Production of Hereford cows individually fed on winter supplements varying in percent protein and phosphorus

by Gary A Wilcock

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
Montana State University

Abstract:
The experiment was conducted to measure the effect of winter-feeding cows four protein levels with, and without, additional phosphorus on the productive ability of cows grazing foothills range. Criteria used to measure this effect were cow weights, calving dates, birth weights, weaning weights, average daily gain of calves from birth to weaning, and calf score.

The experiment extended through three years. Fifty-six, grade Hereford cows were purchased in 1957 and divided into eight lots of seven on the basis of age, breeding and weight. In 1958, cows were added to each lot making a total of nine of ten per lot. Cows were added to the experiment in 1959, making a total of ten or eleven head per lot. Cows remained in the lots they were assigned. All cows were grazed together and rounded up every-other-day and fed two pounds of a supplement containing twenty, thirty or forty percent protein with and without 4.6 grams of additional phosphorus per pound of supplement, lot 1 (control) received no supplement and lot 1P received one pound of a thirteen percent protein supplement containing fourteen grams of additional phosphorus. Supplements containing additional phosphorus supplied about one-half the daily requirement for the element.

The supplemental feeding periods were 147, 137, and 158 days for the three respective years 1957-58, 1958-59 and 1959-60.

Cows receiving higher protein levels lost less weight than cows receiving lower levels. Cows receiving higher protein levels tended to calve earlier. Phosphorus supplementation did not seem to affect calving date, but cows receiving additional phosphorus had more live calves than those receiving no additional phosphorus. Birth weights between lots receiving different levels of protein were significantly different ($P<.01$). Cows receiving protein plus phosphorus had significantly heavier calves at birth ($P< .01$). Cows receiving additional phosphorus weaned significantly heavier calves than cows receiving no additional phosphorus ($P<.01$). Treatments did not seem to affect calf scores. Cows receiving additional phosphorus had higher inorganic plasma phosphorus levels during the winter 1959-60. There was no significant difference in the plasma inorganic phosphorus levels during the winter 1957-58. Blood data were not available for the year 1958-59.

Three of the four lots of cows receiving protein supplement plus phosphorus returned an estimated profit above feed cost, whereas cows receiving protein supplement without additional phosphorus did not return an estimated profit above feed costs.

PRODUCTION OF HEREFORD COWS INDIVIDUALLY FED ON WINTER SUPPLEMENTS VARYING IN PERCENT PROTEIN AND PHOSPHORUS

by

Gary A. Wilcock

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 S. Willson
Head, Major Department

Oscar O. Thomas
Chairman, Examining Committee

Leon Johnson
Dean, Graduate Division

Bozeman, Montana
May, 1961

ACKNOWLEDGEMENTS

The author expresses appreciation to Dr. O. O. Thomas for designing the experiment and collecting part of the experimental data. His suggestions in the preparation of the manuscript and direction of my graduate program are also appreciated. Appreciation is expressed to Dr. D. W. Blackmore for his assistance in the statistical analyses and for his advice and suggestions in preparation of the manuscript. Appreciation is also expressed to Mr. Harold Watling for his suggestions and aid in editing the manuscript.

I express appreciation to my family for their help and sacrifices made throughout the period of graduate work and for the assistance of my wife, Madelyn, who spent many hours aiding in the preparation and typing of the manuscript.

Jim Williams, foreman of the Red Bluff Research Ranch, and other ranch employees were especially helpful in caring for the experimental animals and collecting data; to these men I express thanks.

TABLE OF CONTENTS

Page

INDEX TO THE TABLES

INDEX TO THE FIGURES

INDEX TO THE APPENDIX

ABSTRACT

The experiment was conducted to measure the effect of winter-feeding cows four protein levels with, and without, additional phosphorus on the productive ability of cows grazing foothills range. Criteria used to measure this effect were cow weights, calving dates, birth weights, weaning weights, average daily gain of calves from birth to weaning, and calf score.

The experiment extended through three years. Fifty-six, grade Hereford cows were purchased in 1957 and divided into eight lots of seven, on the basis of age, breeding and weight. In 1958, cows were added to each lot making a total of nine or ten per lot. Cows were added to the experiment in 1959, making a total of ten or eleven head per lot. Cows remained in the lots they were assigned. All cows were grazed together and rounded up every-other-day and fed two pounds of a supplement containing twenty, thirty or forty percent protein with and without 4.6 grams of additional phosphorus per pound of supplement. Lot 1 (control) received no supplement and lot 1P received one pound of a thirteen percent protein supplement containing fourteen grams of additional phosphorus. Supplements containing additional phosphorus supplied about one-half the daily requirement for the element. The supplemental feeding periods were 147, 137, and 158 days for the three respective years 1957-58, 1958-59 and 1959-60.

Cows receiving higher protein levels lost less weight than cows receiving lower levels. Cows receiving higher protein levels tended to calve earlier. Phosphorus supplementation did not seem to affect calving date, but cows receiving additional phosphorus had more live calves than those receiving no additional phosphorus. Birth weights between lots receiving different levels of protein were significantly different ($P < .01$). Cows receiving protein plus phosphorus had significantly heavier calves at birth ($P < .01$). Cows receiving additional phosphorus weaned significantly heavier calves than cows receiving no additional phosphorus ($P < .01$). Treatments did not seem to affect calf scores. Cows receiving additional phosphorus had higher inorganic plasma phosphorus levels during the winter 1959-60. There was no significant difference in the plasma inorganic phosphorus levels during the winter 1957-58. Blood data were not available for the year 1958-59.

