



Self-feeding beef calves mineral mixtures varying in calcium and phosphorus levels
by Samuel H Smyrl

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree
of Master of Science in Animal Industry
Montana State University
© Copyright by Samuel H Smyrl (1958)

Abstract:

Two trials were conducted to determine if level of phosphorus, ratio of calcium to phosphorus, or the addition of "temptors" to mineral mixtures would affect mineral consumption by beef calves being fed a low phosphorus ration, and to observe the effects of these mineral mixtures on growth, weight gains, and blood composition of the calves.

Forty weanling Hereford steer calves were used in the first trial.

The calves were divided into eight lots, and one steer from each lot was assigned to each of five pens. All calves received a ration consisting of dry rolled barley, molasses dried beet pulp and soybean meal, and low phosphorus swamp-grass hay. The calves were individually fed. The lots received either 0, 5, or 10 percent phosphorus in their mineral mixtures, and one of the following ratios of calcium to phosphorus; 0:0, 0:1, 1:1, 2:1, 5:1. The pens received either no "temptor", Vitamins A and D, trace minerals, active dry yeast, or "Stoc-Joy" added to their mineral mixture. Each calf on Experiment I received a different mineral mixture.

In the second trial forty weanling Hereford steer calves were used and were divided in the same manner as those on the first experiment.

The ration fed consisted of dry rolled barley, molasses dried beet pulp pellets, and soybean meal, and low phosphorus swamp-grass hay. The calves were individually fed. Each of the eight lots received either 0, 7 1/2, or 10 percent phosphorus in their mineral mixture, and calcium:phosphorus ratios of 0:0, 0:1, 1:1, 1:2, or 2:1.

Records were kept of mineral consumption, salt consumption, feed consumption, weight gains, and plasma phosphorus, carotene, and vitamin A levels for the calves on each trial.

The calves failed to consume enough mineral to make one gram added phosphorus intake per day for any lot on either trial. Feed consumption was somewhat less than expected, especially during the second trial when the calves found the beet pulp pellets unpalatable. Weight gains were adequate in the first trial, but slightly low in the second because of the low concentrate intake. Plasma phosphorus levels indicated inadequate phosphorus nutrition in both trials. Plasma carotene and vitamin A levels indicated adequate carotene throughout both trials.

SELF-FEEDING BEEF CALVES MINERAL MIXTURES VARYING
IN CALCIUM AND PHOSPHORUS LEVELS

by

SAMUEL H. SMYRL

A THESIS

Submitted to the Graduate Faculty

in

partial fulfillment of the requirements

for the degree of

Master of Science in Animal Industry

at

Montana State College

Approved:

Fred L. Willson
Head, Major Department

Oscar O. Thomas
Chairman, Examining Committee

Leon H. Johnson
Dean, Graduate Division

Bozeman, Montana
May, 1958

~~XXXXXXXXXX~~
N 378
Sm 94s
Cop. 2

1098ⁿ

-2-

ACKNOWLEDGEMENT

The author wishes to express his appreciation to Doctor O. O. Thomas, Associate Professor, in the Animal Industry Department at Montana State College, for his guidance in the organization and conducting of the trials, and his suggestions in the preparation of the manuscript. Appreciation is also expressed for the following Graduate Students, and former Graduate Students who helped in collection of data; David P. Heaney, Stuart W. Tilton, Jerry R. Border and Charles A. Daley.

The author also wishes to express his appreciation to Dr. E. B. Harvey of the Zoology and Entomolgy Department for his aid in editing of the manuscript.

TABLE OF CONTENTS

Index to Tables	5
Index to Figures.	6
Abstract.	7
Introduction.	8
Review of Literature.	11
Experiment I.	23
Procedure.	23
Results and Discussion	28
Feed consumption.	28
Mineral intake.	29
Gains and cost of gains	32
Plasma inorganic phosphorus levels.	33
Plasma carotene levels.	34
Plasma vitamin A levels	34
Phosphorus deficiency symptoms.	38
Analysis of variance.	38
Experiment II	41
Procedure.	41
Results and Discussion	45
Feed consumption	45
Mineral consumption	46
Gains and concentrates per hundredweight gain	48
Plasma inorganic phosphorus levels.	49
Plasma carotene levels.	49

TABLE OF CONTENTS (Cont'd.)

Plasma vitamin A	.52
Phosphorus deficiency symptoms	.52
Summary	.55
Literature Cited	.58

INDEX TO TABLES

I.	Design of the Experiment (1955-1956)	25
II.	Composition of Mineral Mixtures (1955-1956).	26
III.	Chemical Analysis of Feeds Used in Experiment I.	27
IV.	Average Daily Concentrate Consumption, Experiment I.	29
V.	Average Daily Hay Consumption, Experiment I.	30
VI.	Average Daily Mineral Consumption, Experiment I.	31
VII.	Average Daily Phosphorus Consumption from Concentrates, Hay and Mineral Mixture, Experiment I	31
VIII.	Average Daily Salt Consumption, Experiment I	32
IX.	Average Daily Gain, Experiment I	32
X.	Cost Per Hundredweight Gain, Experiment I.	33
XI.	Initial Plasma Inorganic Phosphorus Levels, Experiment I	35
XII.	Final Plasma Inorganic Phosphorus Levels, Experiment I	35
XIII.	Average Plasma Inorganic Phosphorus Levels, Experiment I	35
XIV.	Initial Plasma Carotene Levels, Experiment I	37
XV.	Final Plasma Carotene Levels, Experiment I	37
XVI.	Average Plasma Carotene Levels, Experiment I	37
XVII.	Initial Plasma Vitamin A Levels, Experiment I.	39
XVIII.	Final Plasma Vitamin A Levels, Experiment I.	39
XIX.	Average Plasma Vitamin A Levels, Experiment I.	39
XX.	Analysis of Variance Tables, Experiment I.	40
XXI.	Composition of Mineral Mixtures, Experiment II	43
XXII.	Chemical Analysis of Feeds Used in Experiment II	44
XXIII.	Average Daily Concentrate Intake, Experiment II.	46

XXIV.	Average Total Mineral Consumption Per Steer (140 days), Experiment II.	.47
XXV.	Average Daily Salt Consumption, Experiment II	.47
XXVI.	Average Daily Gain, Experiment II	.48
XXVII.	Concentrates Per Hundredweight Gain, Experiment II.	.48
XXVIII.	Initial Plasma Inorganic Phosphorus Levels, Experiment II . .	.50
XXIX.	Final Plasma Inorganic Phosphorus Levels, Experiment II . . .	.50
XXX.	Average Plasma Inorganic Phosphorus Levels, Experiment II . .	.50
XXXI.	Initial Plasma Carotene Levels, Experiment II	.53
XXXII.	Final Plasma Carotene Levels, Experiment II	.53
XXXIII.	Average Plasma Carotene Levels, Experiment II	.53
XXXIV.	Initial Plasma Vitamin A Levels, Experiment II.	.54
XXXV.	Final Plasma Vitamin A Levels, Experiment II.	.54

INDEX TO FIGURES

1.	Initial, Final, and Average Plasma Inorganic Phosphorus, Experiment I	36
2.	Initial, Final, and Average Plasma Inorganic Phosphorus, Experiment II.	51

ABSTRACT

Two trials were conducted to determine if level of phosphorus, ratio of calcium to phosphorus, or the addition of "temptors" to mineral mixtures would affect mineral consumption by beef calves being fed a low phosphorus ration, and to observe the effects of these mineral mixtures on growth, weight gains, and blood composition of the calves.

Forty weanling Hereford steer calves were used in the first trial. The calves were divided into eight lots, and one steer from each lot was assigned to each of five pens. All calves received a ration consisting of dry rolled barley, molasses dried beet pulp and soybean meal, and low phosphorus swamp-grass hay. The calves were individually fed. The lots received either 0, 5, or 10 percent phosphorus in their mineral mixtures, and one of the following ratios of calcium to phosphorus; 0:0, 0:1, 1:1, 2:1, 5:1. The pens received either no "temptor", Vitamins A and D, trace minerals, active dry yeast, or "Stoc-Joy" added to their mineral mixture. Each calf on Experiment I received a different mineral mixture.

In the second trial forty weanling Hereford steer calves were used and were divided in the same manner as those on the first experiment. The ration fed consisted of dry rolled barley, molasses dried beet pulp pellets, and soybean meal, and low phosphorus swamp-grass hay. The calves were individually fed. Each of the eight lots received either 0, 7½, or 10 percent phosphorus in their mineral mixture, and calcium:phosphorus ratios of 0:0, 0:1, 1:1, 1:2, or 2:1.

Records were kept of mineral consumption, salt consumption, feed consumption, weight gains, and plasma phosphorus, carotene, and vitamin A levels for the calves on each trial.

The calves failed to consume enough mineral to make one gram added phosphorus intake per day for any lot on either trial. Feed consumption was somewhat less than expected, especially during the second trial when the calves found the beet pulp pellets unpalatable. Weight gains were adequate in the first trial, but slightly low in the second because of the low concentrate intake. Plasma phosphorus levels indicated inadequate phosphorus nutrition in both trials. Plasma carotene and vitamin A levels indicated adequate carotene throughout both trials.

INTRODUCTION

Calcium and phosphorus are recognized as important nutrients in animal and human nutrition and are supplied in various forms to livestock and poultry throughout the world. In the discussion of the mineral requirements of animals, calcium and phosphorus are consistently treated together, because they are interdependent. Calcium and phosphorus appear to function in similar areas of metabolism. Calcium is the most abundant element in the skeleton, and is involved in the blood clotting mechanism, as well as the prevention of irritability and tetany. Of the two, phosphorus has the more widespread use in the animal body. Phosphorus has some fourteen functions and is one of the more important elements in metabolism. A few of the more important functions of phosphorus are as follows: a constituent of the skeletal processes, an integral part of many of the enzyme systems, and a necessary constituent of the carbohydrate metabolism cycles.

(Mitchell, 1947; Gemmill, 1956)

The requirements by beef cattle for calcium and phosphorus have been the subject of considerable research. The daily requirements have been established largely through dry-lot supplementation, using force-feeding methods, and metabolism studies. There have been a number of trials conducted comparing force-feeding with self-feeding of mineral mixtures, but the majority of these trials have been conducted using range cattle, either heifers or adult cows, with emphasis on reproductive performance. Most of the work on steers has been in reference to fattening, with little or no work published concerning the self-feeding of mineral mixtures to wintering steer or heifer feeder calves.

In eastern Montana, much of the forage is deficient in phosphorus especially during late fall and winter. In some areas, this deficiency is serious and many cattle herds do not receive adequate phosphorus. Force-feeding mineral supplements to many of these cattle is not practical, because often the only source of feed is dry range grass. Little data is available on the consumption of free-choice mineral mixtures containing different levels of phosphorus and/or calcium, and to what extent palatability affects consumption.

At present, a mineral mixture containing ten percent or more of phosphorus is recommended to Montana cattlemen. This recommendation is based on the assumption that cattle will consume a certain amount of the mixture per day and obtain some phosphorus from range forage. No records are available on the actual consumption by cattle of the recommended mineral mixtures. Most of the commercial phosphorus supplements made in Montana contain at least ten percent phosphorus and less than twenty percent calcium, whereas supplements brought into the state have averaged, in the past, about five percent phosphorus and from fifteen to twenty percent calcium. The mixtures that are shipped into the state also often contain ingredients of questionable value, and sell for a high price.

Because of the lack of data on which to make recommendations to the cattlemen of Montana, a series of mineral trials was initiated at Montana State College in the winter of 1955-56. The objectives were to determine the effect of self-feeding weaned beef steer calves mineral mixtures varying in percent phosphorus and calcium-phosphorus ratio as supplements to a wintering ration which was low in phosphorus; to determine the effect of

vitamins A and D, trace minerals, "flavors", or ingredients other than minerals upon palatability of mineral supplements as measured by utilization and consumption; and to observe the effect of consumption of these mineral mixtures on growth, weight gains, and blood composition of the calves.

REVIEW OF LITERATURE

The role of minerals in animal nutrition has been the subject of considerable research. There are many problems still unsolved, and conflicting results are common. The present author has attempted to report the findings of previous authors representatively, and to point out differences in findings.

