.28	6.52
Av.	6.48	3.60	2.92	2.90	7.60	6.72	6.76	6.44

able 18. Daily Feed Consumption of Lambs
Experiment I. Trial 1
(lb.)

Lamb No.	Period Ending 3/31	4/14	4/28	5/12	5/26	6/9	6/23
			Ration 1 (0.07% P)				
21	2.43	1.74	1.21	0.86	1.00	0.67	0.80
6	2.14	1.93	1.79	1.86	1.50	1.20	1.34
9	2.29	1.93	1.64	1.29	1.57	0.97	1.08
Av.	2.29	1.87	1.55	1.34	1.36	0.95	1.07
			Ration 2 (0.10% P)				
19	1.86	1.21	1.35	1.29	1.57	1.55	1.79
18	2.29	1.74	1.50	1.50	1.57	1.57	1.54
10	1.86	1.50	1.50	1.93	1.14	1.23	1.14
Av.	2.00	1.48	1.45	1.57	1.43	1.45	1.39
			Ration 3 (0.13% P)				
3	2.14	1.64	1.35	1.93	2.21	2.40	2.87
1	1.71	1.50	1.50	1.14	1.43	1.58	1.78
8	1.71	1.21	1.07	2.14	1.50	2.14	2.56
Av.	1.85	1.45	1.31	1.73	1.71	2.04	2.40
			Ration 4 (0.16% P)				
2	1.71	1.35	1.07	1.64	2.93	3.74	3.86
20	2.00	1.50	1.35	1.64	3.14	3.52	3.90
16	1.86	1.50	1.21	1.71	2.00	2.18	2.98
Av.	1.86	1.45	1.21	1.66	2.69	3.38	3.58

Table 19. Body Weight of Lambs
Experiment I. Trial 2
(lb.)

Lamb No.	Period Ending 5/26	6/9	6/23	7/7	7/21	8/4	8/18	9/1	9/15	9/29	10/13	10/27
						Ration 1 (0.07% P)						
05	49	51	52	50	53	53	53	53	54	54	55	55
011	43	44	43	41	43	45	42	43	42	44	46	45
Av.	46	47	47	45	48	49	47	48	48	49	51	50
						Ration 2 (0.10% P)						
01	46	50	50	51	53	55	54	58	62	66	67	65
02	47	48	52	50	52	57	58	59	59	59	59	56
06	42	46	48	45	48	49	49	51	54	56	60	60
Av.	45	48	50	49	51	54	54	56	58	60	62	60
						Ration 3 (0.13% P)						
04	52	55	59	59	63	64	64	67	72	71	71	73
07	38	40	41	43	47	50	51	55	62	62	68	68
010	38	40	37	36	42	45	46	47	50	51	53	55
Av.	43	45	46	46	51	53	54	56	61	61	64	68
						Ration 4 (0.16% P)						
03	51	53	54	54	54	57	62	63	67	72	77	77
09	47	46	45	44	49	53	59	60	65	68	74	78
08	43	44	45	44	48	51	55	58	64	65	71	73
Av.	47	48	48	47	50	54	59	60	65	68	74	76

Table 20. Plasma Inorganic Phosphorus Levels of Lambs
Experiment I. Trial 2
(mg. P/100 ml. plasma)