Three of the four lots of cows receiving protein supplement plus phosphorus returned an estimated profit above feed cost, whereas cows receiving protein supplement without additional phosphorus did not return an estimated profit above feed costs.

INTRODUCTION

Rangeland makes up about two-thirds of the total area of Montana. This rangeland is presently being utilized by a well-developed cattle and sheep industry. Range forage is extremely important to cattle in many areas of the state because the supply of domestic forage is limited and in many cases can only be supplied at a high cost. There is a problem of supplying cattle with winter forage that is adequate in essential nutrients and energy, particularly in areas of the state where domestic forages are scarce. Much of the Montana plains and foothills area supplies year-round grazing because the winters are relatively open; however, the winter forage is often deficient in some essential nutrients, particularly protein and phosphorus.

The importance of proper nutrition to the productiveness of cattle has been highly emphasized and the answers to some of the questions regarding nutrition of cattle are being sought. At the present time, only a moderate amount of experimental data are available on nutritive requirements of range cattle, and the effect of supplementing range forage with feeds supplying the deficient nutrients. Much of the data that are available for range conditions have been collected in southern and western states where climate and conditions are different from that of Montana.

Limited studies, concerned with wintering range cattle, have been conducted in the plains region of eastern Montana but this is not representative of the foothills regions. Experimental work with range cattle has, until recently, been done in confined pastures in which it was necessary to rotate the livestock among pastures to simulate free grazing.

The effects of supplementing range forage under Montana winter conditions have been studied to a limited degree. These studies have not been extensive enough to provide the answers to questions of economic and managerial importance. Questions related to the effect of winter supplements fed cows grazing plains and foothills regions seem to be of immediate importance.

The experiment described in this thesis was initiated to study the effect of feeding supplements varying in protein content with or without additional phosphorus upon the productive ability of cows grazing Montana foothills range during the winter months.

The criteria for measuring these effects were cow weights, calving dates, birth weights, weaning weights, average daily gain of calves, and calf score.

Inorganic blood plasma phosphorus, plasma carotene and plasma vitamin A levels were determined periodically to compare the effect of the treatments on these blood constituents.

LITERATURE REVIEW

PHYSIOLOGICAL FUNCTIONS AND REQUIREMENTS OF PHOSPHORUS

Phosphorus is considered to be the most important mineral for livestock, excluding salt. Although many minerals are required for normal body functions, none have such an extensive and important role in so many functions as phosphorus.

General functions

According to Greaves, et al. (1934), phosphorus is present in every cell and fluid of the body. It has a vital function in carbohydrate, fat and some phases of protein metabolism. It is essential in muscular contractions and in the functioning of the central nervous system. It enters into the buffering powers of the blood and together with calcium, plays a fundamental role in bone formation.

Barmore and Luck (1931) stated that phosphate functions as a catalyzing agent for biological oxidation, the degree of catalysis being proportional to the phosphate concentration. Mitchell (1947) listed phosphorus as an important mineral constituent of enzyme systems. He further emphasized the hand-in-hand relationship between phosphorylation and oxidation and the ability of these functions to provide and distribute energy to body tissue in an efficient manner. Phosphorus would be a limiting factor if not present in adequate amounts. Rittenberg and Sheman (1946) suggested that the synthesis of body protein involving the linking of amino acids from protein digestion, occurs only after phosphorylation. Confirmation of this suggestion is found in the experiments of Morris and Ray (1939). Feeding trials with sheep indicated a depression in the value of protein fed sheep deficient in phosphorus. This depression in protein value did not appear with sheep fed adequate phosphorus rations.

The necessity of vitamin D for optimum calcium and phosphorus utilization has been known for some time. The importance of vitamin D in this role has been emphasized by Palmer _et al_. (1935), Auchinachie and Emslie (1933), Watkins and Knox (1948), Maynard and Loosli (1956), and Taylor and Hubbert (1960). These workers have all stated that vitamin D must be adequately available for a minimum amount of calcium and phosphorus to be utilized to a maximum degree in their normal functions.

Some workers have demonstrated an inverse relationship between blood levels of phosphorus and carotene. (Ross and Gallup, 1949; Thomas, 1951; and Thomas _et al_., 1953). These data indicate that phosphorus may be responsible in part for conversion of carotene to vitamin A. This same inverse relationship was shown to occur in the milk of cows.

<u>Phosphorus requirements</u>

Phosphorus requirements for animals are not well known because of the complexities resulting from studies of different species, complications of pregnancy, lactation, growth and environmental conditions. The recommended levels of phosphorus found in feeding tables and accepted publications seem to be reliable but these levels are not entirely consistent. Some of the experimental work that has been done to determine phosphorus requirements and the conditions involved in the determinations follow. Nelson _et al_. (1955) conducted experiments with heifers and cows under range conditions in north-central Oklahoma. The results of this experiment indicated the minimum daily requirements for growth, reproduction, and lactation were met by a total daily intake of seven grams of phosphorus per head in the winter, an estimated nine grams in early summer and six grams during late summer. They stated that these requirements were met during the winter by sixteen to twenty pounds of average quality prairie hay and 1.25 pounds of a protein supplement. Native grass containing 0.1 to 0.15 percent phosphorus met the requirements during the summer.