Mineral Functions

Minerals function in several general ways in the animal body. They contribute to the body structure, and are involved in the maintenance of the structure and organs. Minerals are involved in muscular activity, reproduction, milk production, and other productive activities of the body. They are an integral part of many enzyme systems, and are involved in the synthesis of certain vitamins by rumen micro-organisms. (Mitchell, 1947; Reynolds, 1953; Bentley, 1954)

Phosphorus is the most important of the dietary essential minerals other than sodium chloride. Seventy-five to eighty-five percent of the phosphorus in the animal body is contained in the skeleton. Phosphorus is essential in carbohydrate, protein, and fat metabolism. (Mitchell, 1947; Reynolds, 1953)

Deficiency Symptoms

Symptoms of phosphorus deficiency in cattle are depraved appetite, and bone chewing in the early stages. Impaired growth and stiffness of the forequarters ("Greeps" in Texas, "Styfsiekte" in South Africa) are noticed in the more advanced stages. Depraved appetite has caused cattle to eat decomposing carcasses containing Clostridium Botulinum. This

organism produces a toxin which results in "Loin Disease" (U.S.) or "Lamsiekte" (South Africa). Calf crop, weaning weight, and weight at eighteen months are increased when cattle previously showing deficiency symptoms are properly supplemented with phosphorus. Time required by cows to re-breed is shortened, and lifetime production increased by supplementation under Texas Coastal Plains conditions. (Black et al., 1949)

Symptoms of phosphorus deficiency in young cattle are bone chewing, gnawing of wood, poor appetite (especially for roughages), stiffness of joints, and poor physical condition. Bone chewing is a specific symptom of phosphorus deficiency because animals deficient in calcium, even to the point of tetany, do not chew bones. When young cattle are supplemented with phosphorus they show immediate appetite stimulation, and more efficient feed utilization, as well as an increase in plasma inorganic phosphorus levels. (Ekles et al., 1933)

Hodgson et al. (1948) reported that steers receiving sub-optimal phosphorus in their rations are unthrifty in appearance, make low gains, have poor appetites, and are inefficient feed convertors. Their data also indicates that the inorganic plasma phosphorus level is related to phosphorus in the diet.

Heifers fed phosphorus deficient rations failed to gain normally, and eventually ceased to gain. The cessation of estrus corresponded with the cessation of growth. The phosphorus deficient heifers developed bone-chewing and coprophagia. Their inorganic phosphorus dropped from 9.0 to 3.9 milligrams per 100 cc. of serum. Heifers fed the same ration containing 0.13 percent phosphorus, supplemented with dicalcium phosphate to furnish

more than 0.4 percent of their ration gained normally while the phosphorus deficient heifers ceased to grow. The supplemented heifers did not develop bone-chewing or coprophagia, and they maintained about nine milligrams of phosphorus per 100 cc. of serum. Phosphorus deficiency was reported to have no effect on body temperature, digestibility, metabolizability of food energy, the respiratory quotient, nor fasting catabolism. (Kleiber, 1936)

In a Montana trial, lack of appetite and poor feed consumption were the most outstanding symptoms of phosphorus deficiency in steer calves. The appearance of these calves indicated starvation. Plasma phosphorus level was an indication of current phosphorus intake, but not of previous phosphorus nutrition. Wood chewing was more prevalent in the low-phosphorus fed groups, but was blamed, at least in part, on the finely divided state of the concentrate fed. Enlargement of the hocks and knees, and some stiffness were noted until more sunlight was available later in the Spring. Phosphorus deficient calves were narrower and shallower than calves fed adequate phosphorus, and this situation was accentuated by excess calcium in the ration. Borderline phosphorus with normal calcium intake reduced gains 24 percent without affecting feed consumption. Phosphorus deficient rations produced 70 percent less gains, but also reduced feed consumption. (Lewis, 1950)

Du Toit (1930), Otto (1938), Thomas (1953), and Clanton (1954) showed that young cattle fed rations deficient in phosphorus, failed to grow and develop normally. Phosphorus deficient cattle eat more hay and salt than normal cattle, but do not thrive, according to Welch (1940). He described the symptoms of deficiency as follows: the animals stand hump-backed or

sway-backed, and in the more advanced stages, they are lame and have stiff and swollen joints. Reynolds (1953), Thomas (1951), and Thomas and co-workers (1953) reported that cows with low plasma inorganic phosphorus exhibited high plasma carotene.

Mitchell (1947) stated that phosphorus deficient steers produce low quality beef.

Trace Minerals

There are conflicting reports concerning the results of feeding trace minerals to cattle. Bently et al. (1954), found that rate of digestion, but not digestibility was increased by feeding trace minerals to steers in stanchions. Alfalfa ash and to a lesser extent "synthetic alfalfa ash" improved digestibility of low quality roughages. Sodium and potassium chloride plus minor elements had no effect on digestibility. It was suggested "that the beneficial effect of alfalfa ash is primarily due to some combination of known nutrient elements, possibly by means of a buffering action against organic acids produced by fermentation in the rumen."

(Chappel et al., 1952) Klosterman et al., (1953) fed steers a full feed of corn-cob meal and late cut timothy hay, and reported a weight gain advantage from supplementing with trace minerals. They reported that the poor quality hay was deficient in trace minerals.

Smith et al. (1954) found no advantage from supplementing trace minerals to calves during the wintering phase of a trial with beef calves. These calves were fattened by a self-feeding method following the winter phase of the trial. During this period, the trace-mineral-fed lot gained faster and made more efficient gains than the lot fed no supplemental

trace-minerals.

No weight advantage was obtained from adding trace minerals to rations for cows or calves. (Totusek, et al., 1955), Plumlee et al. (1953) fed twin steers, and reported that trace minerals depressed the appetite of the twin fed Purdue Supplement A and corn cobs. The twin fed no trace minerals gained faster in all cases.

CALCIUM AND PHOSPHORUS REQUIREMENTS

Dietary requirements

The calcium and phosphorus requirements of growing animals are affected by several factors. Otto (1938) reported that the form in which calcium and phosphorus occur, the calcium-phosphorus ratio, and the vitamin D content of the ration greatly affect absorption and utilization of the minerals. He stated that solubility determines availability. He found that 8.5 grams of phosphorus and 16.4 grams of calcium per day is sufficient for normal growth in cattle; whereas, 5.8 grams of phosphorus and 12.0 grams of calcium per day is not sufficient for normal growth.

Theiler (1932, 1937) reported that recognized requirements were not accurate under all conditions, and that requirements were affected by rate of growth. Beeson et al. (1941) found the daily phosphorus requirement of the beef steer to be 0.18 percent of the daily ration, or 2.0 grams per hundred pounds live weight. Mitchell (1947) gave the daily requirements for the calf as 0.27 percent of the ration as calcium, and 0.19 percent of the ration as phosphorus. The National Research Council (1950), and Morrison Feeding Standards (Morrison, 1956) give the requirements according to age, weight, sex, and type of production.

In a balance trial, equilibrium was reached with lambs when 1.9 to 2.1 grams of phosphorus per 100 pounds live weight was furnished daily.

(Gallup and Briggs, 1950)

Blood phosphorus levels

The use of blood phosphorus levels as a tool for the diagnosis of phosphorus deficiency has met with varied acceptance. Malan (1928) reports that phosphorus deficiency in a pasture is directly reflected in the blood of cattle grazing over it. Greaves et al. (1934) found a close relationship between phosphorus intake and blood phosphorus.

The suggestion was made by Long et al. (1952), that workers using inorganic phosphorus as a measure of phosphorus nutrition exercise considerable caution in the interpretation of data. They reported an average of 7.5 milligrams of phosphorus per 100 cc. of plasma in heifers under six months of age. Two years later the heifers averaged 4.5 milligrams of phosphorus per 100 cc of plasma. This trend might obscure any benefit from supplementation. A series of analyses on five-hundred-sixty animals at the Wyoming Hereford Ranch indicate that blood phosphorus levels vary with age and sex. (Payne et al. 1946) A similar trend was found in dairy cattle, with heifers under a year of age averaging 8.06 milligrams phosphorus per 100 cc. of serum, and two year old cows averaging 6.17 milligrams per 100 cc. (Eveleth et al., 1937) Similarly Green and Macaskill (1928) found inorganic phosphorus slightly higher in weaned calves than in cows.

Beef heifer calves fed adequate phosphorus had serum phosphorus levels around 9.0 milligrams of phosphorus per 100 cc. while heifers fed low phosphorus rations dropped to 3.9 milligrams per 100 cc. (Kleiber, et al. 1936)

SOURCES OF CALCIUM AND PHOSPHORUS

Bone meal

Bone meal is widely recommended, in deficient areas as a source of supplemental calcium and phosphorus. In an early Texas bulletin, Schmidt (1924) described the symptoms of "Loin Disease", and said it could be prevented by the feeding of "sweet bone meal". In South Africa, control calves increased in weight by 42 percent. During the same period calves fed three ounces daily of bonemeal increased 134 percent in body weight. (DuToit, 1930) Theiler and Greene (1932), also in South Africa, recommended the feeding of bone meal to control the symptoms of phosphorus deficiency. Plasma phosphorus was increased to the "recommended" level (5 mg. per 100 cc.) by including steamed bone meal in the ration of cattle. (Greaves et al., 1934) Several other authors have reported bone meal to be a satisfactory source of calcium and phosphorus for supplementing rations low in these minerals. (Becker, 1944; Beeson, 1941; Black, 1949; Haag, 1951; Hodgson, 1948; Lantow, 1933; Maynard, 1933; Reynolds, 1953; Ross, 1950 and Welch, 1940)

Super phosphate

Harmful results from flourine toxicity accompany the feeding of raw rock phosphate to cattle. (Reed et al., 1930) Deflourinated super-phosphate, however, has been used as a satisfactory phosphorus supplements, but is unpalatable to cattle. (Hodgson, 1948; Becker, 1944) Under Texas Coastal Plains conditions, fertilizing pastures with triple-super-phosphate, prevented phosphorus deficiency during non-drought years. (Black, 1949; Reynolds, 1953)

Dicalcium phosphate

Calves fed dicalcium phosphate (two ounces per day) increased body weight by 128 percent, while those fed no dicalcium phosphate gained 42 percent. (DuToit, 1930) Theiler (1932) recommended dicalcium phosphate as a supplement if both calcium and phosphorus deficiencies existed in the native forage. Heifers supplemented with dicalcium phosphate made satisfactory gains while non-supplemented heifers ceased to grow. (Kleiber et al., 1936) Ross and Gallup (1949) reported cows supplemented with dicalcium phosphate, maintained a plasma inorganic phosphorus average level of four milligrams per 100 cc., while the unsupplemented cows did not have that high a level for 23 months.

Calcium-free phosphates

Where phosphorus alone is deficient in a ration, it might be desirable to supplement that mineral separately from calcium. Disodium phosphate, monosodium phosphate, and monoammonium phosphate have been reported as satisfactory sources of phosphorus for cattle. (Bekker, 1932; Lantow, 1932)

Calcium carbonate

In areas where calcium is deficient but phosphorus is adequate in the forage, limestone or calcium carbonate, is a satisfactory source of calcium for cattle. (Ross, 1950; Haag, 1951) Lewis (1950) found that salt consumption was depressed by phosphorus deficiency and suggested that this depression was accentuated by excess calcium in the ration of steer calves. On the other hand, Pope et al. (1955) noted a trend of greater gain in steers when 0.06 pound daily calcium carbonate was added to cottonseed meal. The only other feed source was native grass which contained adequate cal-

cium and phosphorus. The authors did not attempt to explain this phenomenon but the trend was the same as for previous years.

Natural feeds

No particular desire or craving for mineral supplements other than common salt was demonstrated by dairy cattle fed well-cured hay, corn silage, and a grain mixture containing protein feeds rich in phosphorus. (Nevens, 1928) Reed and Huffman (1930) reported a great overemphasis of the need for mineral supplements in their area (Michigan). Dairy cows in that area showed no added production from high calcium alfalfa hay over timothy hay if the timothy-fed lot received equal protein. Cattle, in Arizona, were grazed on pastures containing 6.37 percent crude protein, 0.227 percent calcium, and 0.178 percent phosphorus. No measurable beneficial effect was shown for mineral supplementation under these conditions. (Stanley, 1938) According to Haag (1951), it is practically impossible to produce calcium deficiency where legumes are included in appreciable amounts in the ration of cattle. He further reported that phosphorus deficiency occurs more frequently with poor quality roughages and that the problem is often complicated by underfeeding.