Lamb No.	Period Ending 5/26	6/9	6/23	7/7	7/21	8/4	8/18	9/1	9/15	9/29	10/13	10/27
					Ration 1 (0.07% P)							
05	7.56	3.44	3.16	3.00	2.76	2.48	2.48	2.56	2.84	2.68	2.82	3.00
011	8.24	3.16	3.08	2.56	2.52	2.72	2.28	2.52	2.76	2.64	2.36	2.64
Av.	7.90	3.30	3.12	2.78	2.64	2.60	2.38	2.54	2.80	2.66	2.59	2.82
					Ration 2 (0.10% P)							
01	8.00	4.08	2.40	2.36	2.76	2.92	3.20	3.96	3.52	3.80	2.96	2.00
02	8.08	3.40	4.08	2.80	2.72	3.28	3.48	2.76	3.24	3.60	2.92	4.00
06	6.16	3.76	3.16	2.64	3.12	2.84	2.92	2.56	3.28	2.92	2.76	3.28
Av.	7.41	3.74	3.21	2.60	2.86	3.01	3.20	3.09	3.34	3.44	2.88	3.09
					Ration 3 (0.13% P)							
04	11.44	3.64	2.92	2.40	4.48	2.96	3.20	3.28	3.08	2.92	2.76	2.44
07	8.20	2.68	3.56	2.84	3.92	5.40	4.88	5.44	6.20	4.76	5.20	5.80
010	7.92	3.08	4.32	2.48	3.48	3.56	3.04	3.22	3.04	4.16	2.76	3.00
Av.	9.19	3.13	3.60	2.54	3.96	3.97	3.70	3.97	4.11	3.94	3.57	3.74
					Ration 4 (0.16% P)							
03	9.40	3.32	3.28	2.40	3.52	3.92	4.88	4.84	3.28	5.64	4.36	7.32
09	10.52	3.28	3.96	2.64	4.24	3.56	4.92	3.60	3.96	5.36	4.36	5.84
08	7.08	3.88	3.20	3.24	3.56	4.48	4.60	4.08	4.36	4.40	3.52	5.28
Av.	9.00	3.49	3.48	2.76	3.77	3.98	4.80	4.17	3.87	5.03	4.08	6.14

Table 21. Daily Feed Consumption of Lambs
Experiment I. Trial 2
(lb.)

Lamb No.	Period Ending 6/9	6/23	7/7	7/21	8/4	8/18	9/1	9/15	9/29	10/13	10/27
					Ration 1 (0.07% P)						
05	2.21	1.76	2.28	1.47	1.41	1.36	1.24	1.22	1.00	1.11	1.00
011	1.85	1.42	1.49	1.06	1.36	0.91	0.99	0.92	0.98	1.22	0.99
Av.	2.03	1.59	1.88	1.27	1.39	1.13	1.11	1.07	0.99	1.17	0.99
					Ration 2 (0.10% P)						
01	2.59	2.31	2.57	1.98	2.20	1.74	2.00	2.22	2.15	2.07	1.79
02	2.35	1.59	2.22	1.75	2.14	1.86	2.07	1.60	1.31	1.12	0.86
06	2.60	2.39	2.53	1.86	2.05	1.80	1.93	2.01	1.92	2.03	1.77
Av.	2.51	2.10	2.44	1.86	2.13	1.80	2.03	1.94	1.79	1.74	1.47
					Ration 3 (0.13% P)						
04	2.49	2.61	2.36	2.25	2.15	2.20	2.30	2.19	2.06	1.77	1.66
07	2.15	1.86	2.09	2.11	2.29	2.48	2.32	2.20	2.06	2.22	2.22
010	2.01	0.92	1.26	1.71	1.96	1.81	1.71	1.79	1.43	1.65	1.66
Av.	2.21	1.80	1.90	2.02	2.13	2.16	2.11	2.06	2.18	1.88	1.85
					Ration 4 (0.16% P)						
03	2.53	2.62	2.39	1.49	1.90	2.32	2.14	2.43	2.26	2.26	2.55
09	1.89	1.13	1.37	1.59	2.13	2.29	1.86	2.22	2.02	2.09	2.52
08	2.42	1.94	1.98	1.79	2.11	2.10	2.40	2.70	2.26	2.28	2.50
Av.	2.28	1.90	1.91	1.62	2.04	2.24	2.14	2.45	2.18	2.21	2.52

Table 22. Body Weight of Lambs
Experiment II
(lb.)

Lamb No.	(No Stilbestrol Implant) Period Ending 11/1/57	11/8/57	12/3/57	12/20/57	1/11/58	Lamb No.	(6.0 mg. Stilbestrol Implant) Period Ending 11/1/57	11/8/57	12/3/57	12/20/57	1/11/58
					Ration 1						
35	75	75	80	84	88	91	78	85	100	99	109
99	73	69	88	93	106	44	70	71	87	92	101
51	70	69	78	74	77	6	69	69	83	94	104
17	65	67	77	79	90	7	73	81	88	100	108
27	74	74	78	83	87	29	72	76	80	87	95
36	72	72	80	85	92	46	62	62	64	73	79
47	68	69	70	72	74						
1	62	72	80	91	101						
Av.	70	71	79	83	89	Av.	71	74	84	91	99
					Ration 2						
101	76	77	84	87	95	70	76	78	96	102	109
4	72	73	90	96	110	59	72	76	91	99	110
50	69	70	74	75	75	93	69	70	87	93	104
55	65	73	83	85	91	69	65	71	71	75	82
81	73	77	78	82	86	43	76	75	79	85	87
89	72	77	84	93	102	66	72	75	78	85	92
62	67	68	70	77	81	5	68	67	76	78	89
16	65	70	78	83	80	31	59	61	57	67	81
Av.	70	73	80	85	90	Av.	70	72	79	85	94