Tillman et al. (1959) fed Hereford steers three different levels of phosphorus (a 0.12 percent basal diet plus 1.5, 2.0, or 2.5 grams of phosphorus per one-hundred pounds body weight, daily) and concluded that the highest level was sufficient to satisfy the requirement for bone growth and inorganic blood plasma phosphorus but not for maximum weight gain. They stated that the requirement for weight gain exceeds that for bone growth and maintenance of normal plasma inorganic phosphorus levels. These results are in agreement with those of Burroughs et al. (1956). The experiment described above was similar to that conducted by Beeson et al. (1941); however, the results obtained by Beeson et al. indicated 0.18 percent ration phosphorus was adequate. This level was somewhat less than the high level (0.12 percent basal ration phosphorus plus 2.5 grams per one-hundred pounds body weight) fed by Tillman et al. The latter researchers stated that a possible explanation for the difference in requirements between the two experiments was the intake of five mg. per head per day of diethylstilbestrol for the steers fed by Beeson et al. Steers fed by Tillman et al. were not given stilbestrol and in addition these cattle were individually fed. These authors reported that feed consumption in all animals of their experiment was inconsistent or cyclic. The cycles or inconsistent consumption appeared to be related to the phosphorus content of the ration. This apparent cyclic effect lends support to a theory proposed by Mitchell (1947) and Anderson et al. (1956). These workers stated that since phosphorus is so largely concerned in the utilization of the main organic nutrients and in the microbial digestion of cellulose, it is logical to assume that cattle requirements for this element should parallel the amounts of organic nutrients consumed.

Haag (1951) reported that a ration is not likely to be seriously deficient in calcium and phosphorus unless its dry matter contains less than 0.3 to 0.4 percent calcium and 0.2 to 0.3 percent phosphorus. Even lower levels are adequate in the absence of rapid growth and high milk production according to Haag. The phosphorus levels quoted here are considerably higher than the levels considered to be minimum by other workers. (Colovas, 1952 and 1953; and Dowe et al., 1957). The levels considered minimum by Haag apparently have an ample safety margin while the minimum levels listed by other workers may not include this margin of safety.

A study of phosphorus requirements of growing dairy cattle was conducted by Huffman et al. (1933). Two levels of phosphorus (0.20 percent and 0.41 percent of the dry ration) were fed. The low level feeding resulted in an immediate lowering of the inorganic blood phosphorus of heifers and influenced this factor up to eighteen months of age. Growth, as measured by height at withers, did not differ between calves on the two rations but daily gain was considerably greater for the calves fed the higher phosphorus level. Huffman et al. concluded that the phosphorus requirement for growth is not directly proportional to body weight but probably depends on rate of growth. The work of Burroughs et al. (1956) and Tillman et al. (1959) support this conclusion. In addition, a conclusion of these two groups was that the phosphorus requirement of cattle can be expressed better as a percentage of dry feed consumed, than in grams per one-hundred pounds body weight. Since all three experiments (Huffman et al., 1933; Burroughs et al., 1956; and Tillman et al., 1959) indicate the requirement for growth is not directly proportional to body weight, it appears that the expression of phosphorus requirement as percent of dry feed consumed has considerable experimental support.

Balance studies with lambs by Gallup et al. (1950) indicated phosphorus balances were negative when rations supplied 1.4 to 1.7 grams of phosphorus daily, per one-hundred pounds of body weight. Equally positive and negative values resulted with lambs supplied 1.9 to 2.1 grams of phosphorus per one-hundred pounds of body weight and completely positive balances occurred with lambs supplied 2.4 to 2.9 grams of phosphorus daily, per one-hundred pounds body weight.

The work of Burroughs et al. (1956), in addition to that already discussed, indicated that the phosphorus necessary for proper rumen function in feed lot steers is higher than 0.18 percent of the dry ration and appears to be about 0.20 percent. The National Research Council (1958) suggests that for high rates of liveweight gain a minimum of 0.20 percent phosphorus in fattening rations and 0.15 percent phosphorus in other rations be fed. These are minimum requirements and allow no margin of safety according to the N. R. C. bulletin. The reports of Colovas (1952, 1953) and Dowe et al. (1957) suggests these levels (0.20 percent for fattening and 0.15 percent phosphorus in other rations) are minimum.

According to Otto (1938), Wellman (1932) stated that about 3.6 grams of calcium and 2.0 grams of phosphorus are required for daily maintenance of one-hundred kilograms of body weight and that 2.5 grams of phosphorus are required per one-hundred kilograms of gain in weight.

Theiler and Green (1932) suggested the ratio between "phosphorus content" and "energy value" of forage is a getter guide for evaluating pastures than is the expression "percentage phosphorus of the dry matter". The intake of grass, and hence the absolute intake of phosphorus is determined mainly by the energy requirements of the animal so that a poor pasture of low phosphorus content may actually supply as much phosphorus as a rich pasture of medium phosphorus content, according to these authors.

EFFECTS OF PHOSPHORUS ON GROWTH AND REPRODUCTION

The apparent function of phosphorus in food utilization and reproductive efficiency, was noted by Eckles and Gullickson (1927) and Kleiber _et al_. (1936). The former workers found that dairy heifers receiving adequate amounts of phosphorus utilized their feed more efficiently than heifers fed rations known to be deficient in phosphorus. These authors also noted that cows receiving adequate phosphorus came into estrus more regularly and conceived with fewer services than cows fed phosphorus deficient rations. Kleiber _et al_. (1936) made similar observations.