Excessive calcium in mineral mixtures

Bohstedt (1957) reported that mineral mixtures for cattle averaged 5.9 times as much calcium as phosphorus in 1936 in Wisconsin. In 1957 the calcium:phosphorus ratio was 4.8:1. He stated that this was little improvement in twenty years.

METHODS OF SUPPLYING MINERALS

Force-feeding

In both fattening and wintering trials, faster and more economical gains have been reported when the mineral supplement was mixed with the ration as opposed to self-fed. (Hodgson, 1948; Ross, 1950) Requirements of cattle for a particular nutrient can be more easily determined by force-feeding than self-feeding because consumption can be more easily and exactly controlled. (DuToit, 1930; Lewis, 1950; Kleiber, 1936; Clanton, 1954) Less palatable minerals such as deflourinated superphosphate can be force-fed in adequate amounts, whereas they would not be consumed in adequate amounts to prevent deficiencies if self-fed. (DuToit, 1930; Hodgson, 1948; Kleiber, 1936)

Dissolving supplements in drinking water

Phosphorus supplements have been successfully administered through drinking water to cattle. Bekker (1932) recommended 1.5 ounces of disodium phosphate per head daily dissolved in the drinking water. In order to insure solubility of the disodium phosphate, it was necessary to add one milliliter of 90 percent sulfuric acid per gallon of water. If monosodium phosphate or monoammonium phosphate were used, the sulfuric acid was unnecessary, but preference for treating with disodium phosphate was expressed. Bekker (1932) further reported that animals can utilize more phosphorus from water soluble phosphates than from bone meal, and the soluble phosphates are less expensive per unit of available phosphorus. However, supplementation through the water supply is not practical when large quantities of open water are available. Two different trials in Texas showed that

satisfactory results could be obtained by supplementing phosphorus through the drinking water of cattle. (Black 1949; Reynolds, 1953)

Fertilizing pastures

Phosphorus deficiency symptoms were prevented and production increased by fertilizing pastures with triple-superphosphate. The method was recommended as satisfactory under Texas conditions. (Black 1949; Reynolds, 1953) Bone meal, self-fed, or other phosphorus supplements were recommended to accompany fertilizing in drought years. (Reynolds, 1953) Haag (1951) stated that under range conditions, supplementary minerals were economical only by direct feeding as opposed to fertilizing.

Self-feeding

Self-feeding, or free-choice supplementation, of calcium and phosphorus has met with varied success. According to Lantow (1933), "Livestock undoubtedly tend to correct improper proportions and amounts by selection, if possible, in their feed." Bekker (1932) found that cattle will eat more than enough to balance their ration if allowed free access to bone meal. Eckles et al. (1933) recommended the feeding of bonemeal in self-feeders without salt to avoid overeating of salt or bonemeal. According to Haag (1951), "Cattle allowed free access to bone meal usually will consume such amounts as may be required approximately to balance their ration."

Two year's work in Oklahoma indicates that self-feeding simple mineral mixtures to wintering steers may not be as effective as force-feeding bone meal by mixing it in their concentrates. (Ross et al. 1950) Hodgson (1948) reported that self-feeding was not as effective a method of supplementing phosphorus to fattening steers as was force-feeding.

If cattle are to be self-fed a mineral supplement it is advisable to provide salt, free-choice, in addition to the mineral supplement. (Haag, 1951; Hodgson, 1948)

Additives, or "temptors", may or may not be effective in increasing consumption of free-choice mineral supplements. Totusek (1955) reported that cows fed a mineral mixture containing cottonseed meal consumed ten times the phosphorus consumed by cows fed a simple salt bone meal mixture. On the other hand, anise or licorice had no effect on the consumption of mineral supplements by fattening steers. (Hodgson, 1948)

EXPERIMENT I

A series of trials were conducted during the winters of 1955-56 and 1956-57. The procedures and results will be described separately, and the trials will be summarized together.

1955-1956 PROCEDURE

Forty weaned grade Hereford steer calves, obtained from Billings, Montana, were divided into eight lots of five each on the basis of weight. The calves were fed a ration low in phosphorus, but otherwise calculated to produce three-fourths to one pound of gain per day, according to National Research Council (1950), and Morrison (1948) feeding standards. The ration consisted of swamp-grass hay, known to be low in phosphorus, and enough of the following grain mixture to balance the ration: four parts dry rolled barley, four parts molasses dried beet pulp with LPC^{1/}, and one part soybean oil meal. The high proportion of beet pulp was maintained in order to hold the phosphorus content of the ration as low as possible. A box, constructed of wood, and divided equally for salt and mineral mixture, was available to the calves individually.

Each of the eight lots was assigned to receive a mineral mixture containing either 0, 5, or 10 percent phosphorus, and one of the following ratios of calcium to phosphorus: 0:0, 0:1, 1:1, 2:1, or 5:1. Within the eight lots, each of the five steers was assigned to a pen where it was given an individual feeding stall. The five pens were assigned the following additives which were mixed with the basal mineral mixtures: Pen A,

^{1/} LPC (liquid protein concentrate) produced by the Great Western Sugar Company.

basal minerals only; Pen B, vitamins A and D^{1/}; Pen C, "Flavor"^{2/}; Pen D, trace minerals^{3/}; and Pen E, active dry yeast^{4/}. The complete design of the experiment is shown in Table I.

The various "temptors"^{5/} were substituted for salt to provide the following amounts in the mineral supplements: "Fixtay-Dee" 20,000 I.U. vitamin D, 200,000 I.U. vitamin A per pound of supplement; "Stoc-Joy", 1.5 percent; Trace Minerals, 2.0 percent; "Yeast Culture", 20.0 percent. The composition of the basal mineral mixtures is shown in Table II. Salt was also provided free-choice for each steer.

The calves were fed their grain mixture and hay about eight o'clock in the morning, and as soon as the grain was cleaned up, the mineral boxes were placed before them until between three and four o'clock in the afternoon. At this time, the calves were released into a loafing shed and corral common to the eight steers of each pen so that they could exercise and get water.

The steers were weighed each twenty-eight days, and blood samples were taken from the juglar vein at this time. Records were kept of feed consumption, mineral consumption, salt consumption, weight gains, and blood plasma-carotene, vitamin A, and inorganic phosphorus.

During the first three months of the trial, one pound each of salt and mineral mixture were maintained for each steer. Because mineral consumption

- ^{1/} "Fixtay-Dee" donated by Dawes Laboratories, Inc., Chicago, Illinois.
- ^{2/} Dribase Stoc-Joy "A-M" donated by Flavor Corporation of America.
- ^{3/} Trace Minerals donated by the Calcium Carbonate Company.
- ^{4/} Yeast Culture donated by Diamond V Mills, Inc., Cedar Rapids, Iowa.
- ^{5/} "temptors", a term that will be used to collectively describe the additives used in the mineral mixtures.

Table I. Design of the Experiment.

% of Phosphorus		0%	5%					10%	
Ca:P Ratio		0:0	0:1	1:1	2:1	5:1	0:1	1:1	2:1
Min. Mix. No.		1	2	3	4	5	6	7	8
Pen	Supple. added to No. Min. Mix.								
A	None	0%:0% Ca:P plus None	0%:5% Ca:P plus None	5%:5% Ca:P plus None	10%:5% Ca:P plus None	25%:5% Ca:P plus None	0%:10% Ca:P plus None	10%:10% Ca:P plus None	20%:10% Ca:P plus None
	Steer No.	11	12	13	14	15	16	17	18
B	Vitamins A and D	0%:0% Ca:P plus Vit. A & D	0%:5% Ca:P plus Vit. A & D	5%:5% Ca:P plus Vit. A & D	10%:5% Ca:P plus Vit. A & D	25%:5% Ca:P plus Vit. A & D	0%:10% Ca:P plus Vit. A & D	10%:10% Ca:P plus Vit. A & D	20%:10% Ca:P plus Vit. A & D
	Steer No.	21	22	23	24	25	26	27	28
C	Flavor	0%:0% Ca:P plus Flavor	0%:5% Ca:P plus Flavor	5%:5% Ca:P plus Flavor	10%:5% Ca:P plus Flavor	25%:5% Ca:P plus Flavor	0%:10% Ca:P plus Flavor	10%:10% Ca:P plus Flavor	20%:10% Ca:P plus Flavor
	Steer No.	31	32	33	34	35	36	37	38
D	Trace Minerals	0%:0% Ca:P plus Tr. Min.	0%:5% Ca:P plus Tr. Min.	5%:5% Ca:P plus Tr. Min.	10%:5% Ca:P plus Tr. Min.	25%:5% Ca:P plus Tr. Min.	0%:10% Ca:P plus Tr. Min.	10%:10% Ca:P plus Tr. Min.	20%:10% Ca:P plus Tr. Min.
	Steer No.	41	42	43	44	45	46	47	48
E	Yeast	0%:0% Ca:P plus Yeast	0%:5% Ca:P plus Yeast	5%:5% Ca:P plus Yeast	10%:5% Ca:P plus Yeast	25%:5% Ca:P plus Yeast	0%:10% Ca:P plus Yeast	10%:10% Ca:P plus Yeast	20%:10% Ca:P plus Yeast
	Steer No.	51	52	53	54	55	56	57	58

Table II. Composition of Mineral Mixtures.

% of Phosphorus	0%	5%				10%		
Ca:P Ratio	0%:0%	0%:5%	5%:5%	10%:5%	25%:5%	0%:10%	10%:10%	20%:10%
Lot No.	1	2	3	4	5	6	7	8
Ingredients by %								
Monosodium phosphate	0.0%	22.3%	22.3%	6.7%	0.0%	44.6%	44.6%	13.4%
Bonemeal	0.0%	0.0%	0.0%	25.0%	35.7%	0.0%	0.0%	50.0%
Limestone	0.0%	0.0%	13.0%	6.5%	37.3%	0.0%	26.1%	13.0%
Salt	100.0%	77.7%	64.7%	61.8%	27.0%	55.4%	29.3%	23.6%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

was low up to that time, three pounds each of salt and mineral were maintained thereafter in order to make them more available to the steers.

One other attempt was made to increase mineral consumption. For one week, the steers were released from their stalls as soon as they had finished their grain, in order that they might get water. They were returned to the stalls after about an hour, at which time the mineral boxes were placed before them. This practice was discontinued after one week because the steers would consistently lie down in their stalls, and showed even less interest in the mineral boxes. The original management procedure was resumed at the end of the week.

Table III shows the proximate analysis of the hay and barley used in this trial. The analysis was made by the Chemistry Research Department at Montana State College.

Table III. Chemical Analysis of Feeds Used in Experiment I.

C.R. No.	Description of Sample	Moisture %	Protein %	Phosphorus %	Calcium %	Carotene mcg/gm
7198	Hay	11.3	7.6	0.10	0.17	14
7199	Barley	10.1	9.0	0.39	0.06	None

EXPERIMENT I

RESULTS AND DISCUSSION

1956-1957

The ration was calculated according to Morrison feeding standards (1948), so that the calves could be expected to gain between one-half and three-fourths of a pound per day if they consumed four pounds of concentrates and six pounds of hay per day. The calves were slow to learn to eat their concentrates, presumably because of being trained to their individual stalls. The calves were of nervous temperament, and this condition became progressively worse as the trial continued. At each weigh period, the calves seemed more difficult to move through the chute for weighing and bleeding. The naturally polled steers in this experiment all carried the same brand, and the author believes they represented a progeny group, because they were all extremely excitable. These polled steers were not concentrated in any lot or pen, so it was doubted if they would have any significant effect on results.

Feed consumption

Two things were noted which probably reduced concentrate consumption below the expected level. First, the calves were allowed access to their concentrates only three to four hours each day. Second, each time the amount per day was raised, the calves showed noticeable scouring, consequently concentrates could not be increased as often as desired. The scouring may have been due to the high proportion of beet pulp in the ration.

