The effects of adding cobalt, copper, manganese and phosphorus to rations containing urea or soybean oil meal for wintering steer calves

by Donald Cather Clanton

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

Abstract:
The study reported in this thesis was conducted to determine whether or not any benefit is derived from adding trace minerals to rations varying in phosphorus content and containing urea or soybean oil meal. These rations were fed to steer calves wintered to gain approximately one pound per day. Two feeding trials are reported.

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

The calves were divided into five groups so that average weights were equal. The five groups were individually fed a basal ration containing dried molasses beet pulp, corn gluten feed, and urea. Combinations of three levels of phosphorus and three levels of trace minerals were used in the rations. All calves were fed hay which contained a low amount of phosphorus.

Weights and blood samples were taken approximately every 28 days.

The blood plasma was analyzed for phosphorus, calcium, vitamin A, and carotene. Although the calves receiving a ration containing adequate phosphorus and trace minerals made the best gains, there were no significant differences amoung the average gains observed for the five treatments.

For the second trial, fifty-six weanling Hereford steer calves, averaging about 390 pounds, were obtained from one rancher and divided into eight groups on the basis of weight. Each of the eight rations was individually fed to one steer in each of seven lots. Five lots were located at Bozeman and two lots were located at the Fort Ellis farm, five miles east of Bozeman. Daily individual concentrate and hay intakes were recorded for each calf. The eight rations contained combinations of urea or soybean oil meal, low phosphorus or adequate phosphorus, and no trace minerals or added trace minerals.

Weights and blood samples were taken every 28 days. Calves receiving low-phosphorus rations gained less than those receiving adequate-phosphorus rations. Calves receiving urea rations gained less than those receiving soybean oil meal rations. Calves receiving trace minerals in soybean oil meal rations gained less than those receiving trace minerals in urea rations. These differences in gains were highly significant.

Blood samples obtained were analyzed for phosphorus, calcium, vitamin A, and carotene. In both trials, significantly lower blood phosphorus levels were found in calves fed low-phosphorus rations. There were negative relationships between plasma-phosphorus and plasma-calcium in both trials. The carotene content was high when the phosphorus content was low.

Rations fed in the second trial produced definite nutritional deficiency symptoms similar to those described by many workers as a phosphorus deficiency. These symptoms were low

plasma-phosphorus, depraved appetite, unthrifty condition, rough hair coat, and poor appetite.

The environmental differences between the Bozeman lots and the Fort Ellis lots caused greater variations in gains than the difference due to rations fed.

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Dean, Graduate Division

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TABLE OF CONTENTS

Index to Figures 4

Index to Tables 5, 6

Abstract 7

Introduction 8

Review of Literature 10

Experiment 1

Procedure 20

General Information 20

Rations Fed 22

Results and Discussion 28

Feed Consumption 28

Rate of Gain 32

Plasma-Calcium and Phosphorus 34

Plasma-Vitamin A and Carotene 35

Experiment 2

Procedure 41

General Information 41

Rations Fed 44

Results and Discussion 49

Feed Consumption 49

Rate of Gain 52

Efficiency and Cost of Gain 58

Plasma-Calcium and Phosphorus 61

Plasma-Vitamin A and Carotene 64

Deficiency Symptons 66

Summary 70

Literature Cited 73

INDEX TO FIGURES

1. One lot of calves in their individual feeding stalls at the Fort Ellis farm 21

2. Changes in plasma inorganic phosphorus and calcium during Experiment 1. (1951-1952). 37

3. Differences in gains due to the environmental difference between Bozeman and Fort Ellis are shown. (1952-1953) 57

4. The top pictures show the feeding stalls and exercising pens at Fort Ellis. The bottom pictures show the same facilities at Bozeman. Note the difference in size of stalls, construction of corrals, and slope of the corrals. . . . 59

5. Changes in plasma-inorganic phosphorus and calcium during Experiment 2. (1952-1953) 65

6. Calves on the right were fed ration 2 and those on the left were fed ration 7. The calves on the right show phosphorus deficiency symptoms. Note they are chewing sticks. The difference in the gains can be seen 68

INDEX TO TABLES

I.	Recommended daily allowances for wintering calves	23
II.	Chemical analyses of feeds used in formulating rations for Experiment 1. (1951-1952)	25
III.	Concentrate rations fed in Experiment 1. (1951-1952) . . .	26
IV.	Calculated chemical composition of total rations fed in Experiment 1. (1951-1952)	28
V.	Average daily nutrient intake per calf for rations fed in Experiment 1. (1951-1952)	29
VI.	Performance and cost of gains for calves in Experiment 1. (1951-1952)	31
VII.	Price of feeds used in Experiment 1. (1951-1952)	32
VIII.	Calcium and Phosphorus content of the blood plasma of the calves in Experiment 1. (1951-1952)	36
IX.	Mean squares for weight gains and plasma-phosphorus and calcium values of calves in Experiment 1. (1951-1952) . .	38
X.	Vitamin A and carotene content of the blood plasma of the calves in Experiment 1. (1951-1952)	39
XI.	Composition of rations fed during Experiment 2. (1952-1953)	43
XII.	Chemical analyses of feeds used in formulating rations for Experiment 2. (1952-1953)	45
XIII.	Concentrate rations fed in Experiment 2. (1952-1953) . . .	46
XIV.	Chemical composition of concentrate rations fed in Experiment 2. (1952-1953)	48
XV.	Average daily concentrate and hay intake per calf in Experiment 2. (1952-1953)	50
XVI.	Average daily nutrient intakes per calf, for rations fed in Experiment 2. (1952-1953)	51
XVII.	Average daily gain of calves by rations at 28-day intervals on Experiment 2. (1952-1953)	53