Table 22 (Continued)

Lamb No.	(No Stilbestrol Implant) Period Ending 11/1/57	11/8/57	12/3/57	12/20/57	1/11/58	Lamb No.	(6.0 mg. Stilbestrol Implant) Period Ending 11/1/57	11/8/57	12/3/57	12/20/57	1/11/58
					Ration 3						
94	79	83	91	90	96	40	74	73	87	91	98
24	72	75	86	92	104	3	72	74	79	83	89
67	69	69	80	86	97	58	69	66	75	85	96
14	63	61	71	77	81	88	65	67	82	93	105
63	73	70	78	85	93	23	73	76	80	83	90
73	71	76	81	86	89	18	67	68	70	79	85
54	67	65	69	76	88	11	62	68	74	83	87
15	65	61	64	71	80						
Av.	70	70	77	83	91	Av.	69	70	78	85	93

Table 23. Plasma Inorganic Phosphorus Levels of Lambs
Experiment II
(mg. P/100 ml. plasma)

Lamb No.	(No Stilbestrol Implant) Period Ending 11/1/57	11/8/57	12/3/57	12/20/57	1/11/58	Lamb No.	(6.0 mg. Stilbestrol Implant) Period Ending 11/1/57	11/8/57	12/3/57	12/20/57	1/11/58
					Ration 1						
35	8.52	6.56	6.00	7.72	6.04	91	7.92	8.88	6.20	7.32	6.56
99	8.76	7.56	4.60	7.64	6.00	44	6.16	6.64	6.46	9.28	4.68
51	11.72	8.04	5.76	5.96	6.24	6	7.68	7.88	6.84	7.92	5.96
17	9.84	9.40	7.76	10.88	7.48	7	7.68	5.80	7.72	7.04	5.72
27	11.72	10.00	9.20	10.68	8.20	29	7.84	7.72	7.88	7.36	6.80
36	8.52	8.24	6.88	7.20	5.60	46	7.36	8.24	7.48	6.60	5.64
47	6.96	9.52	6.40	7.40	7.88						
1	5.96	5.96	5.20	7.52	6.12						
Av.	9.00	8.16	6.47	8.12	6.70	Av.	7.44	7.52	7.08	7.58	5.89
					Ration 2						
101	6.80	6.12	7.84	7.04	6.12	70	5.88	6.36	5.32	7.32	5.86
4	7.52	5.12	6.60	7.04	5.64	59	6.64	9.52	6.84	7.88	6.80
50	9.44	8.52	6.36	10.68	5.16	93	6.80	7.64	7.12	7.64	5.04
55	6.84	6.68	7.36	7.08	5.80	69	6.64	5.20	6.00	8.92	5.72
81	7.16	6.48	7.48	6.24	6.00	43	4.60	8.00	8.76	8.24	6.28
89	6.16	6.48	7.64	8.60	8.04	66	9.52	6.60	6.80	6.24	5.56
62	7.84	7.76	7.48	7.04	8.20	5	6.56	7.28	5.52	8.04	6.36
16	5.20	6.56	6.80	7.04	6.12	31	8.76	9.92	7.16	10.68	7.56

Table 23 (Continued)