No definite pattern of concentrate consumption was noted with respect to level of phosphorus or ratio of calcium to phosphorus. Neither were

there any important differences in concentrate consumption due to "temptors". The average daily concentrate consumption was 3.45 pounds for all steers on trial. Table IV shows the average daily concentrate consumption by lots and pens, both including controls, and with the records for the controls subtracted out. The pen (A) that received no "temptors" in their mineral ration were considered to be controls, as was the lot that received 0.0 percent phosphorus and a ratio of 0.0 calcium to phosphorus. Subtracting these records made less than 0.2 pound difference in average daily concentrate consumption, which was considered unimportant.

Table IV. Average Daily Concentrate Consumption, Experiment I.

Lot No.	Average Daily Consumption	Average Daily Consumption	Pen No.	Average Daily Consumption	Average Daily Consumption
	Includ. Controls pounds	Without Controls pounds		Includ. Controls pounds	Without Controls pounds
1	3.51	3.53	A	3.50	3.51
2	3.28	3.22	B	3.44	3.42
3	3.50	3.54	C	3.43	3.42
4	3.46	3.44	D	3.38	3.36
5	3.52	3.51	E	3.48	3.48
6	3.42	3.38			
7	3.44	3.41			
8	3.45	3.43			

All the steers exhibited good appetite for hay throughout the trial with the exception of the week during which they were allowed to have water and exercise before they were allowed access to their hay. During this week, they left considerable hay, and for this reason, the original management procedure was resumed. The steers were offered six pounds of hay daily throughout the trial, and most of what they refused was coarse stems, woody plants, and manure which was heavily mixed with the hay. The average daily hay consumption for all steers was 5.52 pounds. Table V shows the average daily hay consumption for the steers on Experiment I.

Table V. Average Daily Hay Consumption, Experiment I.

Lot No.	Average Daily Consumption pounds	Pen No.	Average Daily Consumption pounds
1	5.58	A	5.57
2	4.48	B	5.52
3	5.51	C	5.52
4	5.56	D	5.56
5	5.54	E	5.46
6	5.53		
7	5.54		
8	5.46		

Mineral Intake

The mineral consumption during this trial was extremely low. The lot receiving no minerals other than salt with the various "temptors" added took the least from their mineral boxes. Their average daily mineral consumption was 0.009 pounds per day. The lots receiving the 1:1 and 2:1 ratios of calcium to phosphorus at the ten percent level took the greatest amount of mineral, with both lots averaging 0.021 pounds per head daily. The differences in mineral consumption due to level of phosphorus or ratio of calcium to phosphorus were not statistically significant. Pen C, which received "Stoc-Joy", consumed 0.026 pounds per head daily, which was the highest mineral consumption for any pen. Pen E, the Yeast pen, consumed 0.009 pounds per head daily which was the lowest mineral consumption for any pen. The difference in mineral consumption due to "temptors" was statistically significant ($P < 0.01$). Even though there were statistically significant differences in mineral consumption, none of the lots, pens or individuals consumed enough of their mineral mixtures to balance their rations for phosphorus. Table VI shows the average daily mineral consumption for Experiment I.

Table VI. Average Daily Mineral Consumption, Experiment I.

Lot No.	Average Daily Consumption	Average Daily Consumption	Pen No.	Average Daily Consumption	Average Daily Consumption
	Includ. Control	Without Controls		Includ. Controls	Without Controls
	pounds	pounds		pounds	pounds
1	0.009	0.009	A	0.011	0.012
2	0.012	0.013	B	0.012	0.012
3	0.014	0.015	C	0.026	0.027
4	0.013	0.014	D	0.013	0.014
5	0.012	0.013	E	0.009	0.010
6	0.014	0.012			
7	0.022	0.021			
8	0.018	0.021			

According to National Research Council, Recommended Nutrient Allowances for Beef Cattle (1950), calves of this weight should receive 15 grams of phosphorus per day. On that basis, these calves fell far short of balancing their rations. All lots and pens averaged between 6.5 and 7.1 grams of phosphorus intake per day, including concentrates, hay and mineral sources of phosphorus. Lot 1 which received no phosphorus in their mineral mixture had the highest total phosphorus intake among the lots. None of the lots or pens ate enough of their mineral mixture to raise the total phosphorus intake of their rations one gram per day. Table VII shows the average daily phosphorus consumption for Experiment I.

Table VII. Average Daily Phosphorus Consumption from Concentrates, Hay and Mineral Mixture, Experiment I.

Lot No.	Average Daily Consumption	Pen No.	Average Daily Consumption
	grams		grams
1	7.01	A	6.94
2	6.66	B	6.89
3	6.96	C	6.89
4	6.94	D	6.84
5	7.00	E	6.92
6	6.87		
7	6.91		
8	6.88		

The salt consumption also was low, and there was very little difference in consumption between lots or pens. Lot 1 had an average daily salt intake of 0.012 pounds which was the lowest for any of the lots, and Lot 6 had the highest consumption with 0.015 pounds per head daily. Among the pens, Pen A was low (0.008 pounds per day), and Pens B, and C were highest (0.018) pounds per day. No statistical analysis was run on salt consumption and no trends were noted. The average daily salt consumption by lots and pens for Experiment I is shown in Table VIII.

Table VIII. Average Daily Salt Consumption, Experiment I.

Lot No.	Average Daily Consumption	Pen No.	Average Daily Consumption
	pounds		pounds
1	0.012	A	0.008
2	0.013	B	0.018
3	0.012	C	0.018
4	0.013	D	0.013
5	0.014	E	0.009
6	0.015		
7	0.014		
8	0.013		

Gains and Cost of Gains

The average daily gain for the forty steer calves was 0.77 pounds per head daily for the 160 day trial. This gain was approximately the gain expected from the ration fed. Table IX shows the average daily gains for

Table IX. Average Daily Gain, Experiment I.

Lot No.	Average Daily Consumption	Pen No.	Average Daily Consumption
	pounds		pounds
1	0.69	A	0.76
2	0.58	B	0.70
3	0.82	C	0.76
4	0.76	D	0.78
5	0.80	E	0.79
6	0.74		
7	0.87		
8	0.80		

lots and pens. The differences are not significant due to "temptors", or the content of the mineral mixtures. Because there was less than one gram per day difference in phosphorus intake, either by lots or pens, it is doubtful if the mineral mixtures had any effect on daily gains.

Lot 2 had the highest cost per hundredweight gain, with \$22.88, and Lot 7 had the lowest cost per hundredweight gain at \$16.43. The differences in cost per hundredweight gain were not statistically significant. The higher cost per hundredweight gain corresponded closely with the lower daily gains. This relationship would be expected, because there was little difference in feed consumption. Table X shows the cost per hundredweight gain for the lots and pens on Experiment I.

Table X. Cost Per Hundredweight Gain, Experiment I.

Lot. No.	Cost/cwt. gain	Pen No.	Cost/cwt. gain
1	\$19.87	A	\$19.31
2	\$22.88	B	\$20.19
3	\$18.25	C	\$18.75
4	\$17.91	D	\$18.29
5	\$17.73	E	\$17.88
6	\$20.16		
7	\$16.43		
8	\$17.83		

Plasma Inorganic Phosphorus Levels

Kleiber et al. (1936) reported that serum inorganic phosphorus levels in beef heifer calves averaged 9.0 milligrams per 100 cc. serum if the heifers received adequate phosphorus in their diet. Eveleth et al. (1937) reported an average of 8.06 milligrams phosphorus per 100 cc. serum in dairy calves between seven and twelve months of age. The average plasma inorganic phosphorus level at the beginning of the trial was 6.0 mg. per 100 cc.; at the end of the trial the average level was 6.4 mg. per 100 cc.;

and the over all average, including all determinations, was 6.2 mg. per 100 cc. These levels indicate at best borderline phosphorus nutrition. Because the mineral consumption was so low, it is doubtful if the mineral mixtures had any effect on plasma phosphorus levels. Table XI, XII, and XIII show the initial, final, and over all average inorganic phosphorus levels for the calves on Experiment I. Figure 1 shows the same information in bar-graph form.

Plasma-Carotene Levels

The plasma carotene level considered minimum, or bordering deficiency by Davis et al. (1941) is 25 micrograms per 100 cc. of plasma. At the beginning of the trial, the calves on this experiment had an average carotene level of 122.2 micrograms per 100 cc. plasma. At the end of the trial, the average carotene level was 128.3 micrograms per 100 cc. of plasma. The average of all analyses was 139.4 micrograms of carotene per 100 cc. of plasma. These levels would indicate that the calves had more than adequate carotene throughout the trial. Tables XIV, XV, and XVI show the initial, final, and average carotene levels, respectively, for the calves on Experiment I.

Plasma Vitamin A Levels

The minimum, or borderline vitamin A level as found by Davis et al. (1941) for cattle is 16 micrograms per 100 cc. of plasma. The calves on Experiment I had an average vitamin A level at the beginning of the trial of 19.1 micrograms per 100 cc. of plasma. At the end of the trial, the average vitamin A level was 20.6 micrograms per 100 cc. of plasma. The average of all determinations during the trial was 26.3 micrograms per

Table XI. Initial Plasma Inorganic Phosphorus Levels, Experiment I.

Lot No.	Pen No.					Total	Average
	A	B	C	D	E		
1	5.2	6.1	7.4	6.5	6.1	31.3	6.3
2	5.9	4.8	5.2	5.3	2.8	24.0	4.8
3	6.7	7.3	7.7	5.9	6.4	34.0	6.8
4	5.6	5.6	7.1	7.2	4.8	30.3	6.1
5	6.2	6.5	5.9	8.3	5.9	32.8	6.6
6	5.7	5.9	6.6	5.9	5.3	29.4	5.9
7	6.1	7.4	5.9	6.3	5.9	31.6	6.3
8	6.0	5.2	6.9	6.9	3.8	28.8	5.8
Total	49.4	48.8	52.7	52.3	41.0	242.2	
Average	5.9	6.1	6.6	6.5	5.1		6.0

Table XII. Final Plasma Inorganic Phosphorus Levels, Experiment I.

Lot No.	Pen No.					Total	Average
	A	B	C	D	E		
1	6.9	5.8	6.6	5.9	5.4	30.6	6.1
2	5.2	7.0	7.3	6.4	4.2	30.1	6.0
3	6.8	6.1	5.5	6.9	5.6	30.9	6.2
4	6.6	6.0	8.3	8.3	6.4	35.6	7.1
5	5.1	7.1	7.0	7.1	5.9	32.2	6.4
6	7.0	4.8	7.4	6.1	5.8	31.1	6.2
7	6.8	5.6	7.4	4.9	6.7	31.4	6.3
8	7.3	6.8	7.9	7.5	5.3	34.8	7.0
Total	51.7	49.2	57.4	53.1	45.3	256.7	
Average	6.5	6.2	7.2	6.6	5.7		6.4

Table XIII. Average Plasma Inorganic Blood Phosphorus Levels, Experiment I.