XVIII.	Mean squares for weight gains and plasma-phosphorus and calcium values of calves in Experiment 2. (1952-1953)	55
XIX.	Average daily gain of calves by lots at 28-day intervals in Experiment 2. (1952-1953)	56
XX.	Performance and cost of gains for calves in Experiment 2. (1952-1953)	60
XXI.	Cost of feeds used in Experiment 2. (1952-1953)	62
XXII.	Calcium and phosphorus content of the blood plasma of the calves in Experiment 2. (1952-1953)	63
XXIII.	Vitamin A and carotene content of the blood plasma of calves in Experiment 2. (1952-1953)	67

ABSTRACT

The study reported in this thesis was conducted to determine whether or not any benefit is derived from adding trace minerals to rations varying in phosphorus content and containing urea or soybean oil meal. These rations were fed to steer calves wintered to gain approximately one pound per day. Two feeding trials are reported.

Forty weanling Hereford steer calves were used in the first trial. The calves were divided into five groups so that average weights were equal. The five groups were individually fed a basal ration containing dried molasses beet pulp, corn gluten feed, and urea. Combinations of three levels of phosphorus and three levels of trace minerals were used in the rations. All calves were fed hay which contained a low amount of phosphorus.

Weights and blood samples were taken approximately every 28 days. The blood plasma was analyzed for phosphorus, calcium, vitamin A, and carotene. Although the calves receiving a ration containing adequate phosphorus and trace minerals made the best gains, there were no significant differences amoung the average gains observed for the five treatments.

For the second trial, fifty-six weanling Hereford steer calves, averaging about 390 pounds, were obtained from one rancher and divided into eight groups on the basis of weight. Each of the eight rations was individually fed to one steer in each of seven lots. Five lots were located at Bozeman and two lots were located at the Fort Ellis farm, five miles east of Bozeman. Daily individual concentrate and hay intakes were recorded for each calf. The eight rations contained combinations of urea or soybean oil meal, low phosphorus or adequate phosphorus, and no trace minerals or added trace minerals.

Weights and blood samples were taken every 28 days. Calves receiving low-phosphorus rations gained less than those receiving adequate-phosphorus rations. Calves receiving urea rations gained less than those receiving soybean oil meal rations. Calves receiving trace minerals in soybean oil meal rations gained less than those receiving trace minerals in urea rations. These differences in gains were highly significant.

Blood samples obtained were analyzed for phosphorus, calcium, vitamin A, and carotene. In both trials, significantly lower blood phosphorus levels were found in calves fed low-phosphorus rations. There were negative relationships between plasma-phosphorus and plasma-calcium in both trials. The carotene content was high when the phosphorus content was low.

Rations fed in the second trial produced definite nutritional deficiency symptoms similar to those described by many workers as a phosphorus deficiency. These symptoms were low plasma-phosphorus, depraved appetite, unthrifty condition, rough hair coat, and poor appetite.

The environmental differences between the Bozeman lots and the Fort Ellis lots caused greater variations in gains than the difference due to rations fed.

INTRODUCTION

This thesis includes a study of wintering trials with steer calves. A study of weight gains, blood analyses, and environmental differences, as affected by rations containing either urea or soybean oil meal as a nitrogen source, trace minerals, and low or adequate phosphorus is reported.

A problem in western range areas is how to winter calves economically without affecting growth, vigor, and general health of the calves. Cheaper supplemental feeds can now be formulated by using non-protein nitrogen or urea as a replacement for vegetable proteins. Research at many experiment stations has shown that urea can satisfactorily replace a portion of the protein in wintering calf rations without affecting weight gains.

Protein is a very important nutrient for growth. The distinguishing characteristic of protein is the fact that it contains approximately 16 percent nitrogen. To determine the crude protein in a feed, the amount of nitrogen in the feed is multiplied by a conversion factor (6.25), which is found by dividing 100 by 16. Urea, a white crystaline compound, which has the chemical formula $NH_2\overset{O}{\overset{\|}{C}}NH_2$, contains 42 percent nitrogen; therefore, on the basis of protein, it would have an equivalence of 262 percent. The process by which urea is converted to protein takes place in the rumen. The microorganisms in the rumen utilize the nitrogen of the urea in the manufacturing of protein in their own bodies. Later, the microorganisms are digested by the animal, and it is at this time that the ruminant obtains the benefit from the urea. Urea is produced for commercial use by a process of combining water, coke, and air and is rather inexpensive considering its protein equivalence. The urea used in this study was labled

"Two-Sixty-Two" Feed Compound and is made by the Du Pont Plant at Belle, West Virginia.

Soybean oil meal was used in this study because it is the protein supplement most commonly used in the northwestern range areas.

There are no known copper, cobalt or manganese dificient areas in the northwest. It is assumed the forage contains these minerals in adequate amounts to satisfy the needs of the livestock that feed upon them; therefore, it is questionable whether or not there is need for trace mineral supplementation. Sounder bases for recommendations regarding mineral supplementation are needed. These three elements will be referred to in this paper as the trace minerals. Trace minerals were added to the experimental rations to determine their value. Only in the last few years has emphasis in nutrition research been placed on determining the relationship that exists between the various nutrients.

Phosphorus and calcium are the two major minerals essential in animal nutrition. There are many phosphorus deficient areas in the northwest, but there are only a few calcium deficient areas. Because cattle and sheep utilize large amounts of roughages, which are high in calcium, the problem has been to supplement these roughages with the proper minerals. In this study, various phosphorus levels were fed to learn more of their effect on growth.

Vitamin A deserves considerable attention in range areas as there have often been deficiencies occurring in cattle, especially after drought periods.