Eckles _et al_. (1935) conducted an experiment intended to measure the effects of uncomplicated phosphorus deficiency on estrus cycle and reproduction of dairy cows. Two rations were fed; one was considered adequate, the other considered deficient. Cows on the deficient ration did not develop symptoms of serious deficiency, but blood and bone analyses indicated the animals were deficient. This type of ration did not alter the estrus cycle of the cows; however, the cows on the deficient ration appeared to have poorer breeding efficiency as measured by reduced fertility, but not due to failure to come into estrus. These researchers stated that the animals' resistance to disease was significantly lowered by the deficiency of phosphorus. This lowered resistance could have been a contributing factor in the lowered breeding efficiency of the phosphorus deficient cows.

Watkins and Knox (1948) reported the results of an experiment in which cows receiving a seasonal calcium and phosphorus supplement were compared with cows that received a continuous calcium and phosphorus supplement under year-round grazing conditions. The cows receiving continuous supplement in the form of calcium-phosphorus-salt mixture were heavier, had only a slightly higher level of inorganic blood phosphorus and weaned more and heavier calves than the cows given the same supplement seasonally. These workers further expressed doubt that additional phosphorus to the continuously fed group would have increased production on the level of nutrition studied. They explained the possibility of a higher requirement at a higher level of nutrition, however. Although the inorganic phosphorus level of the blood from the continuously supplemented group was only 0.32 mg. higher than that of the seasonally supplemented group, Watkins and Knox stated it might represent an increment over the minimum which may have contributed to the higher percentage of calf crop.

An earlier report (Knox and Watkins, 1942) gave similar results. In the experiment covered by this report, the addition of salt mineral mixtures containing 6.5 percent phosphorus to rations fed cattle on winter range resulted in smaller death loss in new-born calves, larger number of calves weaned, and greater weight of calves at weaning. Yearling and two-year old cattle receiving the supplement made greater weight gains than the controls of the same age.

Eckles et al. (1933) reported that a phosphorus supplement given to young cattle suffering from a lack of this element produced a stimulation of the appetite with a corresponding increase in feed efficiency and increased weight gain. These workers also stated that lactating dairy cows fed ample amounts of nutrients except phosphorus, have a relatively short milking period and consequently a low total production. The same cows, fed sufficient phosphorus, produced more milk in a more extended lactation period resulting in reduced cost per unit of milk produced. According to these workers, growing heifers, either dry or in milk production, made more economical gains in live weight, when receiving adequate amounts of phosphorus, than animals consuming rations deficient in this element but containing the same amount of total digestible nutrients.

Becker et al. (1927) reported phosphorus deficient cows produced considerably less milk than cows receiving adequate phosphorus. The milk did not differ in composition between phosphorus deficient cows and those receiving adequate phosphorus. The deficient cows in this experiment were exhibiting symptoms of severe phosphorus deficiency including anorexia, stiff joints and muscular weakness.

Investigation of seasonal calcium and phosphorus requirements of range cattle in New Mexico by Knox et al. (1941) indicated that except for a short period during the height of the growing season, the phosphorus consumed in range forage in this area was usually not sufficient to nourish breeding cows properly.

THE CALCIUM-PHOSPHORUS RATIO

Maynard and Loosli (1956) state, "while the desirable calcium-phosphorus ratio has been defined as one lying between 2:1 and 1:2, adequate nutrition is possible outside these limits". The work of Theiler _et al_. (1927) bears this out in part. Experimental data collected by these workers indicate that the minimum requirements for growth of cattle are higher in the case of phosphorus than calcium and a ratio of P_2O_5 to CaO as high as three to one is not necessarily disadvantageous.

The growth and development of dairy animals were studied by Henderson and Weakley (1930). They fed one ration that was nutritionally adequate in everything except calcium, one ration that was adequate in all nutrients except phosphorus, one ration that was adequate except for calcium and phosphorus, and one ration that was believed to be completely adequate for normal growth. The animals on the deficient rations grew almost as well as those on the adequate rations; however, animals fed low phosphorus and sufficient calcium were observed to have much lower inorganic phosphorus levels in their blood than those fed adequately.

Fairbanks (1939) proposed in a critical review of the calcium-phosphorus ratio that factors other than the ratio of the two elements _per se_ must be considered. He stated that the presence of calcium and phosphorus in a ration does not assure availability of either even though the ratio of the elements might be optimum. The variable availability of these elements, as they exist in feed, does not add to the accuracy of the calcium-phosphorus ratio.

Lewis (1950) studied the calcium-phosphorus ratio using beef steers as experimental animals. Maximum gain on a wintering ration was observed when the ration contained 0.47 percent calcium, 0.20 percent phosphorus and a calcium-phosphorus ratio of 2.27:1. In this study where the calcium-phosphorus ratio was near the recommended range (2:1 or 1:2), the rate of gain was almost proportional to the level of phosphorus fed.

In 1952, Thomas fed five lots of beef steers rations containing 0.20 percent phosphorus and varying levels of trace minerals. In this experiment, varying the amount of trace minerals was found to have an effect on rate of gain. This indicates there is a possible balance among several of the minerals that must be considered for optimal nutritional allowances.

Observations of steers fed wintering rations by Dowe _et al_. (1957) indicate when phosphorus was adequate, a high ratio of calcium to phosphorus resulted in lower gains. Lower gains did not appear to be due to an interference with absorption of phosphorus but with the digestion and/or absorption of other nutrients when excess calcium was present. This agrees with the work of Colovas (1952, 1953). Taylor and Hubbert (1960) state that phosphorus and calcium should be given simultaneous consideration since an excess of calcium will interfere with absorption of phosphorus.