Lamb No.	(No Stilbestrol Implant) Period Ending 11/1/57	11/8/57	12/3/57	12/20/57	1/11/58	Lamb No.	(6.0 mg. Stilbestrol Implant) Period Ending 11/1/57	11/8/57	12/3/57	12/20/57	1/11/58
					Ration 3						
94	8.24	10.52	7.16	8.40	6.28	40	8.04	8.16	6.80	8.32	6.20
24	7.40	7.28	6.48	6.92	5.84	3	7.72	7.52	7.64	10.36	5.84
67	8.08	8.76	6.88	8.52	6.64	58	7.84	7.76	5.36	6.32	5.24
14	6.08	5.88	5.04	7.04	4.48	88	8.04	5.24	6.28	9.52	7.52
63	7.28	6.88	6.28	8.16	6.48	23	7.52	7.64	7.56	7.04	5.32
73	9.20	9.92	7.36	7.52	6.28	18	5.92	12.52	6.48	4.84	6.48
54	6.64	8.04	8.60	7.64	5.72	11	8.20	7.84	7.40	8.76	6.72
15	5.28	9.24	5.80	6.80	5.36						
Av.	7.27	8.31	6.70	7.62	5.88	Av.	7.61	8.09	6.78	7.88	6.18

Table 24. Daily Feed Consumption of Lambs
Experiment II
(lb.)

Lamb No.	(No Stilbestrol Implant) Period Ending 11/8/57	12/3/57	12/20/57	1/11/58	Lamb No.	(6.0 mg. Stilbestrol Implant) Period Ending 11/8/57	12/3/57	12/20/57	1/11/58
					Ration 1				
35	2.4	3.3	2.6	2.9	91	2.8	5.1	3.5	4.1
99	1.4	4.5	3.5	4.7	44	2.0	3.9	3.2	3.5
51	1.9	2.9	2.2	1.9	6	2.3	3.9	3.4	4.3
17	3.3	3.8	2.2	3.2	7	2.6	4.3	4.0	4.8
27	1.7	2.3	2.6	2.9	29	2.2	2.4	3.6	3.7
36	1.3	2.1	2.8	3.4	46	1.1	1.4	2.6	3.1
47	1.5	1.8	2.1	2.0					
1	3.8	4.0	4.5	4.2					
Av.	2.2	3.0	2.8	3.1	Av.	2.2	3.0	2.9	3.3
					Ration 2				
101	3.1	3.4	2.8	3.0	70	2.8	4.6	4.3	4.3
4	3.1	4.6	3.7	4.6	59	1.7	3.5	3.7	3.5
50	1.9	2.7	1.7	2.1	93	1.6	3.1	3.5	4.3
55	3.2	3.6	2.7	3.0	69	2.9	3.2	2.3	2.9
81	2.8	2.4	2.3	2.4	48	0.9	2.3	2.5	2.5
89	2.7	3.8	4.9	4.7	66	2.0	1.9	3.1	3.9
67	1.7	1.6	2.5	2.4	5	2.1	2.7	3.4	4.0
16	2.4	2.8	3.4	3.9	31	2.3	1.3	2.4	3.6
Av.	2.6	3.1	3.0	3.3	Av.	2.0	2.8	3.1	3.6

Table 24 (Continued)

Lamb No.	(No Stilbestrol Implant) Period Ending 11/8/57	12/3/57	12/20/57	1/11/58	Lamb No.	(6.0 mg. Stilbestrol Implant) Period Ending 11/8/57	12/3/57	1/20/57	1/11/58
					Ration 3				
94	2.6	4.6	2.8	2.4	40	2.4	4.1	3.2	3.4
24	3.3	3.6	3.6	4.4	3	2.7	2.7	2.3	2.7
67	1.9	3.3	3.5	3.8	58	1.0	2.2	3.1	3.9
14	1.5	2.4	2.9	3.1	88	2.0	3.2	3.5	3.1
63	1.6	2.8	3.4	2.4	23	2.5	2.4	2.6	2.5
73	2.0	2.4	3.4	2.9	18	1.3	2.0	3.2	3.1
64	1.9	2.8	2.8	4.0	11	2.1	2.8	3.3	3.3
15	0.8	2.2	2.7	3.4					
Av.	1.9	3.0	3.1	3.3	Av.	2.0	2.8	3.0	3.1

Table 25. Body Weight of Steers
Experiment III
(lb.)