REVIEW OF LITERATURE

The use of urea in animal feeding is not new, as urea was fed before the turn of the century. Voltz (1907) worked with sheep and reported that within wide limits the amid substances of molasses can replace proteins in the metabolism of adult ruminants. At this early time, he stated that probably the organism of the ruminant possessed the capacity of building up high molecular nitrogen compounds from a very limited number of amid substances and using them in metabolism.

Mangold and Stotz (1936) found that the nitrogen balances of two young bullocks on a basal ration of hay and soya bean meal were unaltered when 25 percent of the digestible protein in the ration was replaced by an equivalent amount of urea. Fingerling, et al. (1937) reported a series of nitrogen balance experiments with two young oxen and showed that 50 to 60 percent of the nitrogen of urea is available for deposition as compared with 60 to 63 percent of nitrogen in wheat gluten. They surmised, within quite wide limits, that the nitrogen of urea can be utilized by growing animals. The appropriate use of urea produced no harmful effects.

The first work with urea conducted in the United States was reported by Hart, et al. (1938, 1939). They stated that, when 43 percent of the nitrogen in the ration was from urea nitrogen, the growth rate was little less than that secured with a ration containing 66 percent of its nitrogen as casein nitrogen; this work was done with growing calves.

According to McNaught and Smith (1947), the economy of utilization of nitrogen in the rumen will depend on: (a) the rate of growth of the bacteria, which in turn depends on a liberal supply of starch; and (b) the balance between the nitrogen requirements of the bacteria as determined by (a), and the supply of simple nitrogenous compounds in the diet. If more nitrogen is consumed than can be synthesized, the excess enters the blood and may cause toxic effects.

Briggs, et al. (1947) and Dinning, et al. (1949) showed that nitrogen retention by steers was increased by the addition of 25 and 50 percent urea nitrogen to the ration; however, urea alone was a poor supplement to prairie hay. Johnson, et al. (1942) found that the addition of urea to a basal ration, in amounts to produce the equivalent of 12 percent crude protein on the dry basis, induced a retention of nitrogen in growing lambs that could not be improved by further urea additions but could be improved by increasing the true protein content of the ration. It appeared that the conversion of urea in the paunch does not proceed at a sufficiently rapid rate to meet the protein requirements of the growing lamb.

Loosli and McCoy (1943) and Watson, et al. (1949) demonstrated that urea added to a low protein ration caused an increase in growth gains when fed to beef or dairy calves. Loosli increased a 4.4 percent protein ration to a 16.2 percent protein ration by using urea and showed that this additional nitrogen increased growth gain.

Bartlett and Cotton (1938) used a control ration with a limited amount of protein. To this ration, they added 0.127 pounds of urea daily and fed it to growing dairy heifers. The weight gains were increased, but when the same amount of nitrogen was given in the form of protein, the weight gains were greater than with urea. For growing calves, they considered protein a better source of nitrogen than urea. McClymont (1948) concluded that, for growth or feed utilization in calves, the effeciency of urea nitrogen was not greatly affected by the presence, or proportion, of grain in a low protein ration, and that urea could not compete with protein rich concentrates at prevailing prices but might be economical where protein concentrates are costly or not available.

Contrary to the above conclusions, several workers have reported satisfactory gains from rations containing urea. Embry and King (1953) reported that a protein supplement containing four percent urea compared favorably with soybean oil meal when either was fed with prairie hay; they wintered beef calves to gain 0.75 to 1 pound daily. Beeson and Perry (1952) used urea to replace from one-third to two-thirds of the protein equivalent supplied by soybean oil meal; this supplement was fed with ground corn cobs. No significant difference in growth rate was obtained when the gains of these beef calves were compared with those of calves receiving all their protein from soybean oil meal. Hamilton (1948) concluded that urea was as satisfactory a source of nitrogen for growing lambs as that from most ordinary feeds, provided at least 25 percent of the food nitrogen was in the form of preformed protein, and provided further that the total protein equivalent of the ration did not exceed 12 percent.

Urea utilization varies considerably because of the presence or absence of different quality proteins and carbonaceous materials. Burroughs, et al. (1951) stated that good quality protein, when not fed above a certain level, gives better urea utilization but when fed in large amounts lowers urea utilization. Cellulose digestion was greater when urea was in the ration. Wegner, et al. (1941) showed the rate of conversion of urea nitrogen to protein in th rumen decreased when the level of protein in the concentrate was increased to more than 18 percent.

Loosli and Harris (1945), Lofgreen, et al. (1947), and Gallup, et al. (1952) reported that an addition of methionine to a urea ration increased the nitrogen retention and that protein synthesis from urea in lambs is greatly enhanced by the addition of methionine. Apparently the quality of protein accompanying urea in a ration is important.

Mills, et al. (1942) reported, when using timothy hay as the basal ration, that utilization of added urea took place only when starch was added to the ration. Mills, et al. (1944) worked with growing dairy calves and found that, for maximum growth, a ration composed of a roughage and molasses and urea must be supplemented with some additional source of a readily available carbohydrate or protein such as any cereal grain or protein concentrate. Arias, et al. (1951) and Bell, et al. (1951) reported that a source of energy in the ration, either a readily available carbohydrate, or a complex carbohydrate, aided urea utilization.

Burroughs, et al. (1951) studied the effects of minerals on urea utilization. They found phosphorus and iron effective in stimulating urea utilization and cellulose digestion by rumen microörganisms. Evidence was presented that other elements besides iron and phosphorus were involved in rumen bacterial physiology. These elements were in addition to sodium, potassium, calcium, magnesium, chlorine, and sulfur, which were routinely used in the artificial saliva of an artificial rumen.