Lot No.	Pen No.					Total	Average
	A	B	C	D	E		
1	5.6	5.7	6.6	5.1	5.8	28.8	5.8
2	5.8	5.8	5.3	6.0	4.2	27.1	5.4
3	5.6	6.7	6.6	6.2	7.3	32.4	6.5
4	5.7	6.2	7.2	7.2	6.2	32.5	6.5
5	5.3	6.6	6.2	6.7	6.7	31.5	6.3
6	6.4	6.0	6.9	6.0	6.1	31.4	6.3
7	6.8	6.3	7.2	5.2	7.0	32.5	6.5
8	6.4	6.1	7.0	6.7	5.8	32.0	6.4
Total	47.6	49.4	53.0	49.1	49.1	248.2	
Average	6.0	6.2	6.6	6.1	6.1		6.2

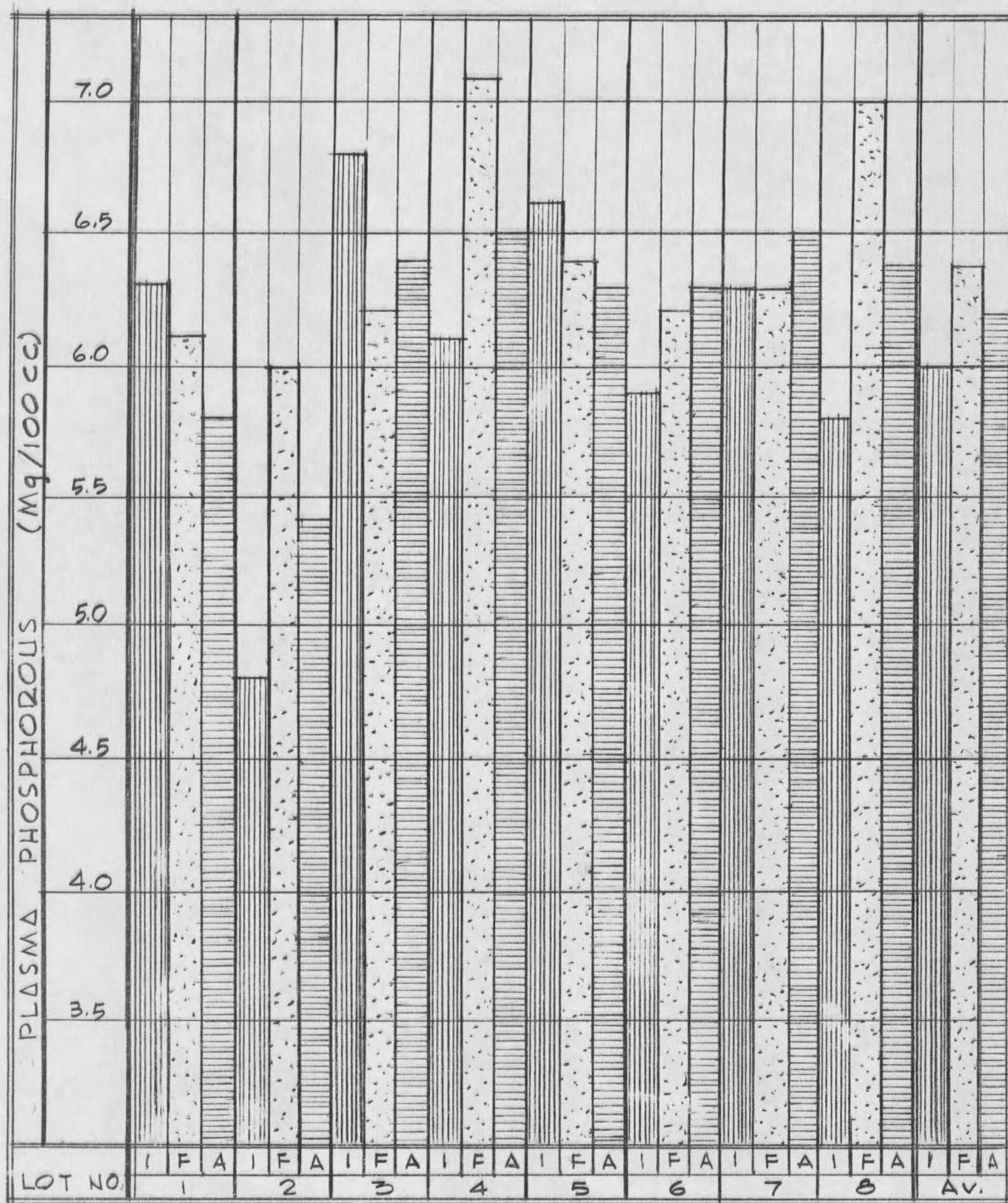


Figure 1. Initial, final, and average plasma inorganic phosphorus, Experiment I, 1955-1956.

Table XIV. Initial Plasma Carotene Levels, Experiment I.

Lot	Pen No.					Total	Average
No.	A	B	C	D	E		
1	60.2	81.3	179.2	137.8	107.2	560.7	112.1
2	165.5	94.0	130.0	104.8	104.8	599.1	119.8
3	76.8	122.2	158.4	117.2	109.7	584.3	116.9
4	139.2	162.7	102.4	81.3	121.0	606.6	121.3
5	135.2	151.4	109.7	90.5	108.5	595.3	119.1
6	165.5	109.7	234.7	76.8	131.3	718.0	143.6
7	100.0	103.6	124.7	104.8	161.2	594.3	118.9
8	97.6	98.7	157.0	151.4	126.1	630.8	126.2
Total	940.0	923.6	1191.1	864.6	969.8	4889.1	
Average	117.5	115.4	148.9	108.1	121.2		122.2

Table XV. Final Plasma Carotene Levels, Experiment I.

Lot	Pen No.					Total	Average
No.	A	B	C	D	E		
1	151.4	87.0	130.0	113.4	124.8	606.6	121.3
2	96.4	135.2	118.5	87.0	172.7	609.8	127.0
3	103.6	107.2	133.9	118.5	130.0	593.2	118.6
4	139.3	204.8	141.9	110.9	164.1	761.0	152.2
5	132.6	172.7	123.5	140.5	114.7	684.0	136.8
6	169.8	104.8	141.2	90.5	118.5	624.8	123.0
7	123.4	106.0	70.1	130.0	174.2	603.7	120.7
8	130.0	109.7	88.2	150.0	171.2	649.1	129.8
Total	1046.5	1027.4	947.3	940.8	1170.2	5132.2	
Average	130.8	128.4	118.4	117.6	146.3		128.3

Table XVI. Average Plasma Carotene Levels, Experiment I.

Lot	Pen No.					Total	Average
No.	A	B	C	D	E		
1	139.5	111.3	167.3	166.9	133.2	718.2	143.6
2	113.3	145.7	122.7	135.7	121.6	639.0	127.8
3	117.8	121.5	156.6	132.9	124.6	653.4	130.7
4	169.0	201.0	135.0	123.6	146.5	775.1	155.0
5	151.6	174.9	123.4	129.9	104.0	683.8	136.8
6	178.0	111.8	196.9	111.9	111.1	709.7	141.9
7	124.3	132.5	118.9	128.6	169.5	673.8	134.8
8	127.0	119.5	148.4	168.8	157.4	721.1	144.2
Total	1120.5	1118.2	1169.2	1098.3	1067.9	5574.1	
Average	140.1	139.8	146.2	137.3	133.5		139.4

100 cc. of plasma. Tables XVII, XVIII, and XIX show the initial, final and average vitamin A levels of the steers on Experiment I. The plasma vitamin A levels show the calves received adequate vitamin A throughout the trial.

Phosphorus Deficiency Symptoms

At least one steer from each lot, and at least one steer from each pen was at some time during the trial seen chewing the poles in the corral or the paint on the wall of the barn. Several of the steers were noticed chewing wood from the feed troughs or the mineral boxes. There was no noticeable swelling of the joints, but the hair coats were long and shaggy at the end of the trial.

Analyses of Variance

Table XX shows the analysis of variance for mineral consumption, average daily gains, and cost per hundredweight gain. The only statistically significant differences were in mineral consumption due to "temptors" but as mentioned before the difference in mineral consumption made less than a gram per day difference in daily phosphorus intake, and was considered unimportant.

Table XVII. Initial Plasma Vitamin A Levels, Experiment I.

Lot	Pen No.					Total	Average
No.	A	B	C	D	E		
1	16.8	27.4	20.1	19.0	16.7	100.0	20.0
2	16.0	12.2	13.6	18.7	24.1	84.6	16.9
3	24.8	21.7	21.5	14.4	17.0	99.4	19.9
4	20.3	26.5	18.3	12.2	9.4	86.7	17.3
5	15.5	31.0	23.9	11.7	24.8	106.9	21.4
6	20.6	23.9	24.1	22.1	24.5	115.2	23.0
7	18.9	17.8	17.5	15.5	11.8	81.5	16.3
8	16.4	19.9	23.9	10.6	20.1	90.9	18.2
Total	149.3	180.4	162.9	124.2	148.4	765.2	
Average	18.7	22.6	20.4	15.5	18.6		19.13

Table XVIII. Final Plasma Vitamin A Levels, Experiment I.

Lot	Pen No.					Total	Average
No.	A	B	C	D	E		
1	14.1	21.5	19.0	23.7	21.6	99.9	20.0
2	16.5	16.9	15.6	21.5	13.8	84.3	16.9
3	17.8	20.3	21.5	24.7	17.6	101.9	20.4
4	15.7	31.0	25.2	19.2	21.6	112.7	22.5
5	18.8	23.9	15.3	25.8	24.5	108.3	21.7
6	29.0	15.1	20.5	21.3	21.9	107.8	21.6
7	15.3	19.0	21.6	25.5	20.1	101.5	20.3
8	23.1	21.5	25.1	16.0	23.1	108.8	21.8
Total	150.3	169.2	163.8	177.7	164.2	825.2	
Average	18.8	21.2	20.5	22.2	20.5		20.6

Table XIX. Average Plasma Vitamin A Levels, Experiment I.

Lot	Pen No.					Total	Average
No.	A	B	C	D	E		
1	20.8	25.4	27.8	29.2	27.9	131.1	26.2
2	25.2	21.2	20.0	30.5	23.2	120.1	24.0
3	27.2	27.1	27.6	28.4	23.5	133.8	26.8
4	26.6	32.6	31.4	26.2	32.6	149.4	29.9
5	26.9	34.8	24.3	27.8	28.9	142.7	28.5
6	29.1	19.8	24.4	28.8	22.4	124.5	24.9
7	25.0	24.8	24.6	26.0	22.8	123.2	24.6
8	24.7	25.7	28.0	23.7	24.0	126.1	25.2
Total	205.5	211.4	208.1	220.6	205.3	1050.9	
Average	25.7	26.4	26.0	27.6	25.7		26.27

Table XX. Analysis of Variance Tables, Experiment I.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
<u>Mineral Consumption, Experiment I</u>				
"Temptors"	4	35.949750	8.987438	4.57
Rations	7	14.313000	2.044714	1.04
T x R	28	55.10200	1.967929	
Total	39	105.36475		
<u>Average Daily Gains</u>				
"Temptors"	4	00.0406	0.0102	0.32
Rations	7	0.4797	0.0685	2.16
T x R	28	0.8888	0.0317	
Total	39	1.4091		
<u>Cost Per Cwt. Gain</u>				
"Temptors"	4	26.0541	6.5135	0.31
Rations	7	141.9021	20.2717	0.98
T x R	28	579.8912	20.7104	
Total	39	747.8474		

EXPERIMENT II

Procedure

1956-1957

Forty weaned Hereford steer calves were obtained from the Madison River area, near Ennis, Montana. These calves were from two herds in the same area, and were quite uniform in size and quality. The calves were weighed for the first time on December 4, 1956, and were divided into eight lots of five on the basis of this weight and previous owner. Actual lotting took place on December 12, 1956, and another individual weight was taken at this time. The calves were first introduced to their individual feeding stalls December 13, 1956, and were offered dry rolled barley, molasses dried beet pulp pellets^{1/}, and low phosphorus swamp-grass hay. From November 27 to December 13 the calves had been fed only the swamp-grass hay. January 2, 1957 was taken as the starting date of the trial. The calves were weighed in early afternoon after standing in their stalls all morning, and being kept from water until after they were weighed. These conditions were maintained on each succeeding weigh day.

The calves were fed a ration low in phosphorus, but otherwise calculated to produce about one pound per day gain. (National Research Council, 1950, Morrison, 1956) The ration consisted of swamp-grass hay, known to be deficient in phosphorus, and enough of the following grain mixture to balance the ration: equal parts dry rolled barley and molasses dried beet pulp pellets. This concentrate mixture was continued until April 2, 1957,

^{1/} With LPC (liquid protein concentrate) a product of Great Western Sugar Company.

when each steer was given one-fourth pound of soybean oil meal daily for the remainder of the trial. The high proportion of beet pulp was maintained in order to hold the phosphorus content of the daily ration as low as possible. Two wooden boxes, one for salt and the other for mineral mixture were available individually to the calves.

Each of the eight lots was assigned to receive a mineral mixture containing either $7\frac{1}{2}$, 10 or 0 percent phosphorus, and one of the following ratios of calcium to phosphorus: 0:0, 0:1, 1:1, 1:2, or 2:1. Lot 2 and Lot 3 received the same mixture except that for Lot 2, Yeast Culture was substituted for salt to make up 15 percent of the mixture. Lot 7, and Lot 8 received mixtures calculated to contain the same calcium and phosphorus percentages. The mixture for Lot 8 was equal parts bone meal and salt, whereas the mixture for Lot 7 was made up of a number of ingredients. Wheat bran and linseed meal were substituted for salt to make up five and two and one-half percent, respectively, of each of the eight mixtures. The wheat bran and linseed meal were included to prevent caking of the mixtures, and to attempt to improve palatability, thereby to increase consumption. The composition of the mineral mixtures is shown in Table XXI. Within the eight lots, the calves were assigned at random to one of five pens so that each pen contained one steer from each lot.