Steer No.	Period Ending 8/24	9/7	9/22	10/6	10/20	11/3	11/17	12/1	12/15	12/31	1/12	1/26	2/9
						Ration 1 (0.08% P)							
121	435	440	445	455	455	430	400	402	385	380	382	365	368
63	430	445	445	470	450	435	412	417	415	413	405	415	412
138	380	395	405	410	420	395	378	370	355	360	347	357	363
128	395	430	430	450	465	450	443	449	453	458	450	435	431
Av.	410	427	431	446	447	427	408	409	402	394	396	393	394
						Ration 2 (0.12% P)							
92	390	420	425	440	455	425	418	425	450	447	454	450	458
136	425	430	425	415	435	395	410	450	462	467	476	482	489
122	405	405	390	455	470	450	445	475	489	497	495	509	512
156	400	425	420	440	445	430	435	462	475	472	480	487	495
Av.	405	420	415	437	451	425	427	453	469	471	476	482	488
						Ration 3 (0.16% P)							
199	410	430	440	440	460	424	425	446	466	470	481	495	509
120	490	460	450	480	475	434	458	490	520	535	450	563	572
140	370	400	405	430	430	390	395	408	425	430	441	454	466
68	375	400	400	425	440	424	420	443	460	472	475	492	518
Av.	411	423	424	444	451	418	425	447	468	477	487	501	516

Table 26. Plasma Inorganic Phosphorus Levels of Steers
Experiment III
(mg. P/100 ml. plasma)

Steer No.	Period Ending 8/24	9/7	9/22	10/6	10/20	11/3	11/17	12/1	12/15	12/31	1/12	1/26	2/9
						Ration 1 (0.08% P)							
121	10.16	3.32	3.20	2.16	2.16	3.48	3.04	3.04	2.48	2.84	2.68	3.32	2.68
63	8.80	3.28	3.20	3.68	2.48	3.04	2.60	3.04	2.64	2.28	2.60	2.64	2.60
138	8.52	3.80	3.56	3.32	2.08	3.72	2.40	2.92	3.04	2.36	2.72	3.08	2.72
128	7.68	3.04	2.68	2.88	2.76	3.00	3.92	2.76	2.36	2.00	1.96	2.76	1.96
Av.	8.79	3.11	3.16	3.01	2.37	3.31	2.99	2.94	2.63	2.37	2.49	2.95	2.49
						Ration 2 (0.12% P)							
92	7.64	3.56	3.48	3.76	2.20	2.84	3.92	3.44	3.28	3.24	3.60	3.04	3.60
136	7.92	2.96	3.04	2.52	2.29	2.84	3.92	3.16	3.28	2.92	3.60	3.20	3.60
122	8.00	3.38	4.96	4.20	2.40	3.92	3.92	4.40	3.32	3.28	2.96	2.92	2.96
156	7.64	3.40	4.48	3.84	2.76	3.48	4.60	4.48	3.32	3.64	3.52	4.24	3.52
Av.	7.80	3.33	3.99	3.58	2.40	3.27	4.09	3.87	3.30	3.27	3.42	3.47	3.42
						Ration 3 (0.16% P)							
199	7.84	2.60	2.84	3.24	2.36	3.16	3.48	3.68	3.76	3.60	4.60	4.08	4.60
120	8.44	3.48	4.16	3.80	2.28	3.56	3.60	3.68	4.36	3.92	4.44	4.32	4.44
140	7.12	3.00	2.60	2.76	2.24	3.20	2.56	2.56	2.64	2.72	4.24	3.52	4.28
68	7.72	3.88	3.80	3.28	2.64	2.80	3.40	4.24	3.96	4.28	4.48	3.56	4.48
Av.	7.78	3.24	3.35	3.27	2.38	3.18	3.26	3.54	3.68	3.63	4.44	3.87	4.44

Table 27. Daily Feed Consumption of Steers
Experiment III
(lb.)