Gallup, et al. (1951) observed trends indicating greater vitamin A storage when cottonseed meal was fed than when soybean oil meal was fed as the protein supplement. Urea had no effect on carotene and vitamin A metabolism as measured by the plasma and liver values.

The palatability of rations containing urea is important, and most workers have reported that rations containing urea are palatable. One of the first reports on palatability was by Mangold and Stotz (1937), who found that rations containing 15 percent urea were very palatable. Bowstead and Fredeen (1948) listed some factors concerning the palatability of urea rations. Differences in individual animals had the greatest influence on palatability; molasses enhanced palatability; the most palatable of all urea-grain mixtures were those containing five percent urea. Briggs, et al. (1947) found that pellets containing 50 percent of their nitrogen from urea were a satisfactory supplement in the early phases of a fattening period but proved unpalatable in the late phases.

Hart, et al. (1939) observed that kidney damage was present when urea was fed at the rate of 4.3 percent of the dry matter of the ration and was also apparent when urea was fed at a 2.8 percent level. Work, et al. (1943) showed that urea fed for long periods of time, at the rate of 0.88 and 2.29 percent of the dry matter of the ration, did not cause liver or kidney damage in steers under dry lot management. They also showed that urea, when fed to steers on pasture at the rate of 0.18 and 0.35 pound per head per day, and as complete replacement for cottonseed meal supplement, did not cause liver or kidney damage. Briggs, et al. (1947) found that when 25, 50, 75, or nearly 100 percent of the supplemental nitrogen has been furnished by urea there are no indications of toxic effects from urea. Harris and Mitchell (1941) found that rations containing up to 3.16 percent urea on the dry basis did not exert any observable toxic effect in lambs.

Considerable work has been reported concerning phosphorus and calcium levels for animal feeding. Theiler, et al. (1927) reported that minimal requirements for growth are higher in the case of phosphorus than in the case of calcium. Gallup and Briggs (1950) indicated the breaking point bewteen negative and positive phosphorus balance was when the ration supplied about two grams of phosphorus daily per 100 pounds of body weight. Beeson, et al. (1937) also concluded that two grams of phosphorus daily per 100 pounds of live weight were adequate for normal growth. They indicated that an organic form of phosphorus, as present in cottonseed meal, is not as available to the beef animal as an inorganic form and that an excess supplementation of bone meal gives lower gains than adequate supplementataion. Huffman, et al. (1933) said the phosphorus requirement for growth is not directly proportional to body weight but depends on rate of growth. Lewis (1950) concluded that excess calcium added to a ration of borderline phosphorus content reduced both feed consumption and rate of gain.

Kleiber, et al. (1936) reported that a low-phosphorus intake diminished appetite and the efficiency with which food energy was converted to body energy but had no effect on the digestibility and metabolism of the food. Hughes, et al. (1933) concluded the metabolizable energy of a ration is not influenced by phosphorus deficiency in cattle.

Van Landingham, et al. (1935) reported that whole blood-inorganic phosphorus level was found to be a good index of the degree of phosphorosis. The fall in phosphorus level was roughly proportional to the degree of deficiency. Payne, et al. (1946) found that the blood levels of inorganic phosphorus decreased with age of cattle. Green and Macaskill (1928) showed the plasma-phosphorus values of new born calves were much higher than the plasma-phosphorus values of their mothers. Thomas (1950) showed that plasma-phosphorus decreased as calves grew to 20 weeks of age. Watkins and Knox (1948) reported that a yearly average of 3.53 milligrams per 100 milliliters of blood for range cows was adequate for good production.

There has been considerable work done with cobalt in the United States but little work with copper and manganese. The major cobalt and copper deficient areas in the United States are Florida and surrounding states, around the Great Lakes, and New York and New Hampshire. These deficiencies cause poor gains in livestock in those areas, and livestock have responded very well to supplementation of these minerals.

When using a late cut timothy hay and a ration in which 39 percent of the nitrogen was furnished by urea, Bentley and Moxon (1952) found that adding a mineral mixture containing copper, cobalt, manganese, zinc, and iron improved average daily gain of steers by 43 percent. Klosterman, et al. (1953) showed that the ash of dehydrated alfalfa meal, of molasses fermentation solubles, or a trace mineral mixture significantly increased the gains of steer calves fed poor quality hay. The daily intake of the calves was 800, 200, 25, 14, and 0.5 milligrams, respectively of iron, manganese, copper, zinc, and cobalt. Their results indicate that the poor quality hay ration was deficient in trace minerals and that these minerals apparently were present in alfalfa ash or molasses fermentation solubles.

Gallup, et al. (1952) found that excess manganese in a ration caused large fecal excretions of phosphorus and calcium. Calcium and phosphorus balances were positive when manganese was added to the ration at rates of 250 and 500 parts per million. With young Holstein heifers, Bentley and Phillips (1951) found that rations with less than 10 parts per million manganese were adequate for growth. Addition of manganese as a mineral supplement to provide 30, 40, or 60 parts per million did not stimulate faster growth. Cattle readily tolerated 60 to 70 parts per million manganese so Bentley and Phillips felt that 20 parts per million would be a satisfactory level. If a ration contained less manganese, they advised supplementation.

Kidder (1949) had a 500-pound steer develop chronic copper poisoning and die after 122 days on a daily drench containing five grams of $CuSO_4 \cdot 5H_2O$. Davis and Hannan (1947) studied copper deficient Devon cattle. They observed an increase in the alkaline blood phosphatase values as copper values decreased. The blood inorganic phosphorus values rose from below six milligrams per one hundred milliliters of blood to over twelve milligrams per one hundred milliliters of blood. Copper administration quickly restored the phosphatase and blood inorganic phosphorus values to normal.