The calves were fed their concentrates about eight o'clock in the morning. As soon as the grain was cleaned up, or the calves had quit eating, the mineral and salt boxes were placed before them and the hay was fed. The hay was not fed at the same time as the grain, because it was noticed during the pre-trial period that the calves would not clean up their

Table XXI. Composition of Mineral Mixtures, Experiment II.

% of Phosphorus	0%	10%					7½%	
Ca:P Ratio	0%:0%	20%:10%	20%:10%	10%:10%	0%:10%	5%:10%	15%:7½%	15%:7½%
Lot No.	1	2	3	4	5	6	7	8
Ingredients in %								
Monosodium phosphate	0.0%	13.4%	13.4%	44.6%	44.6%	44.6%	13.0%	0.0%
Steamed bonemeal	0.0%	50.0%	50.0%	0.0%	0.0%	0.0%	33.0%	50.0%
Ground limestone	0.0%	13.0%	13.0%	26.1%	0.0%	13.0%	13.3%	0.0%
Salt	92.5%	1.1%	16.1%	21.8%	47.9%	34.9%	33.2%	42.5%
Wheat bran	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
Linseed oil meal	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%
Yeast culture	0.0%	15.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

grain as well if the hay was available at the same time. Shortly after noon, the calves were turned out to water for about an hour, during which time the grain for the next day was weighed into the troughs and covered with the mineral and salt boxes. The calves were then returned to their stalls and were confined there until approximately four o'clock.

Each twenty-eight days, the calves were individually weighed, and blood samples from the juglar vein were taken. Records were kept of feed consumption, mineral consumption, salt consumption, weight gains, and blood plasma inorganic phosphorus, carotene and vitamin A.

Three pounds of mineral and three pounds of salt were weighed into the boxes for each calf at the beginning of the trial. Each time the minerals were weighed during the trial the supply was restored to the original amount. Between times of weighing, the supply of mineral and salt was watched and replenished if an individual calf appreciably lowered his supply.

Table XII shows the proximate analyses of the feeds used in Experiment II. The proximate analyses were run by the Chemistry Research Department at Montana State College.

Table XXII. Chemical Analysis of Feeds Used in Experiment II.

C.R. No.	Description of Sample	Moisture	Protein	Phosphorus	Calcium	Carotene
8459	Hay	6.4	9.2	0.12	1.27	52
8460	Barley	10.2	10.7	0.35	0.16	03
8461	Soybean oil meal	7.9	47.3	0.65	0.46	03
8463	Beet pulp pellets	9.6	17.1	0.03	0.98	04

EXPERIMENT II

RESULTS AND DISCUSSION

1956-57

The calves in the second trial appeared to be more uniform in quality than the calves used in Experiment I. The calves were more even tempered and they were more easily trained to their individual stalls. Although the calves on Experiment II were weighed and bled at the same intervals as those on Experiment I, they did not become nervous and unmanageable as those on Experiment I. This difference was due in part to the temperament of the calves, in part to the greater experience of the author in bleeding cattle.

A pronounced undershot jaw condition was noted in at least two of the calves, but this had no measurable effect on the weight gains of these calves.

Feed consumption

The appetite of the calves for hay was good throughout the trial. The average daily consumption of hay was very close to six pounds per day which was intended at the inception of the trial; however, accurate records of hay consumption were not kept.

The average daily concentrate intake was considerably lower than expected at the outset of the trial. The ration was calculated, according to Morrison Feeding Standard (1956), to produce one pound per head daily gain if the calves ate five pounds of an equal parts dry rolled barley, molasses dried beet pulp mixture. The calves were very slow to learn to eat their concentrates, especially the beet pulp pellets. Some of the calves consistently sorted out and refused to eat the beet pulp pellets. Other calves

would occasionally leave the pellets, and others would refuse the pellets for only a few days after an increase in allowances. According to Morrison (1956) if the calves were to produce one pound per day gain they should have eaten five pounds of concentrates per day; whereas the actual concentrate intake for the forty head during the 140 day trial was 3.45 pounds per head daily. The average daily concentrate consumption is shown by lots in Table XXIII. Lot 3 took the least concentrates with average of 3.12 pounds per head daily and Lot 2 took the most with an average of 3.60 pound per head daily. Because mineral consumption was so low, it is doubtful if the differences in concentrate intake were due to the mineral mixtures. The differences in concentrate intake were more likely due to the individual calves finding the beet pulp/pellets unpalatable.

Table XXIII. Average Daily Concentrate Intake, Experiment II.

<u>Lot No.</u>	<u>Average Daily Consumption (lbs.)</u>
1	3.56
2	3.60
3	3.12
4	3.42
5	3.27
6	3.59
7	3.59
8	3.42
<u>All lots</u>	<u>3.45</u>

Mineral consumption

Mineral consumption by the calves on Experiment II was even lower than mineral consumption by the calves on Experiment I. Lot 1, whose mineral mix consisted of salt with five percent wheat bran and two and one-half percent linseed meal, took the most minerals. The five steers consumed an average of 1.200 pounds per steer for the whole 140 day trial. The five steers in Lot 4 took no minerals from their boxes, and none of the remain-

ing lots (2, 3, 5, 6, 7, 8) took more than 1.000 pounds per head for the whole 140 day trial. Table XXIV shows the average total mineral consumption per steer by lots. Because the consumption of minerals was so low no statistical analyses were run on the steers in this trial. The mineral consumption could have had no important effect on the calves.

Table XXIV. Average Total Mineral Consumption Per Steer (140 days), Experiment II.

Lot No.	Average Minerals Per Steer (lbs.)
1	1.200
2	0.575
3	1.000
4	0.000
5	0.050
6	0.025
7	0.775
8	0.650
All lots	0.534

The average daily salt consumption for the calves on Experiment II was slightly greater than for those on Experiment I. In Experiment I the daily salt intake was 0.013 pound per head, and on Experiment II the average daily salt consumption was 0.020 pound per head. The author has no explanation for the low salt consumption by the calves on either trial. The average daily salt consumption by the calves on Experiment II is shown in Table XXV.

Table XXV. Average Daily Salt Consumption, Experiment II.

Lot No.	Average Daily Consumption (lbs.)
1	0.015
2	0.026
3	0.033
4	0.019
5	0.012
6	0.022
7	0.019
8	0.014
All lots	0.020

Gains and concentrates per hundredweight gain

The average daily gain for the forty steer calves on Experiment II was 0.89 pound per head daily for the 140-day trial. This gain was somewhat less than the gain expected at the outset of the trial. The calves should have gained approximately one pound per head daily if they had consumed the calculated ration, which, as mentioned above, they did not do. It is doubtful if the mineral had any effect on daily gain, because none of the lots consumed enough mineral mixture to make a gram of phosphorus intake from that source per day. Probably the most important factor affecting gains was the consumption, or lack of consumption of the beet pulp pellets. Table XXVI shows the average daily gains by lots of the steers on Experiment II.

Table XXVI. Average Daily Gain, Experiment II.

Lot No.	Average Daily Gain (lbs.)
1	0.84
2	0.99
3	1.04
4	0.75
5	0.69
6	0.93
7	0.97
8	0.92
All lots	0.89

The higher average daily gains correspond with the lower concentrates

Table XXVII. Concentrates Per Hundredweight Gain, Experiment II.

Lot No.	Concentrates Per Hundredweight Gain (lbs.)
1	423
2	362
3	298
4	455
5	473
6	387
7	369
8	373

per hundredweight gain, which are shown by lots in Table XXVII.

Plasma inorganic phosphorus levels

The plasma inorganic phosphorus determinations indicated that the calves on Experiment II were more deficient throughout the trial than the calves on Experiment I. The average inorganic phosphorus level in the plasma of the calves on Experiment II was 4.23 milligrams per 100 cc. of plasma. At the end of the trial, the average level was 5.50 milligrams per 100 cc of plasma, and the average of all analyses was 4.59 milligrams per 100 cc of plasma. These levels were considerably below the level (9.0 milligrams per 100 cc.) reported by Kleiber et al. (1936) for heifers of about the same age, which were receiving adequate phosphorus in their ration. Table XXVIII shows the plasma inorganic phosphorus levels for the calves on Experiment II at the beginning of the trial. Table XXIX shows the plasma inorganic phosphorus levels at the end of the trial, and Table XXX shows the average of all analyses of inorganic phosphorus levels for the calves on Experiment II. Figure 2 is a graphic representation of the initial, final, and average inorganic phosphorus levels by treatments.

Plasma carotene levels

At the beginning of the trial, the calves on Experiment II had an average carotene level of 127.6 micrograms per 100 cc of plasma. At the end of the trial, the average plasma carotene level was 143.8 micrograms per 100 cc. plasma, and the average of all analyses was 161.8 micrograms carotene per 100 cc. of plasma. These levels are well above the minimum of 25 micrograms per 100 cc. of plasma as found by Davis et al. (1941). It is evident from these determinations that the calves on Experiment II received ade-

Table XXVIII. Initial Plasma Inorganic Phosphorus Levels, Experiment II.

Lot	Pen No.					Total	Average
No.	A	B	C	D	E		
1	6.10	2.82	3.56	4.05	4.26	20.79	4.16
2	4.88	4.57	4.14	4.88	4.01	22.48	4.50
3	3.80	5.15	4.70	3.80	3.60	21.05	4.21
4	3.24	4.05	6.21	4.61	3.36	21.47	4.29
5	3.08	4.77	4.61	2.67	3.32	18.45	3.69
6	4.65	3.68	4.48	4.48	3.97	21.26	4.25
7	3.44	4.31	3.89	5.34	4.70	21.68	4.34
8	3.44	4.35	4.26	5.06	4.97	22.08	4.42
Total	32.63	33.70	35.85	34.89	32.19	169.26	
Average	4.08	4.21	4.48	4.36	4.02		4.23

Table XXIX. Final Plasma Inorganic Phosphorus Levels, Experiment II.

Lot	Pen No.					Total	Average
No.	A	B	C	D	E		
1	5.91	3.05	7.93	5.57	5.81	28.27	5.65
2	5.43	4.18	6.21	4.92	4.35	25.09	5.02
3	5.67	6.36	6.77	6.93	5.10	30.83	6.17
4	5.06	4.70	6.30	7.36	3.56	26.98	5.40
5	4.44	4.35	5.20	5.86	6.00	25.85	5.17
6	4.70	6.41	4.35	7.09	5.67	28.22	5.64
7	4.52	5.86	6.15	6.15	6.21	28.89	5.78
8	4.70	4.26	5.67	5.71	5.67	26.01	5.20
Total	40.43	39.17	48.58	49.59	42.37	220.14	
Average	5.05	4.90	6.07	6.20	5.30		5.50

Table XXX. Average Plasma Inorganic Phosphorus Levels, Experiment II.