Steer No.	Period Ending 11/17	12/1	12/15	12/31	1/12	1/26	2/9
			Ration 1 (0.08% P)				
121	2.50	3.29	3.71	3.21	2.29	3.07	2.85
63	3.07	3.36	2.64	3.00	2.14	3.35	3.57
138	2.79	3.93	3.21	2.43	3.14	3.57	3.42
128	4.71	6.29	6.14	6.50	3.86	4.00	3.85
Av.	3.26	4.22	3.92	3.78	2.86	3.49	3.42
			Ration 2 (0.12% P)				
92	3.79	6.85	5.57	4.86	4.71	5.28	7.00
136	5.92	8.29	7.85	6.93	5.57	5.65	7.42
122	5.71	8.36	7.29	6.57	5.85	5.57	7.42
156	6.21	8.57	8.42	6.43	5.14	5.29	7.00
Av.	5.40	8.01	7.28	6.20	5.32	5.44	7.21
			Ration 3 (0.16% P)				
199	5.14	7.21	7.00	7.64	7.85	7.00	8.78
120	5.78	8.14	7.93	8.00	9.28	7.21	8.78
140	4.35	7.79	7.35	7.64	8.28	8.85	9.14
68	5.09	7.71	7.42	7.76	8.47	8.85	8.78
Av.	5.09	7.71	7.42	7.76	8.47	7.97	8.87

Table 28. Body Weight of Steers and Heifers
Experiment IV
(lb.)

Animal No.	Period 1					Period 2				Period 3			
	8/24	9/7	9/22	10/6	10/20	11/3	11/17	12/1	12/15	12/31	1/12	1/26	2/9
						Ration 1							
45	450	455	460	465	465	475	475	470	485	510	495	515	530
196	415	405	415	445	425	435	425	430	425	530	410	400	390
189	330	350	350	360	360	370	390	370	370	380	360	400	395
69	370	390	405	415	420	430	435	420	440	425	405	425	415
108	515	550	565	580	595	600	625	615	645	640	615	620	630
53	425	425	430	450	460	480	500	495	500	505	520	505	510
115	445	460	450	480	500	510	540	525	540	525	520	515	500
177	360	400	410	420	415	415	435	370	420	435	415	425	455
Av.	414	429	436	452	455	464	478	462	478	481	367	476	478
						Ration 2							
117	405	410	420	425	450	450	450	425	445	470	455	475	500
182	390	415	405	430	435	440	460	455	485	505	485	515	545
195	510	540	535	590	595	600	630	650	660	710	680	720	750
101	500	535	560	520	560	560	570	580	600	620	620	650	695
183	355	360	350	380	400	400	405	415	430	460	445	475	555
141	440	455	450	465	490	490	500	490	470	540	515	535	580
186	415	425	420	470	490	490	515	515	520	545	540	540	555
181	365	385	390	385	380	370	390	390	420	395	365	375	365
Av.	423	441	441	458	475	475	490	490	504	531	513	536	568

Table 28 (Continued)

Animal No.	Period 1					Period 2				Period 3			
	8/24	9/7	9/22	10/6	10/20	11/3	11/17	12/1	12/15	12/31	1/12	1/26	2/9
						Ration 3							
129	435	430	455	485	490	470	490	470	535	545	540	590	590
124	320	350	355	370	375	380	395	380	375	370	380	390	400
71	425	440	460	500	495	510	510	505	560	565	575	615	620
142	420	440	440	440	475	500	515	520	565	570	585	620	620
155	390	375	370	385	390	400	410	410	450	455	460	485	490
118	492	505	505	520	515	545	560	510	570	580	580	620	620
97	435	470	460	490	500	510	525	540	575	595	590	620	620
160	430	460	450	480	515	515	535	555	600	590	635	640	670
Av.	418	434	437	459	469	479	490	486	529	534	543	573	579
						Ration 4							
46	435	420	410	440	440	465	480	485	510	550	550	575	600
116	450	450	450	450	460	470	460	435	460	485	480	520	520
197	375	400	400	410	410	410	430	425	440	455	460	500	495
130	375	410	405	410	405	425	455	440	465	495	485	525	555
184	405	435	430	450	485	500	515	535	560	590	595	630	660
158	420	440	460	485	500	510	530	540	570	580	565	600	620
198	380	410	400	410	400	410	400	410	390				
114	550	585	590	630	640	650	680	675	690	725	735	760	790
Av.	424	444	443	461	467	480	494	493	511	554	553	587	606

Table 28 (Continued)