Gee (1952) reported the daily requirement of cobalt and copper for cattle is 1 milligram cobalt and 100 milligrams copper. McNaught, et al. (1950) found rumen bacteria can tolerate 10 parts per million copper and somewhat less than 10 parts per million cobalt. Growth of bacteria was inhibited by 25 parts per million copper and 1000 parts per million cobalt.

Klosterman, et al. (1951) fed wheat straw, cane molasses, field peas, cerelose, dicalcium phosphate, and salt to lambs. The addition of cobalt significantly improved the biological value of protein but had no effect on the digestibility of the protein.

Chamberlain, et al. (1948) found one milligram cobalt per day per lamb, added to a ration of 45 percent corn and 55 percent hay, increased gains the last four weeks of a 14-week feeding period.

Pope, et al. (1947) reported that the most noticable effect of supplementing a ration with cobalt was the rapid resumption of appetite in cobalt deficient sheep.

Sedgwick, et al. (1950) worked with cobalt-deficient sheep. They found cobalt salts given by mouth gave increased appetites in a week, quickly followed by an increase in weight. Cobalt injections were of no value. Cobalt deficiency had no effect on blood phosphorus.

Neal and Akmann (1937) produced a malnutrition in calves that was prevented or cured by cobalt supplementation and was aggravated by the use of iron and copper supplements. Appetite failure was the most prominent symptom.

Geyer, et al. (1945) corrected a cobalt deficiency in calves by feeding three milligrams of elemental cobalt per day. They found feeding as much as 50 milligrams of cobalt per day produced no polycythemia. Kenner, et al. (1949) found growing dairy calves were able to consume daily up to approximately 50 milligrams of cobalt per 100 pounds body weight for many weeks without definite harmful effects. On the contrary, Ely, et al. (1948) reported cobalt fed in excess of 40 milligrams daily per 100 pounds body weight produced toxic effects in dairy calves.

Guilbert, *et al*. (1940) stated that the daily vitamin A requirement for cattle was 21 to 27 I. U. per kilogram of body weight, or 43 to 55 I. U. of carotene per kilogram of body weight. The National Research Council (1950) recommended a minimum of 1000 I. U. of vitamin A daily, for each 100 pounds of live weight for growth and prevention of deficiency symptoms in calves.

EXPERIMENT I

The experiment was conducted for two winter feeding periods; the procedure and results will be discussed according to the year conducted and the two year's work will be summarized together.

PROCEDURE

General Information

Forty weanling Hereford steer calves were purchased from a Gallatin Valley commercial breeder. The calves averaged 384 pounds on November 13, 1951, when individual weights were obtained for lotting purposes. At this time the calves were ear tagged and number branded. All brands were two digit numbers, the first digit representing the lot the calf would be in and the ration he would receive, the second digit representing the stall number to which he was assigned. The calves were divided into five lots on the basis of weights, each lot being fed a different ration. Individual stalls representative of those used in this trial are shown in Figure 1.

The calves were weighed on the experiment, December 10, 1951. The average weights of the lots at this time were not equal because of variations in growth rate; however, these variations were not great. The calves were weighed about every 28 days, and blood samples were taken at the same time for the determination of calcium, phosphorus, carotene, and vitamin A. The Veterinary Research Laboratory analyzed the blood samples.

The steers were fed in the college experimental steer barn. This barn was divided into five sections, each of which contained eight individual feeding stalls and a small loafing shed, adjoined by an exercise pen.

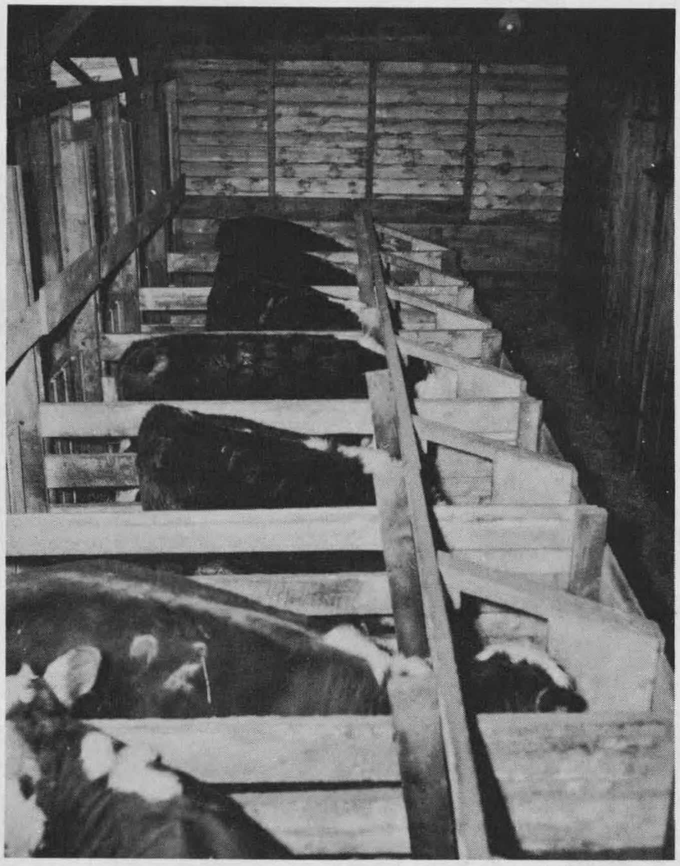

Figure 1. One lot of calves in their individual feeding stalls at the Fort Ellis farm. This is Lot 7 in Experiment 2. (1952-1953)

Each calf was fed in the same individual stall throughout the experiment. The calves were fed their concentrate and hay ration in the morning and remained in the stalls until mid-afternoon. Calves were then turned out into the exercise pens where they had access to salt, water, and shelter.