Blum (1931), Holmes and Pigott (1931), and Hartman and Meigs (1931), showed that the calcium to phosphorus ratio of the bones of animals can be altered by varying the mineral content of the ration. Yeager and Winters (1935) concluded there is some indication that the calcium to phosphorus ratio in the bones depends to some extent on the amounts of calcium and phosphorus present in the ration.

METHODS OF SUPPLYING LIVESTOCK WITH SUPPLEMENTAL PHOSPHORUS AND SOURCES OF PHOSPHORUS USED

Experiments comparing methods of supplying phosphorus supplement have been conducted by two groups of researchers. Black et al. (1949) and Reynolds et al. (1953). In both experiments, bonemeal supplied to range cows in self-feeders, disodium phosphate dissolved in the drinking water, and range fertilized with triple super-phosphate were the methods compared. The results were similar in both trials. The range fertilization was superior to the other two methods in reducing symptoms of aphosphorosis in the cows, increasing breeding efficiency, and increasing weaning weights of the calves. The range fertilization method was the most expensive of the three. Dissolving disodium phosphate in the drinking water appeared to be slightly superior to the self-fed bonemeal method in all respects studied. All three methods improved productiveness of the cows and all three methods resulted in greater returns per cow.

Another method of supplemental feeding of phosphorus was reported by Knox and Neale (1937). Three supplements were provided ad libitum to three groups of cattle as follows: sixty percent bonemeal, forty percent salt; forty percent monocalcium phosphate, sixty percent salt; and forty percent dicalcium phosphate, sixty percent salt. The mixtures ranged from about seven to ten percent phosphorus. All three mixtures were effective in supplementing the forage with phosphorus as measured by cow weights, weaning weights of the calves and inorganic blood phosphorus levels. Knox and

Watkins (1942) stated that salt-phosphorus mixtures containing about six and one-half percent phosphorus had been used with results similar to those of Knox and Neale (1937). Increased reproductive efficiency and heavier calves at weaning as a result of phosphorus supplementation was reported by both groups.

Studies at the Kansas Agricultural Experiment Station, Anonymous (1955), with beef heifers grazing green summer pastures indicated phosphoric acid supplementation would raise the inorganic blood serum phosphorus levels of heifers higher than supplements of steamed bonemeal. The two sources were equal in terms of weight gained by heifers and both supplements produced gains greater than that of control heifers.

Long et al. (1957) individually fed a group of steers to determine the effects of three levels of phosphorus on weight gain, feed consumption and inorganic phosphorus levels of blood plasma. In addition, three sources of phosphorus were observed; all were force fed. The 0.19 percent phosphorus and 0.15 percent phosphorus rations were superior to the 0.11 percent level in terms of weight gained by the steers, feed consumption and inorganic phosphorus content of the blood plasma. No significant difference was observed between sources of phosphorus (steamed bonemeal, Curacao Island phosphate and dicalcium phosphate).

A study comparing salt-protein blocks and salt-protein loose mixtures with and without additional phosphorus from bonemeal was conducted by Smith et al. (1960). Heifers grazing mature bluestem grass pastures and receiving the salt-protein mixture plus phosphorus, did not gain significantly faster than heifers on the same type of pastures receiving the salt-protein mixture without phosphorus.

Ross et al. (1950) conducted winter grazing trials with two and three-year-old steers. Steers fed soybean cake with phosphorus gained more than steers fed soybean cake only. Steers allowed to eat mineral (bonemeal and ground limestone) free-choice, made greater winter gains than steers that were not allowed a mineral supplement. Four different groups of steers were fed mineral supplements with the protein supplement as follows: salt, ground limestone, bonemeal 1:1:1; salt and bonemeal 1:1; salt only; and salt and bonemeal 3:1. The rations of salt, ground limestone and bonemeal 1:1:1 and the salt and bonemeal 1:1 produced significantly greater gains than the rations of salt only and salt-bonemeal 3:1. The rations producing the greatest animal gains were also consumed in greater quantities.

FACTORS THAT AFFECT BLOOD CONSTITUENTS

Age

Experimental data from 122 beef cows under nutritional conditions assumed normal by Robinson et al. (1926) indicated a range of 3.00 to 8.99 mg. of inorganic phosphorus per 100 ml. of blood plasma. The average was 5.87 mg. per 100 ml. The inorganic phosphorus level of blood plasma in mature Hereford cows, reported by Haag and Jones (1935), was 5.2 mg. per 100 ml. Palmer et al. (1930) found the average inorganic blood phosphorus of a small group of calves to be 7.26 mg. per 100 ml. of plasma. Malan et al. (1928) reported beef heifers approaching two years of age showed a normal level of five mg. of inorganic phosphorus per 100 ml. of whole blood. Payne et al. (1946) reported the normal levels for blood serum inorganic phosphorus in mg. percent were 7.30, 4.76, 5.07, and 4.89 for yearling bulls, herd bulls, two-year-old heifers, and aged cows, respectively. These data were obtained from 560 animals. The phosphorus levels for bulls appeared to be somewhat greater than for cows and the quantity of blood inorganic phosphorus diminishes with age according to these data. Eveleth _et al._ (1937) reported a variation in the inorganic serum phosphorus according to age, with the higher levels occurring under six months of age and gradually descending to forty-eight months of age.

Ration

According to Robinson _et al._ (1926), inorganic phosphorus is one of the constituents of the blood in mature animals that is influenced by the amount of phosphorus in the diet. Van Landingham _et al._ (1935) support this hypothesis.