Animal No.	Period 1					Period 2				Period 3			
	8/24	9/7	9/22	10/6	10/20	11/3	11/17	12/1	12/15	12/31	1/12	1/26	2/9
						Ration 5							
62	385	385	385	385	375	390	410	415	415	430	445	435	430
59	360	375	370	385	380	375	385	385	405	425	460	460	465
113	385	410	425	455	455	475	480	490	500	540	560	590	635
102	490	525	535	560	550	570	570	530	560	610	650	660	695
112	385	415	420	440	430	435	460	415	445	475	500	510	535
109	450	470	480	500	500	505	515	510	490	535	530	545	550
139	480	515	510	530	540	525	550	550	575	590	625	620	635
185	440	465	460	490	490	490	535	545	550	590	605	610	630
Av.	422	445	448	468	465	471	488	480	493	524	547	554	572

Table 29. Plasma Inorganic Phosphorus Levels of Steers and Heifers
Experiment IV
(mg. P/100 ml. plasma)

Animal No.	Period 1					Period 2				Period 3			
	8/24	9/7	9/22	10/6	10/20	11/3	11/17	12/1	12/15	12/31	1/12	1/26	2/9
						Ration 1							
45	7.04	2.92	2.92	4.00	3.64	3.04	--	2.92	2.32	2.64	1.92	1.96	2.04
196	7.16	2.84	3.36	3.60	2.16	2.40	2.24	2.52	1.76	1.92	1.60	1.88	1.60
189	8.24	3.08	4.24	3.10	2.16	2.24	2.24	2.16	1.64	2.40	1.76	1.56	1.76
69	6.64	2.48	3.00	3.00	2.40	2.24	2.00	1.96	1.44	1.76	1.56	1.76	1.60
108	8.00	3.48	4.24	3.88	3.12	2.72	3.20	3.48	2.68	2.52	2.48	2.44	1.96
53	7.20	3.56	3.60	4.48	3.12	2.32	2.68	2.12	2.04	2.32	1.84	2.00	2.04
115	7.72	4.08	4.72	3.84	3.36	3.28	2.76	2.68	2.32	2.04	2.28	2.72	2.36
177	6.84	3.56	3.72	3.28	1.88	2.40	2.80	2.92	2.24	3.20	3.00	1.52	2.28
Av.	7.35	2.89	3.25	3.65	2.10	2.57	2.56	2.59	2.05	2.05	2.05	1.98	1.96
						Ration 2							
117	6.88	3.36	3.92	3.84	3.28	3.96	3.28	2.64	3.28	3.92	4.52	3.48	3.32
182	9.64	3.32	3.80	3.44	2.72	2.76	3.32	3.12	3.44	4.60	4.24	4.36	3.84
195	7.52	3.16	4.24	4.16	3.16	3.24	3.44	3.90	3.48	5.44	3.60	3.36	3.96
101	6.36	2.40	4.48	3.16	2.56	3.04	3.24	3.48	3.28	4.68	4.60	4.16	4.60
183	8.80	3.08	3.36	3.04	2.76	2.24	3.24	2.68	3.16	3.80	3.36	3.92	3.84
141	7.04	3.12	3.36	3.08	2.52	2.84	2.76	3.56	3.20	4.76	3.76	4.88	3.76
186	6.48	2.96	3.64	4.00	2.76	2.96	3.00	3.28	2.80	3.36	3.20	3.52	2.84
181	8.04	2.84	3.08	2.84	2.16	2.16	2.48	2.44	3.60	2.92	2.80	3.40	2.80
Av.	7.59	3.03	3.73	3.45	2.74	2.90	3.09	3.13	3.28	3.76	3.76	3.88	3.62

Table 29 (Continued)