The concentrate ration and hay for each calf was individually weighed each day, and a daily record was kept of each calf's, daily intake of both concentrate and hay. All calves received the same kind of hay. The rations varied in amount of phosphorus and amounts of trace minerals. The concentrate rations were mixed by an electrically driven feed mixer to assure adequate mixing of the large and small quantities of ingredients.

The rations fed during the experiment were formulated so they would provide adequate protein and total digestible nutrients but would be low in phosphorus. Corn gluten feed was used to provide protein, and because it contained a low amount of phosphorus.

After the winter feeding trial of 162 days, the steers were put on irrigated pasture. They were observed closely to see what effect the winter feeding had on the subsequent summer gains.

Rations Fed

With the exception of phosphorus, all calves were fed a basal ration which supplied all the necessary nutrients in the proper amounts to provide for one pound per day gain. The National Research Council's recommended nutrient allowances for calves are shown in Table I, and these recommended nutrient allowances were used in computing rations for the calves.

All feeds that were used to make up the rations were chemically analyzed for protein, calcium, and phosphorus. Digestibility estimates

TABLE I. RECOMMENDED DAILY ALLOWANCES FOR WINTERING CALVES 1/

Body wt.	Expected daily gain	Feed per animal	Digestible protein	Digestible nutrients	Calcium	Phosphorus	Carotene
lbs.	lbs.	lbs.	lbs.	lbs.	gms.	gms.	mgs.
400	1.0	11	0.7	6.0	16	12	24
500	1.0	13	0.8	7.0	16	12	30
600	1.0	15	0.8	8.0	16	12	36

1/ Recommended Nutrient Allowances for Beef Cattle, National Research Council Bulletin No. 4. 1950.

were arrived at by comparing similar feeds and by using analyses of feeds shown in Morrison's "Feeds and Feeding" (1948). The chemical analyses of the feeds and minerals used are shown in Table II. It is interesting to note that the percent digestible protein and phosphorus content of the grass hay used was very low, indicating that the hay was of low quality. The locally grown hay was used in the experiment because of its low phosphorus content. The urea used was considered one hundred percent digestible, although this digestibility is too high for all conditions under which it may be used. Harris, et al. (1943) reported a digestion coefficient of 74 for urea when fed to six to eight month old calves; however, they fed it at the rate of six percent of the grain ration which, according to McNaught and Smith (1947), is probably more nitrogen intake than can be used for synthesis by the bacteria, the excess nitrogen being wasted. The consequence would be a low digestion coefficient. In this experiment, urea was incorporated at the rate of approximately 2 percent of the concentrate ration, 0.68 percent of the total ration, and 31.25 percent of the total protein in the concentrate ration. It is believed that urea was fed at low enough amounts in these rations to insure a high percent digestibility.

The amounts of the different feed constituents used to make up the different concentrate rations are shown in Table III. Approximately seventy percent of the concentrate ration for all lots was beet pulp. This is a high percentage of beet pulp and may have had a tendency to decrease the palatability of the ration although palatability was not a problem. The reason for the use of large amounts of beet pulp was to decrease the

TABLE II. CHEMICAL ANALYSES OF FEEDS USED IN FORMULATING RATIONS FOR EXPERIMENT 1. (AIR-DRY BASIS) (1951-1952)

Feed	Protein	Calcium	Phosphorus	Cobalt	Copper	Manganese
	%	%	%	%	%	%
Hay	7.7	0.52	0.09	----	----	----
Dried molasses beet pulp	8.7	0.62	0.07	----	----	----
Corn gluten feed	23.3	0.48	0.42	----	----	----
Urea 1/	262.0	----	----	----	----	----
Monosodium phosphate	----	----	19.12	----	----	----
Cobalt carbonate	----	----	----	45.0	----	----
Copper sulphate	----	----	----	----	25.0	----
Manganese sulphate	----	----	----	----	----	24.0

1/ Acknowledgement is made to E.I. DuPont De Nemours and Co. for suppling the "Two-Sixty-Two" Feed Compound.

TABLE III. CONCENTRATE RATIONS FED IN EXPERIMENT 1. (1951-1952)

Ration No.	1	2	3	4	5
Treatments	Adequate Phosphorus Added Trace Minerals	Low Phosphorus Added Trace Minerals	Adequate Phosphorus Excess Trace Minerals	High Phosphorus Added Trace Minerals	Adequate Phosphorus No Trace Minerals
	%	%	%	%	%
Dried molasses beet pulp	72.37	73.40	72.37	69.91	72.37
Corn gluten feed	24.16	24.50	24.16	23.33	24.16
Urea	2.07	2.10	2.07	2.00	2.07
Monosodium phosphate	1.40	----	1.40	4.76	1.40
Trace Minerals			(mg./lb. of ration)		
Cobalt carbonate	0.53	0.54	2.66	0.51	----
Copper sulphate	19.72	20.00	98.60	19.05	----
Manganese sulphate	102.71	104.17	513.53	99.20	----

phosphorus content of the rations. The crude protein content of all the rations was approximately seventeen percent. The calcium content of all rations was the same.

The rations were mixed in 1000-pound mixtures, the monosodium phosphate and trace minerals being added to the 1000 pounds. In rations 1, 3, and 5, 14.25 pounds of monosodium phosphate were added to a 1000-pound mixture; in ration 4, fifty pounds were added; and in ration 2, none was added. Because of the addition of these different amounts of monosodium phosphate, the percent composition of the rations were changed; however, this change was slight and is shown in Table III.