Lot	Pen No.					Total	Average
No.	A	B	C	D	E		
1	5.21	3.23	4.85	4.60	4.61	22.50	4.50
2	4.77	4.12	4.34	4.96	4.41	22.60	4.52
3	3.93	5.38	4.81	4.95	4.61	23.68	4.74
4	4.26	4.08	4.68	5.33	3.46	21.81	4.36
5	4.00	4.12	4.81	4.06	4.66	21.65	4.33
6	4.04	4.57	4.52	4.92	4.73	22.78	4.56
7	3.94	4.70	4.26	5.39	4.90	23.19	4.64
8	4.24	4.00	4.80	5.00	4.86	22.90	4.58
Total	34.39	34.20	37.07	39.21	36.24	181.11	
Average	4.30	4.28	4.63	4.90	4.53		4.59

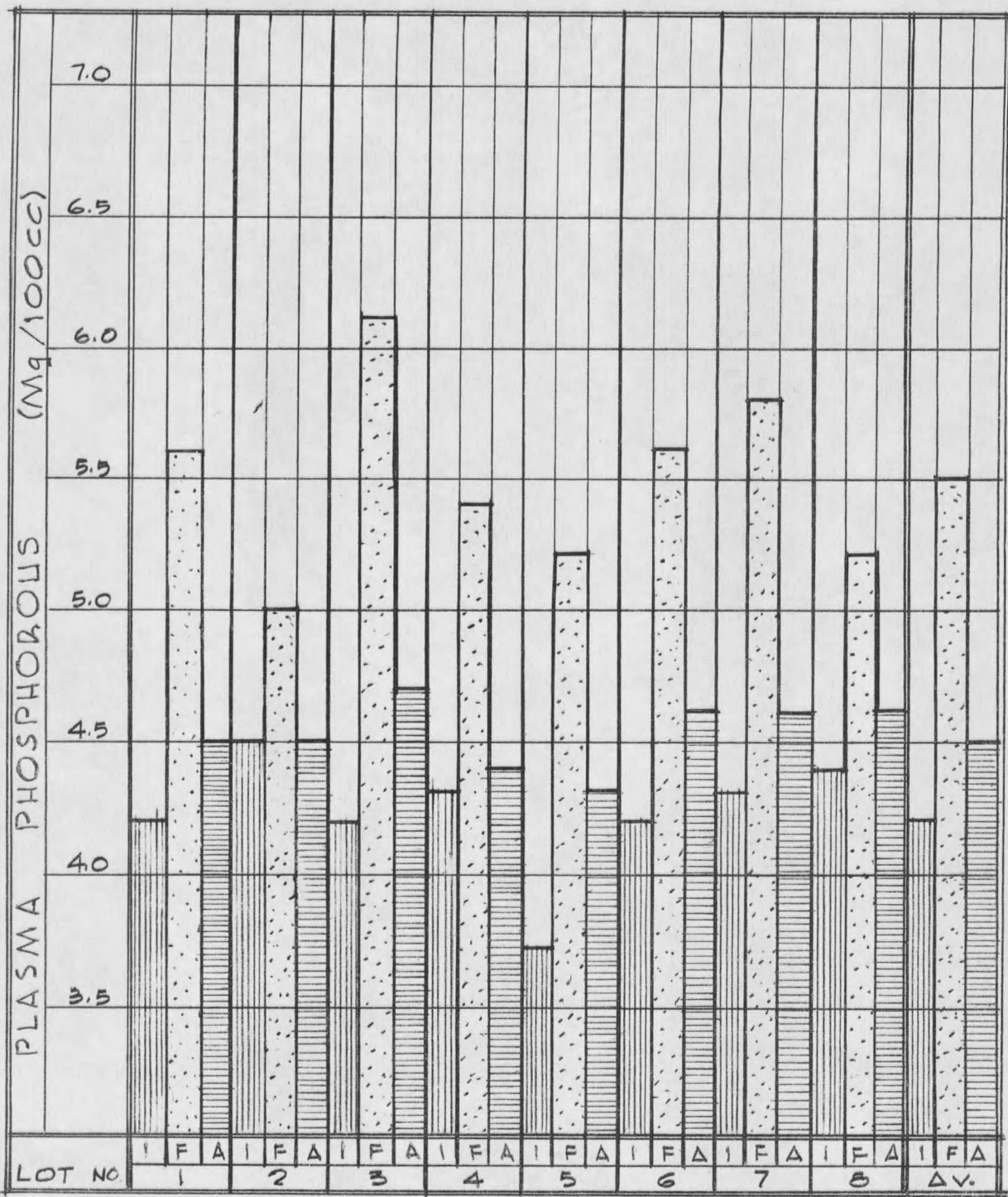


Figure 2. Initial, final, and average plasma inorganic phosphorus levels, Experiment II, 1956-1957.

quate carotene throughout the trial. Table XXXI, Table XXXII, and Table XXXIII show the initial, final, and average of all analyses of plasma carotene for the calves on Experiment II.

Plasma vitamin A

The vitamin A levels of the calves on Experiment II were well above the minimum of 16 mcg. per 100 cc. of plasma (Davis et al. 1941) throughout the trial as would be expected from the high carotene levels. At the beginning of the trial the average plasma vitamin A level was 23.70 mcg. per 100 cc. of plasma, and at the end of the trial the average level was 35.70 mcg. of vitamin A per 100 cc of plasma. Table XXXIV and XXXV show the initial and final vitamin A levels for the calves on Experiment II.

Phosphorus deficiency symptoms

All the calves exhibited phosphorus deficiency symptoms during the trial, but they consistently refused the mineral mixtures offered them. When the calves were turned out for water, some would consistently chew on the corral poles or the painted wall of the barn even before drinking water. Many of the mineral boxes showed evidence of having been chewed. No swollen joints were noted, but the calves had shaggy hair coats.

Table XXXI. Initial Plasma Carotene Levels, Experiment II.

Lot	Pen No.					Total	Average
No.	A	B	C	D	E		
1	109.7	119.7	73.4	208.1	168.4	679.3	135.9
2	158.4	145.9	85.9	108.1	132.6	730.9	146.2
3	128.7	61.3	122.2	186.1	155.6	653.9	130.8
4	115.9	102.4	101.2	196.9	145.9	662.3	132.5
5	107.2	98.7	61.3	106.0	117.2	490.4	98.1
6	81.3	106.0	130.0	90.5	196.9	604.7	120.9
7	124.8	81.3	128.7	143.2	183.1	661.1	132.2
8	94.0	82.4	112.2	208.1	123.5	620.2	124.0
Total	920.0	797.7	814.9	1347.0	1223.2	5102.8	
Average	115.0	137.2	101.9	168.4	152.9		127.6

Table XXXII. Final Plasma Carotene Levels, Experiment II.

Lot	Pen No.					Total	Average
No.	A	B	C	D	E		
1	158.4	124.8	143.2	178.6	180.1	785.1	157.0
2	154.2	121.0	148.7	145.9	177.1	746.8	149.4
3	144.6	121.0	164.1	178.6	216.2	824.4	164.9
4	136.5	76.8	100.0	193.8	171.2	678.3	135.6
5	80.1	172.7	122.2	164.1	178.0	717.2	143.4
6	108.5	117.2	98.7	123.5	255.9	703.8	140.8
7	136.5	112.2	124.8	119.7	165.5	658.6	131.7
8	91.7	140.5	115.9	165.5	123.5	637.2	127.4
Total	1010.4	986.1	1017.6	1269.7	1467.5	5751.3	
Average	126.3	123.3	127.2	158.7	183.4		143.8

Table XXXIII. Average Plasma Carotene Levels, Experiment II.

Lot.	Pen No.					Total	Average
No.	A	B	C	D	E		
1	176.6	154.3	157.3	227.5	168.1	883.8	176.8
2	175.4	157.3	165.3	223.6	172.9	894.6	178.9
3	140.5	124.0	174.6	237.0	199.3	875.4	175.1
4	164.2	111.8	124.6	229.3	181.1	811.1	162.2
5	130.2	166.8	123.7	174.7	158.8	754.2	150.8
6	118.3	127.0	137.5	116.6	242.3	741.8	148.4
7	156.2	121.0	159.6	162.1	180.2	779.2	155.8
8	122.1	128.2	147.6	218.9	116.8	733.7	146.7
Total	1183.7	1090.5	1190.3	1589.6	1419.6	6473.7	
Average	148.0	136.3	148.8	198.7	177.5		161.8

Table XXXIV. Initial Plasma Vitamin A Levels, Experiment II.

Lot	Pen No.					Total	Average
No.	A	B	C	D	E		
1	25.23	27.02	21.33	19.01	25.13	117.72	23.54
2	19.61	28.40	17.11	25.72	22.03	112.87	22.57
3	26.95	23.93	21.26	23.12	22.53	117.79	23.56
4	22.56	24.74	15.32	28.33	18.52	109.47	21.89
5	25.87	24.95	22.10	19.01	22.46	114.39	22.88
6	31.21	25.93	23.58	28.25	21.05	130.02	26.00
7	23.90	27.38	22.74	19.12	26.22	119.36	23.87
8	29.48	23.62	18.24	25.23	29.70	126.27	25.25
Total	204.81	205.97	161.68	187.79	187.64	947.89	
Average	25.60	25.75	20.21	23.47	23.46		23.70

Table XXXV. Final Plasma Vitamin A Levels, Experiment II.

Lot.	Pen No.					Total	Average
No.	A	B	C	D	E		
1	31.24	24.35	36.51	24.97	51.70	178.77	35.75
2	43.23	29.34	30.68	40.56	40.80	184.61	36.92
3	42.73	31.31	47.55	40.73	32.75	195.07	39.01
4	32.86	20.31	37.53	46.95	29.34	166.99	33.40
5	22.81	38.97	35.74	37.36	32.50	167.38	33.48
6	34.51	24.32	24.95	36.65	43.86	164.29	32.86
7	41.08	23.23	53.80	34.33	36.76	189.20	37.84
8	37.01	30.19	47.65	37.29	29.70	181.84	36.37
Total	285.47	222.02	314.41	308.84	297.41	1428.15	
Average	34.43	27.75	39.30	38.60	37.18		35.70

SUMMARY

Two trials were conducted to determine if level of phosphorus, ratio of calcium to phosphorus, or the addition of "temptors" to mineral mixtures would affect mineral consumption by beef calves being fed low phosphorus wintering rations, and to observe the effect of these mineral mixtures on growth, weight gains and blood composition of calves.

The first experiment was conducted during the winter of 1955-1956. Forty weanling Hereford steer calves were divided into eight lots of five each, and one steer from each lot was placed in each of five pens. Eight basal mineral mixtures were used so that one steer of each pen received a mineral mixture containing either zero, five or ten percent phosphorus, and either a 0:0, 1:1, 0:1, 2:1, or 5:1 ratio of calcium to phosphorus. The five pens received either no "temptors", vitamins A and D, trace minerals, "Stoc-Joy", or active dry yeast in their mineral mixtures. With this design each of the forty steers received a different mineral mixture.

The second experiment was conducted during the winter of 1956-1957. Forty weanling steers were lotted the same as the year before with each pen containing one steer from eight different treatments. There were five steers receiving each mineral mixture. One lot of five received only salt with five percent wheat bran, and 2.5 percent linseed oil meal in their mineral boxes, and the other lots received either ten percent or seven and one-half percent phosphorus in their mineral mixtures with ratios of 2:1, 1:1, 0:1, or 1:2 calcium to phosphorus in their mineral mixtures. One of the lots receiving a mixture containing ten percent phosphorus and a ratio of 2:1 calcium to phosphorus, had fifteen percent as yeast. One of the

lots containing seven and one-half percent phosphorus was made up of fifty percent steamed bone meal and forty-two and one-half percent salt with the rest of the mixture as wheat bran and linseed meal. The other seven and one-half percent mixture was formulated to have the same calcium and phosphorus content but to be made up of several ingredients.

In both experiments, the calves were individually fed and had individual mineral and salt boxes. Records were kept of feed consumption, mineral consumption, and salt consumption. Weights and blood samples were taken each twenty-eight days, and the blood was analyzed for plasma inorganic phosphorus, plasma carotene and plasma vitamin A.

Consumption of minerals was very low in both trials, and there were not enough differences to be important even though the differences due to "temptors" were significant ($P < 0.01$). None of the calves ate enough minerals to provide adequate phosphorus to supplement the phosphorus deficiency symptom by chewing wood, and the painted wall of the barn, or the wooden boxes in which their minerals were placed. Salt consumption was very low both years, and especially low the second year. No explanation for the low intake of salt was found.

Concentrate consumption was slow during both experiments. The first year it was thought to be due to the extremely nervous temperament of the calves. The second year, the low concentrate intake was blamed on the unpalatability of beet pulp pellets for many of the calves.

The phosphorus determinations on the blood indicated borderline, if not deficiency intake of phosphorus during both trials.

Carotene and vitamin A levels in the plasma indicated adequate content

-57-

of carotene in the hay during both experiments.