Animal No.	Period 1					Period 2				Period 3			
	8/24	9/7	9/22	10/6	10/20	11/3	11/17	12/1	12/15	12/31	1/12	1/26	2/9
						Ration 3							
129	9.20	3.04	4.16	3.68	3.12	3.28	2.68	2.24	3.48	6.12	4.44	5.16	4.28
124	6.60	2.92	2.64	2.00	1.92	2.12	2.28	2.36	2.16	2.64	2.24	3.20	2.92
71	6.64	2.64	3.56	3.76	2.64	3.92	2.84	3.52	3.92	5.04	3.72	5.16	3.96
142	8.56	3.48	3.72	3.60	3.24	3.76	3.72	2.84	3.92	5.80	3.60	5.96	5.56
155	7.28	4.76	4.68	4.20	3.48	4.24	3.28	4.24	3.36	5.32	3.80	4.64	4.88
118	7.72	2.92	3.24	3.12	2.24	3.48	2.48	2.92	2.84	3.56	3.08	4.24	4.40
97	5.96	3.48	3.04	3.40	3.20	3.40	2.72	2.84	3.52	6.12	3.42	3.88	3.68
160	7.88	3.20	3.36	3.28	2.88	2.92	2.68	3.36	3.68	5.44	4.12	4.88	4.40
Av.	7.48	3.31	3.55	3.38	2.83	3.39	2.84	3.04	3.36	5.00	3.55	4.64	4.26
						Ration 4							
46	8.76	3.44	3.36	3.80	3.08	3.72	4.36	2.80	3.84	5.56	5.00	5.32	4.88
116	9.80	3.32	3.20	3.28	2.44	2.68	2.16	3.80	2.64	4.92	3.24	4.52	3.84
197	8.76	3.48	3.80	2.64	2.76	2.84	3.32	2.72	2.56	4.24	3.96	4.08	4.36
130	5.84	3.52	4.08	3.68	3.40	2.80	2.84	2.76	3.24	5.28	3.92	5.48	4.88
184	8.52	2.60	3.20	3.96	3.68	3.20	4.52	3.48	3.00	5.96	4.08	5.40	4.84
158	7.76	3.36	3.96	3.44	2.64	3.48	3.28	3.08	3.08	5.04	4.24	5.56	5.04
198	6.20	3.08	3.00	3.12	2.40	3.00	3.20	2.68	2.56				
114	7.48	3.44	3.28	3.76	2.76	3.36	4.24	3.28	2.92	4.36	3.80	4.16	4.60
Av.	7.89	3.28	3.49	3.46	2.89	3.13	3.49	3.07	3.40	5.05	4.03	4.93	4.64

Table 22 (Continued)

Animal No.	Period 1					Period 2				Period 3			
	8/24	9/7	9/22	10/6	10/20	11/3	11/17	12/1	12/15	12/31	1/12	1/26	2/9
						Ration 5							
62	8.04	3.16	3.20	3.60	2.04	2.32	1.84	1.92	1.92	2.92	3.36	3.36	2.8
59	8.24	3.28	2.72	2.92	2.16	3.00	2.04	2.84	2.52	3.16	3.48	3.60	4.2
113	9.20	3.40	3.84	3.84	3.20	2.88	2.92	3.04	1.76	4.40	4.92	4.84	6.4
102	8.76	4.00	3.60	3.68	3.08	2.96	2.64	3.00	2.84	5.28	5.84	5.32	5.6
112	6.08	3.36	3.84	4.28	3.56	2.88	2.56	3.24	2.60	4.88	5.44	4.24	3.9
109	8.04	3.68	3.36	4.40	2.40	2.28	2.24	2.28	2.84	3.68	3.60	3.28	3.7
139	7.72	3.48	3.36	3.88	3.36	2.64	2.64	2.24	2.44	4.68	5.12	4.60	5.3
185	8.00	3.16	3.28	2.68	2.24	2.64	2.32	2.84	2.24	3.68	3.48	3.60	3.6
Av.	8.01	3.44	3.40	3.66	2.75	2.70	2.40	2.67	2.39	4.08	3.15	4.10	4.4

Table 30. Daily Feed Consumption of Steers and Heifers
Experiment IV
(lb.)

Period Ending	Ration 1	Ration 2	Ration 3	Ration 4	Ration 5
			Period 1		
	During this 56-day depletion period all animals were fed the basal ration ad libitum in the same lot. Average daily feed consumption during this period was approximately 9.0 lb.				
			Period 2		
12/29/56	8.56	8.02	8.78	8.47	6.79
11/17/56	8.52	8.92	9.10	8.92	6.83
12/1/56	9.64	9.81	9.91	9.86	7.81
12/14/56	9.77	10.00	10.71	10.31	9.73
Av.	9.12	9.18	9.63	9.39	7.79
			Period 3		
12/29/56	8.92	14.29	14.73	15.03	11.16
1/12/57	8.55	14.53	14.93	14.86	14.82
1/26/57	8.51	14.20	14.90	15.00	14.71
2/9/57	8.02	14.46	14.82	14.95	14.46
Av.	8.50	14.37	14.85	14.96	13.78

VITA

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