Cobalt carbonate, copper sulphate, and manganese sulphate were added to rations 1, 2, and 4 in sufficient amounts to supply each steer a daily intake of 1 milligram cobalt, 20 milligrams copper and 100 milligrams manganese. These minerals were added to ration 3 to supply a daily intake of 5 milligrams cobalt, 100 milligrams copper, and 500 milligrams manganese. No trace minerals were added to ration 5. There were no chemical analyses of the ration constituents for the trace minerals, so the total daily intake of these trace minerals is not known.

The rations were formulated so that the National Research Council's recommended nutrient allowances would be met if the steers ate 4 pounds of concentrate and 8.5 pounds of hay per day. The chemical composition of rations fed is shown in Table IV. The deficient, adequate, and excess phosphorus percentages of the various rations are shown in the table.

TABLE IV. CALCULATED CHEMICAL COMPOSITION OF TOTAL RATIONS FED IN EXPERIMENT 1. (1951-1952)

Ration No.	1	2	3	4	5
	%	%	%	%	%
Crude protein	10.83	10.91	10.83	10.64	10.83
Calcium	0.54	0.54	0.54	0.53	0.54
Phosphorus	0.20	0.11	0.20	0.40	0.20

RESULTS AND DISCUSSION

Feed Consumption

Based on the daily intake of 4 pounds of concentrate and 8.5 pounds of hay, the daily intake in terms of pounds, grams, and milligrams of the important nutrients has been calculated and is shown in Table V. All of the daily intakes are in accordance with the requirements listed in Table I, except for phosphorus. Rations 1, 3, and 5 contained an adequate amount of phosphorus; ration 2 contained a deficient amount of phosphorus; and ration 4 contained an excess amount of phosphorus.

Throughout the experiment, the calves did not average as high an intake of feed as was expected. The average intake of feed was 3.7 pounds of concentrate and 6.9 pounds of hay. Because of this lower daily feed intake, the daily intake of all nutrients was not as high as was anticipated. The actual daily intakes are shown in Table V. The following are some factors which may have caused the calves to eat less than was expected: the calves were allowed to eat only six or seven hours a day in small

TABLE V. AVERAGE DAILY NUTRIENT INTAKE PER CALF FOR RATIONS FED IN EXPERIMENT 1. (1951-1952)

Ration No.	1	2	3	4	5
Protein (lbs.)	1.19	1.20	1.22	1.19	1.19
Calcium (gms.)	25.44	25.51	25.44	25.42	25.42
Phosphorus (gms.)	9.68	5.34	9.69	19.82	9.67
Cobalt (mgs.)	0.89	0.91	4.48	0.86	----
Copper (mgs.)	18.39	18.70	92.19	17.76	----
Manganese (mgs.)	91.95	93.50	460.94	88.80	----

stalls; the calves were slow to start on feed because they were being trained to the stalls at the same time they were being started on the experiment. Palatability of the rations may have been a factor at the start of the experiment.

On the average, all steers ate very well after they had become accustomed to their own stalls and the rations. After the calves had been on the experiment about three weeks, they started consuming four pounds per day of the concentrate ration; they were fed this amount the remainder of the experiment. All calves in all lots ate their rations readily. The calves started eating five to six pounds of hay per day, and in about four weeks time, they were consuming between seven and eight pounds per day; and, after six weeks, they were consuming eight pounds per day. The calves were fed this amount during the remainder of the experiment as it seemed this amount was the maximum they would consume. The calves were not eating their allotted portions during the first four weeks, and low intake of feed partially accounts for the low gains that were made during that period. This low consumption the first period lowered the overall average daily intakes of hay and concentrate, thus making it appear as though the calves did not eat as much total ration during the experiment as they should have. During the last eighteen weeks, the calves were eating four pounds of concentrate and eight pounds of hay, which was the amount calculated as necessary to meet their daily requirements. The calves did not eat an adequate amount the first four or five weeks, but did the last eighteen weeks. The gains, as previously mentioned, corresponded to these feed intakes. Salt was fed free choice at all times throughout the experiment.

The feed consumed per one hundred pounds of gain for the different rations was very closely associated with weight gains. The feed efficiency and gains are shown in Table VI. The high gaining lot (1) had the highest feed efficiency for both concentrate and hay. As the gains decreased for the other lots, the feed efficiency for both concentrate and hay decreased.

The cost of the gains is shown in Table VI. The most economical gains were made by steers in lot 1. The least economical gains were made by steers in lot 4. The excess amount of phosphorus added to this ration did not increase the gains of the steers but added greatly to the cost of the ration. The second least economical was ration 5. This ration cost the same as ration 1 but the gains made by steers were less, therefore resulting in a higher cost per pound of gain.

TABLE VI. PERFORMANCE AND COST OF GAINS FOR CALVES IN EXPERIMENT 1. (1951-1952)

Ration No.	1	2	3	4	5
No. of Calves	8	8	8	8	8
Average Weight (lbs.)					
Initial	393.6	406.5	407.4	401.0	396.0
Final	554.2	542.0	559.0	541.8	531.8
Gain	160.6	135.5	151.6	140.8	135.8
Daily gain	0.99	0.84	0.94	0.87	0.84
Average Daily Feed (lbs.)					
Concentrate	3.73	3.74	3.74	3.73	3.73
Hay	6.93	6.96	6.93	6.92	6.92
Feed/cwt. Gain					
Concentrate	376.00	446.90	400.10	428.80	444.70
Hay	698.90	831.80	740.40	796.20	826.10
Feed Cost/cwt. 1/					
Concentrate	3.00	2.83	3.01	3.39	3.00
Hay	1.00	1.00	1.00	1.00	1.00
Cost/cwt. Gain					
Concentrate	11.28	12.65	12.04	14.54	13.34
Hay	6.99	8.32	7.40	7.96	8.26
Total	18.27	20.97	19.44	22.50	21.60

1/ Cost of feed ingredients are shown in Table VII.