Green and Macaskill (1928) stated that the inorganic phosphorus level of the blood varies with the diet.

Malan _et al._ (1928) reported cows grazing on phosphorus deficient pasture without a phosphorus supplement had significantly lower inorganic phosphorus, as well as total phosphorus levels in the blood, than cows grazing the same pasture but receiving additional phosphorus from bonemeal.

Van Landingham _et al._ (1935) concluded from experimental work with young dairy heifers that the concentration of inorganic phosphorus in the blood is an important index of the severity of phosphorus deficiency in the ration. Feeding low phosphorus rations to dairy heifers caused a lowering of the inorganic phosphorus in the blood. The rate of lowering was roughly proportional to the severity of phosphorus deficiency in the ration; however, physical symptoms of phosphorus deficiency followed only after several weeks in which the blood phosphorus level had been decreasing.

Blood inorganic phosphorus levels of dairy cows were higher during the summer months than during winter months according to Eveleth et al. (1937). These data are supported by those of Knox and Watkins (1942). They stated that the forage contains less phosphorus during the winter months and this affects the inorganic phosphorus level of the blood.

The effect of three different levels of carotene intake, supplied by alfalfa hay, upon the carotene and vitamin A concentrations of the blood and milk of Hereford cows were studied by Van Arsdell et al. (1950). They found a positive correlation between carotene intake and plasma carotene levels. Levels of carotene and vitamin A as low as 57 and 10.9 mcg. per 100 ml. plasma respectively were recorded for short periods during this experiment without symptoms of avitaminosis occurring. No abnormalities were observed during calving and the calf crop appeared to be normal.

Differences in blood constituents due to parturition, environmental temperature, moisture, and other factors.

Long et al. (1952) observed the blood composition of three breeds of beef cattle. They found the plasma carotene level declined subsequent to parturition. Sutton and Soldner (1943) also reported this characteristic in dairy cattle. According to Long et al. this observation suggests a physiological stress due to lactation and the concentration of this constituent should be taken into consideration in evaluating the results of blood analysis in lactating cows.

Repp and Watkins (1958) made an extensive study of the blood of range cattle in New Mexico. They found that precipitation and air temperature influenced the carotene content of forage. Vitamin A levels of blood plasma of cows grazing the forage were proportional to the carotene content of the forage.

Palmer et al. (1930) reported day-to-day variation in inorganic phosphorus levels of the blood of dairy cows even when the blood was drawn under identical conditions. The inorganic blood phosphorus in individual cattle may vary considerably from hour to hour although the data of the experiment reported concerning this point are very limited. According to these researchers, exercise resulted in a marked change in the blood phosphorus level of cattle under conditions of their experiment.

FACTORS ASSOCIATED WITH DIGESTION AND METABOLISM.

Effects of phosphorus

The importance of adequate phosphorus in feed utilization is shown in part by the following reports: digestion trials with dairy cows conducted by Hughes et al. (1933) indicated that the degree of utilization of metabolizable energy of the ration is not influenced by phosphorus deficiency. Riddell et al. (1934) pursued the same problem. They concluded that a shortage of phosphorus in the ration, becomes a limiting factor in the economical utilization of feeds. They reported that phosphorus deficiency did not depress the digestive functions of the animals. Oxygen consumption was taken as an indirect measure of energy produced during metabolism. Results of these measurements indicated a higher energy metabolism for animals on the phosphorus deficient ration than the controls. Anorexia was a definite symptom of the cows on the phosphorus deficient rations; this partly explains their loss of weight. The rapid gains made by these same cows, when phosphorus supplement was added, could not be explained entirely by their improved appetities.

Work on mineral metabolism of sheep by Morris and Ray (1939) showed a phosphorus deficiency resulted in lower feed intake and a lowered state of health but only in an insignificant lower weight gain. A slight but not statistically significant decrease in the digestibility of the protein was observed in lambs on phosphorus deficient rations.

Kleiber _et al_. (1936) reported phosphorus deficient beef heifers utilized feed poorly and had a lower feed consumption and lower gains than heifers maintained on a ration adequate in phosphorus. The phosphorus deficient animals used the digested protein less efficiently for sparing body protein than the control animals.

Effects of high energy and protein feeds on digestibility of the nutrients in fibrous feeds

The literature available for this review on the effects of adding high protein and energy feeds upon the digestibility of nutrients in fibrous feeds was limiting. The work of Kolari and Hanson (1960) indicates there is some effect however. They conducted digestion trials with sheep to determine the effect of additions of corn, molasses, soybean oil meal, linseed oil meal, urea and alfalfa meal, alone or in various combinations, upon the digestibility of nutrients in flax plant product rations. The inclusion of corn in flax plant product rations exerted a significantly favorable effect upon digestibility of crude fiber and a slightly favorable effect on dry matter and nitrogen free extract. Addition of soybean oil meal to flax product rations had little effect upon ration nutrient digestibility while the addition of soybean oil meal plus corn significantly increased the digestibility of dry matter, organic matter and nitrogen free extract. Molasses had no effect on digestibility of the flax plant product. Urea affected digestibility of fiber adversely, but aided digestion of the flax plant protein. Alfalfa meal increased digestibility of most of the flax product nutrients.

LEVEL OF NUTRITION FOR RANGE CATTLE.