LITERATURE CITED

- Becker, R. B., G. K. Davis, W. G. Kirk, R. S. Glascock, P. T. Dix Arnold, and J. E. Pace. 1944. Deflourinated superphosphate for livestock. Florida Agr. Exp. Sta. Bul. 401.
- Beeson, W. M., D. W. Bollin, G. W. Hickman, and R. F. Johnson. 1941. The phosphorus requirements for growing and fattening beef steers. Idaho Bul. 240.
- Bekker, J. G. 1932. Studies in mineral metabolism. XXIV, On the administration of phosphorus to animals through their water supply. Eighteenth report of the Director of Veterinary Services and Animal Industry, Union of South Africa, pp. 751-797.
- Bently, O. G., T. D. Moinuddin, E. W. Klosterman, and A. L. Moxon. 1954. The effect of trace minerals on growth performance and vitamin B₁₂ synthesis of steers. Jour. Anim. Sci. 13:789.
- Black, W. H., L. H. Tash, J. M. Jones, and R. J. Kleberg, Jr. 1949. Comparison of methods of supplying phosphorus to range cattle. U. S. Agr. Tech. Bul. 981. pp. 1-22.
- Bohstedt, G. 1957. Recent advances in mineral nutrition. Proceedings of the Symposium on Mineral Nutrition. International Minerals and Chemical Corporation.
- Brodie, S., Gloria Burge, C. Blincoe, J. Barton, R. Tary, and W. Platner. 1949. Environmental physiology with special reference to domestic animals: III Influence of ambient temperature 50 degrees to 100 degrees F on the blood composition of Jersey and Holstein Cows. Mo. Agr. Res. Bul. 433, pp. 37.
- Chappel, C. F., R. J. Sirny, C. K. Whitehair, and R. MacVicar. 1952. Effect of minerals on digestion of low-quality roughage by sheep. Jour. Anim. Sci. 11:758.
- Clanton, D. C. 1954. The effects of adding cobalt, copper, manganese, and phosphorus to rations containing urea or soybean oil meal for wintering steer calves. Master's Thesis, Montana State College.
- Davis, R. E. and L. L. Madsen. 1941. Carotene and vitamin A in cattle blood plasma with observations on reproductive performances at restricted levels of carotene intake. Jour. Nutr. 21:135-146.
- Du Toit, P. J. and H. H. Green. 1930. Dicalcium phosphate as a source of phosphorus in nutrition.

- Du Toit, P. J., A. L. Malan and J. W. Groenwald. 1933. Studies in mineral metabolism. XXVII, The effect of two different calcium phosphorus ratios upon the growth of calves. Onderstepoort Jour. Vet. Sci. and Anim. Ind. 1:421.
- Eckles, C. H., T. W. Gullickson, and L. S. Palmer. 1933. Phosphorus deficiency in the rations of cattle. Minn. Agr. Exp. Sta. Tech. Bul. 91.
- Eveleth, D. F., M. W. Eveleth, and F. E. Walsh. 1937. Inorganic phosphorus of the serum of dairy cattle. North Am. Vet. 18:no 9. pp. 18-22.
- Fairbanks, B. W. 1939. The calcium-phosphorus ratio. North Am. Vet. 20: no. 1. pp. 17-21.
- Fiske, C. H and Y. Subbarow. 1925. The colorimetric determination of phosphorus. Jour. Biol. Chem. 66:375.
- Forbes, E. B. and M. H. Keith. 1914. Phosphorus compounds in animal metabolism. Ohio Agr. Exp. Sta. Tech. Series Bul. 5.
- Forbes, E. B., R. B. French, and T. V. Luttonoff. 1929. The mineral metabolism of the beef steer. Jour. Nutr. 1:201.
- Gallup, W. D. and H. M. Briggs. 1950. The minimum phosphorus requirements of lambs for phosphorus equilibrium. Jour. Anim. Sci. 9:426-430.
- Gemmell, C. L. 1956. Part IV Metabolism and Nutrition. Medical Physiology. Tenth Edition. Philip Bard, editor. C. V. Mosby Co., St. Louis. pp. 689.
- Greaves, J. E., E. J. Maynard and W. Reeder. 1934. Influence of calcium and phosphorus intake on bovine blood. Jour. Agr. Res. 48:1033-1041.
- Green, H. H. and E. H. Macaskill. 1928. Studies in mineral metabolism. VI. Comparison of the blood of cow and calf in respect to mineral constituents. Jour. Agr. Sci. 18:384-390.
- Guilbert, H. R., C. E. Howell and C. H. Hart. 1940. Minimum vitamin A and carotene requirements of mammalian species. Jour. Nutr. 19:91-103.
- Haag, J. R. 1951. Minerals for livestock. Oregon Agr. Exp. Bul. 503.
- Hughes, J. S., W. H. Riddell and J. B. Fitch. 1933. The influence of phosphorus deficiency on the metabolizable energy of the ration. Proc. Am. Soc. Anim. Prod. pp. 241-243.

- Kimble, M. S. 1939. Photocolorimetric determination of vitamin A and carotene in human plasma. Jour. Lab. and Clin. Med. 24:1055.
- Kleiber, M., H. Goss and H. R. Guilbert. 1936. Phosphorus deficiency, metabolism, and food utilization in beef heifers. Jour. Nutr. 12:121-153.
- Klosterman, E. W., L. E. Kunkle, O. G. Bently and W. Burroughs. 1953. Supplements to poor quality hay for fattening cattle. Ohio Agri. Exp. Sta. Bul. 732.
- Lantow, J. L. 1933. The assimilation of calcium and phosphorus from different mineral compounds and their effect on range cattle. N. Mex. Agr. Exp. Sta. Bul. 214.
- Lewis, J. K. 1950. The effect of excess calcium with borderline and deficient phosphorus in the rations of steer calves. Master's Thesis, Montana State College.
- Long, R. A., W. A. Van Arsdell, R. MacVicar and O. B. Ross. 1952. Blood composition of normal beef cattle. Okla. Agr. Exp. Tech. Bul. T-43. pp. 1-23.
- Malan, A. L., H. H. Green and P. J. Du Toit. 1928. Studies in mineral metabolism. V. Composition of bovine blood on phosphorus deficient pasture. Jour. Agr. Sci. 18:376-383.
- Maynard, E. J. 1933. Phosphorus supplements in beet by-product rations. Am. Soc. Anim. Prod. Proc. pp. 86-89.
- Mitchell. 1947. The mineral requirements of farm animals. Jour. Anim. Sci. 6:365.
- Morrison, F. B. 1948. Feeds and Feeding. 21st Edition. Morrison Publishing Company. Ithaca, New York.
- Morrison, F. B. 1956. Feeds and Feeding. 22nd Edition. Morrison Publishing Company. Ithaca, New York.
- National Research Council. 1950. Recommended nutrient allowances for domestic animals. IV. Recommended nutrient allowances for beef cattle.
- Nelson, A. B. 1955. The value of trace minerals in winter rations for stocker cows. Okla. Agr. Exp. Sta. 1955 Livestock Feeders' Day. pp. 63.
- Nelson, A. B., W. D. Gallup, O. B. Ross and A. E. Darlow. 1955. Supplemental phosphorus requirement of range beef cattle in North Central and South Eastern Oklahoma. Okla. Agr. Exp. Sta. Tech. Bul. No. T-54. pp. 29.

- Nevens, W. G. 1928. An experiment in the free-choice feeding of mineral supplements to dairy cattle. III. Agr. Exp. Sta. Bul. 316.
- Otto, J. S. 1938. The assimilation of calcium and phosphorus by the growing bovine. Onderstepoort Jour. Vet. Sci. and Anim. Ind. 10:282-345.
- Payne, M. G., A. C. Clark, H. E. Kingman and W. M. Stansbury. 1946. Blood levels of calcium and inorganic phosphorus in Hereford cattle. Jour. Agr. Res. 72:357-363.
- Plumlee, M. P., R. Totusek and W. M. Beeson. 1953. The effect of adding trace minerals to the rations of identical twin beef cattle. Jour. Anim. Sci. 12:928. (abstract)
- Pope, L. S., R. D. Humphrey and V. G. Heller. 1955. Effect of adding calcium to cottonseed meal for steers wintering on native grass. Okla. Agr. Exp. Sta. 29th Annual Livestock Feeders' Day. pp. 54.
- Reed, O. E. and C. F. Huffman. 1930. The results of a five-year mineral feeding investigation with dairy cattle. Mich. Agr. Exp. Sta. Tech. Bul. 105. pp: 1-63.
- Reynolds, E. B., J. M. Jones, J. H. Jones, J. F. Fudge and R. J. Kleberg, Jr. 1953. Methods of supplying phosphorus to range cattle in south Texas. Tex. Agr. Exp. Bul. 773.
- Ross, O. B. and W. D. Gallup. 1949. The effect of phosphorus deficiency on blood plasma carotene. Jour. Anim. Sci. 8:628-629. (abstract)
- Ross, O. B., R. W. MacVicar and D. F. Stephens. 1950. Feeding trials with mineral and protein supplements for two and three-year-old steers wintering on dry grass. Okla. Agr. Exp. Sta. Bul. No. B-359.
- Schmidt, H. 1924. Field and laboratory notes on a fatal disease of cattle occurring on the coastal plains of Texas. (Loin Disease). Tex. Agr. Exp. Sta. Bul. No. 319.
- Smith, E. F., R. F. Cox and F. H. Baker. 1954. Wintering grazing and fattening steer calves. Kan. Agr. Exp. Sta. Cir. 308.
- Stanley, E. B. 1938. Nutritional studies with cattle on a grassland type range in Arizona. Ariz. Agr. Exp. Sta. Bul. 79.
- Theiler, A., H. H. Green and P. J. Du Toit. 1927. Minimum mineral requirements in cattle. Jour. Agr. Sci. 17:291-314.
- Theiler, A. and H. H. Green. 1932. Aphosphorosis in ruminants. Nutr. Abstr. and Rev. 1:359-385.

- Theiler, A., P. J. Du Toit and A. I. Malan. 1937. Studies in mineral metabolism. XXXVII. The influence of variations in the dietary and in the calcium-phosphorus ratio on the production of rickets in cattle. Onderstepoort Jour. Vet. Sci. and Anim. Ind. 8:375-414.
- Thomas, O. O. 1951. II. The effect of low phosphorus rations upon carotene metabolism in ruminants. Doctor of Philosophy Thesis. Okla. A. and M. College.
- Thomas, O. O., D. C. Clanton and F. S. Willson. 1953. Efficiency of urea utilization as influenced by mineral constituents in a wintering ration for beef steers. Jour. Anim. Sci. 12:933. (abstract)
- Thomas, O. O., W. D. Gallup and C. K. Whitehair. 1953. Effects of phosphorus deficiency on metabolism of carotene and vitamin A by beef cows. Jour. Anim. Sci. 12:372-378.
- Totusek, R., W. D. Gallup and A. Swader. 1955. Mineral management studies with beef cows in southeastern Oklahoma. Okla. Ag. Exp. Sta. Livestock Feeders' Day Report. pp. 80-84.
- Van Landingham, A. H., H. O. Henderson and G. A. Bowling. 1935. Studies on the chemical composition of the blood of dairy cattle. I. The effect of age and phosphorus intake on the calcium and inorganic phosphorus content of whole blood of dairy heifers. Jour. Dairy Sci. 18:557-572.
- Van Landingham, A. H., H. O. Henderson and G. A. Bowling. 1942. Studies on the chemical composition of the blood of dairy cattle. III. The normal concentration of inorganic phosphorus in the whole blood of dairy cattle and factors affecting it. Jour. Dairy Sci. 25:537.
- Watkins, W. E. and J. H. Know. 1948. Inorganic blood phosphorus levels necessary for satisfactory production of range cattle in the southwest. Jour. Anim. Sci. 7:263-272.
- Welch, H. 1940. Phosphorus for livestock in Montana. Mont. Agr. Exp. Sta. Cir. 157.

MONTANA STATE UNIVERSITY LIBRARIES



3 1762 10015521 5

N378

Sm94s

cop.2

128921

Smyrl, S. H.

Self-feeding beef calves
mineral mixtures varying in
calcium and phosphorus levels.

NAME AND ADDRESS

17-5-60 ⁹⁰⁰ _{dm} *Hebe Jensen* ^{TEWICKIN}

12/1/61 *1035 E. Olive*
Kurt Smith
704 South 6

6-5-67 *W. H. Heston*
Diane m
lib. use only *Rt 1, b*

N378
Sm94s
Cop. 2

128921