Rate of Gain

As previously mentioned, the calves were fed to gain approximately one pound per day; however, all the daily gains were lower than one pound, probably due to a lack of feed consumption. The range of daily gains was from 0.84 to 0.99 of a pound. If the calves had been accustomed to their stalls prior to the starting of the experiment, it is believed that all lots would have averaged one pound per day gain, or better, during the experiment. The average daily gain for the 28-day period prior to the start of the experiment was from 0.33 of a pound for those to be fed ration 1 to 0.82 of a pound for those to be fed ration 3. The average daily gain or loss for the first 28-day period of the experiment ranged from a loss of 0.1 of a pound for lot 3 to a gain of 0.2 of a pound for lot 1. Most calves lost weight during the first week or two because they were afraid of

TABLE VII. PRICE OF FEEDS USED IN EXPERIMENT 1. (1951-1952)

Feed	Price/cwt.
Hay	1.00
Dried molasses beet pulp	2.23
Corn gluten feed	4.65
Urea (262)	8.50
Monosodium phosphate	14.92
Cobalt carbonate	198.00
Copper sulphate	14.00
Manganese sulphate	11.00

the stalls and did not eat well. This one factor held the average gains below one pound per day. The fourth period, March 11th to April 8th, seemed to be the period of most rapid gains. All lots averaged more than one pound a day gain; lot 5 had the least gain during this period but had greater gains than any of the other lots during the fifth period, April 8th to May 6th. There was little difference in the average daily gains of all lots for the 162-day experiment.

Weight gains of the various lots are shown in Table VI. Statistical analysis revealed no significant differences in the gains of the five lots; however, there were definite trends. It is believed a more precise experimental design would have revealed statistically significant results as is indicated by Experiment 2. Statistical analyses are shown in Table IX. There seemed to be a tendency for increased gains when the urea ration was supplemented with trace minerals when the phosphorus content of the ration was adequate. This trend is shown by the fact that the steers fed rations 1, 3, and 4 had average daily gains of 0.99, 0.94, and 0.87 of a pound respectively, while steers fed rations 2 and 5 had average daily gains of 0.84 of a pound. Ration 2 was deficient in phosphorus and ration 5 was not supplemented with trace minerals. It is believed that the lower gains of steers fed ration 2 were due to the phosphorus-deficient ration fed, although no real phosphorus deficiency symptoms appeared in the lot 2 steers. According to Welch (1940), bone chewing, board and corral pole chewing are first indications of phosphorus deficiency. The steers in lot 2 did not seem to crave bones or sticks to chew; therefore, it was assumed that these steers were not suffering from a phosphorus deficiency.

Plasma-Calcium and Phosphorus

Blood samples were collected from all steers at the beginning of the experiment, approximately every 28 days, and when the steers were weighed off the experiment. Each sample was analyzed for phosphorus and calcium, except samples collected when the steers were weighed off the experiment. The blood samples were not analyzed for phosphorus and calcium at this time because the previous samples had been collected only two weeks before and it was felt that little change would have taken place in the blood mineral constituents.

The plasma-phosphorus varied directly with the phosphorus intake, which is in agreement with results published by Knox, et al. (1941) and Greaves, et al. (1934). There were highly significant differences in the plasma-phosphorus levels of the steers fed the high or adequate or low-phosphorus rations. There were also significant differences in the plasma-phosphorus levels of the three lots of steers that were receiving adequate-phosphorus rations. This difference cannot be explained by the author. The only difference in the rations fed was the trace mineral content. No trend in plasma-phosphorus was found. The plasma-phosphorus level of the steers receiving the high trace mineral ration was between the level of those receiving no trace minerals and those receiving moderate amounts. The plasma-phosphorus and calcium levels at sampling dates are shown in Table VIII.

As the plasma-phosphorus levels increased or decreased, the plasma-calcium levels had the reverse trend; this negative relationship became more pronounced as the experiment advanced. These differences in plasma-calcium levels among the steers fed the high, adequate, and low-phosphorus rations were highly significant. There were significant differences in the plasma-calcium levels of the steers fed the three adequately supplemented phosphorus rations just as there was with the plasma-phosphorus levels of those steers. These findings are in agreement with Greaves, et al. (1934) who observed a low-negative correlation between the inorganic calcium and inorganic phosphorus in the blood of beef steers. Lewis (1950) reported no correlation. These findings bring up the point of the calcium-phosphorus ratio, which under most conditions can have a wide range. The observations of this experiment tend to show that if the phosphorus intake is controlled at optimum or above optimum levels, the plasma-calcium will vary accordingly and will establish a desirable ratio in the blood. The effect on the mineral content in the bone and muscle is unknown. The plasma-calcium and plasm-phosphorus relationships are shown in Figure 2. The statistical analyses of plasma-phosphorus and plasma-calcium values are shown in Table IX.

Plasma-Vitamin A and Carotene

Only three vitamin A and carotene blood level determinations were made. These were at the beginning, on the March 11th weigh day, and the end of the experiment. The determinations were made to see if there would be any interactions or effects due to the rations fed. There were no statistical analyses conducted on the carotene and vitamin A blood levels; however, trends were observed. The phosphorus-deficient steers had the highest plasma-carotene levels, which is in agreement with work reported by Thomas, et al. (1953). In the first half of the experiment, the carotene