A range nutrition study with beef cows covering a five-year period was reported by Marsh et al. (1959). Three levels of grazing were observed by allowing different acreage per group. The stocking rates were 23.1, 30.5, 38.8 acres per cow per year. No supplemental feed was given except when deep snow covered the range or when drouth caused insufficient forage for wintering. In these conditions all cows were fed hay. Cows grazed on the light intensity (more acres per cow) were not nutritionally deficient and wintered well. The moderate intensity of grazing produced somewhat thinner cows with some stiffness and arched spines indicating a phosphorus deficiency. The heavy grazing produced considerably thinner cows than either of the other intensities with some definite nutritional deficiency symptoms. The average crude protein of the forage for the five-year-period was eight percent. The average inorganic phosphorus level of the blood for all lots was 3.7 mg. per 100 ml. plasma which was at, or near, the critical level. Lower weaning weights of calves and lower percentage calf crop in the group of cows on heavy grazing was not attributed to deficiencies of specific nutrients.

Thomas (1951) reported the results of a lifetime study on beef cows.

Observations were made of the relation of nutrition and age at first calving to lifetime performance of beef cows. One-hundred and twenty yearling heifers were wintered on low, medium or high planes of nutrition the first year and subsequent years. The heifers were bred to calve as two-year-olds or three-year-olds. Those calving as two-year-olds had more trouble calving and reached a mature weight more slowly than those calving at three years of age. Two-year-old heifers, suckling calves, weighed about 120 pounds less than dry two-year-olds wintered at the same level. Wintering at a low plane of nutrition (range grass plus 0.93 pounds of cottonseed cake per day per head) appeared to be most economical.

Pope (1960) reported results of an experiment similar to that conducted by Thomas (1951). In the report of Pope, there were four levels of winter feeding. (Low level-fed to gain no weight the first winter and lose twenty percent or more of fall weight each subsequent winter, medium level-fed to gain one pound per day the first winter and lose ten percent or more of the fall weight each subsequent winter, high level-fed to gain one pound per day the first winter and lose no weight each subsequent winter, very high level-fed to gain maximum amount the first and each subsequent winter.) The results of the first calf crop only were reported for the group wintered at the very high level. The low level wintering adversely affected the percent calf crop and weaning weights of the calves. The maturity and conception of the cows was delayed. The delay in skeletal development of cows on the low level was not overcome until three and one-half years of age. Levels of feeding above medium were not profitable. The very high level did not appear to affect conception, but increased calving difficulty and reduced the number of live calves at weaning. Calving dates, as they probably reflected appearance of first heat after calving, were directly related to winter feed levels. Useful, productive life appeared to be shortened by liberal winter feeding.

Van Horn et al. (1959a) reported the results of wintering trials with range ewes. They compared the value of ewes fed one-third or two-thirds pound of an eleven, eighteen, or thirty percent protein pellet with ewes fed no supplement or with ewes fed eleven percent protein supplement according to the weather. Ewes gained or lost weight in proportion to the amount of supplemental feed given. Increasing winter feed levels increased birth weights of lambs, pounds of lamb weaned per ewe, grease fleece weights and clean fleece weights.

A moderate amount of supplement appeared to be profitable. This varied from feeding only during bad weather to a higher level in which ewes received one-third pound of supplement the first half of the feeding period and two-thirds pound during the last half.

EFFECTS OF PROTEIN SUPPLEMENTATION OF WINTER RANGE FORAGE ON PERFORMANCE OF RANGE CATTLE

McCall (1940) reported that one-half pound of linseed cake per one hundred pounds live weight, improved the palatability and digestibility of range forage for beef cattle. Lower levels of linseed cake did not seem to improve digestibility of the ration appreciably but it did improve palatability as determined by willingness to consume and completeness of consumption. The experimental work was conducted under enclosed, closely observed conditions in which the range forage was clipped and fed to the experimental animals.

Mature range grasses and hays have wide nutritive ratios, according to Hopper and Nesbitt (1930), and require a high protein feed to supplement them so that sufficient protein will be available to meet the requirements of production, reproduction and growth.

Smith (1935) found little difference between corn and cottonseed cake as supplements to the range forage at the U. S. Range Livestock Experiment Station, Miles City, Montana. He suggests this is probably due to the higher crude protein content of the grass in that area.

A comparison of cows receiving supplemental cottonseed cake with cows receiving no supplement while grazing winter range in eastern Montana (U. S. Livestock Experiment Station, Miles City) was studied by Black et al. (1938). The supplemented group was fed according to the weather. The level fed ranged from 0.5 to 3.0 pounds of cottonseed cake per day with a usual range of 0.75 to 1.5 pounds per head per day. The supplemented group had slightly larger calves at birth, weaned larger calves and the cows lost less weight during the winter than the non-supplemented groups. The non-supplemented group had a higher calving percentage. The advantages due to supplementation were not great enough to pay for the cost of the supplement and labor of feeding it according to these workers.

Gallup et al. (1951) studied the effect of cottonseed meal, soybean oil meal and urea on vitamin A metabolism in sheep. The results indicated cottonseed meal affected the amount of vitamin A storage more positively than soybean oil meal. Urea had no effect on this relationship. The results were not statistically significant.

Moustgaard (1956) stated the daily protein required for fetus formation, colostrum production and growth of the mammary gland of cattle, is higher than the reported recommended level throughout the world. The requirements for the functions stated by Moustgaard are not higher than the level recommended for pregnant animals by the N. R. C. (National Research Council). The N. R. C. requirements for pregnant cows are well above the recommendations of Moustgaard except for the last two weeks of pregnancy.

Van Horn et al. (1959b) fed range ewes one-third pound of pellets per head, per day, containing either ten, twenty, thirty, or forty percent protein. A control group received no supplement. The ewes receiving the pellets with the higher protein levels gained more during the wintering period. The differences in lambing percentage were not significant between groups. The higher protein levels affected the birth weights of the lambs; the weights increased with the protein level. This advantage in weight at birth was overcome by weaning time. No significant difference in weaning weight occurred. Returns per ewe, above feed cost, were slightly higher for the group receiving one-third pound of ten percent protein supplement. The returns from the non-supplemented groups were lowest of all groups studied.

PROCEDURE

Experimental animals and allotting procedure

Fifty-six grade Hereford cows were purchased for this experiment in February, 1957. Forty head were from the North Montana Branch Station at Havre, Montana and sixteen were from two commercial breeders at Livingston, Montana. All cows were three or four years old. They were fed together at the experiment station Red Bluff Research Ranch, Norris, Montana, through the remainder of the winter and subsequent summer of 1957. The first experimental year began with the 1957-58 winter.

The fifty-six head of cows were grouped according to breeding, age, and weight. Selections from the groups were randomly assigned to one of eight lots. The method of allotting resulted in lots containing the same number of cows from each source and about the same age and weight.

Additional cows were added to the experiment during the fall of years 1958-59 and 1959-60. Nineteen bred, grade Hereford heifers, eighteen months old, were selected from the experiment station herd in the fall of 1958. These were randomly assigned to the eight experimental lots bringing the total for each lot to nine or ten head for the year 1958-59. During the summer of 1959, two cows died of Larkspur poisoning. All experimental cows were pregnancy tested each year by rectal palpation. Those cows that were not pregnant, according to the test, were sold. Seven eighteen month old bred, grade Hereford heifers from the 1958 experimental calf crop were selected in the fall of 1959. These were randomly assigned to seven of the eight lots bringing the total for each lot to ten or eleven head during 1959-60. The cows remained in the lot to which they were assigned throughout the experiment.

The design of the experiment and number of cows in each lot for the three experimental years 1957-58, 1958-59, and 1959-60 are shown in Table I.

TABLE I. DESIGN OF EXPERIMENT.

Treatment	1 1/	1P	2	2P	3	3P	4	4P
Calculated level of protein, %	0	13	20	20	30	30	40	40
Calculated level of phosphorus, %	0	3.4	0.7	1.7	0.7	1.7	0.7	1.7
Daily feed, pounds	0	0.5	1.0	1.0	1.0	1.0	1.0	1.0
No. cows per treatment								
1957-58	7	7	7	7	7	7	7	7
1958-59	9	9	10	9	10	9	10	9
1959-60	10	10	10	11	11	10	10	10

1/ No supplement was fed cows on this treatment.

Treatments

The treatments consisted of supplemental-winter-feeding of pellets containing zero, twenty, thirty, or forty percent protein with and without fourteen or 4.6 grams of additional phosphorus to eight lots of Hereford breeding cows at the level of two pounds per head, every-other day. The only mineral fed, except that included in the pellets, was salt. Salt was available *ad libitum* throughout the experiment. Table I shows the calculated level of protein and phosphorus of each supplemental ration. Table II shows the constituents of the supplemental rations. Table III shows the results of chemical analysis determined for the supplemental rations.

Pellet number 1P, fed to lot number 1P was composed primarily of sun-cured alfalfa hay which served as a phosphorus carrier (14 grams per pound). The phosphorus content of pellet 1P was about twice that of all other

TABLE II. CONSTITUENTS OF THE SUPPLEMENTAL PELLETS.

Ration No.	1P	2	2P	3	3P	4	4P
Ingredients							
Barley	---	950	800	550	400	100	---
Wheat mixed feed	---	500	500	250	250	---	---
Soybean oil meal	---	450	500	1000	1150	1800	1800
Molasses	100	100	100	100	100	100	100
Alfalfa sun-cured	1600	---	---	---	---	---	---
Dicalcium phosphate	300	---	100	---	100	---	100
"CCC" Trace Mineral	3	3	3	3	3	3	3
Vitamin A 1/	X	X	X	X	X	X	X
Vitamin D 2/	X	X	X	X	X	X	X
	2003	2003	2003	2003	2003	2003	2003

1/ Vitamin A added to supply 10,000 I.U. per pound of feed to all pellets except 1P to which vitamin A was added to supply 20,000 I.U. per pound of feed.

2/ Vitamin D added to supply 1,000 I.U. per pound of feed except to 1P to which vitamin D was added to supply 2,000 I.U. per pound of feed.

phosphorus fortified pellets but the amount fed was one-half that of all others. This presumably supplied the same amount of phosphorus as pellets 2P, 3P or 4P, but reduced the amount of protein consumed by lot 1P cows. Theoretically, lots 1 and 1P received no additional protein. Actually, pellet 1P contained about thirteen percent protein but the low level of feeding (one pound every other day) was assumed to supply an insignificant amount of protein. Lot 1 did not receive supplemental pellets. The level of phosphorus in pellets 1P, 2P, 3P, and 4P supplied about one-half of the daily requirement of the cows in grams.

The pellets were fed from one of four campsites located on three different winter feeding areas. The cattle were all grazed together and were gathered from the range every-other-day during the winter feeding period and fed two pounds per head of the respective supplemental rations except that lot 1 cows did not receive a supplement and lot 1P cows received only one pound per head every-other-day as mentioned.

TABLE III. CHEMICAL ANALYSES OF SUPPLEMENTAL PELLETS, PERCENT. 1/

Year Analyzed	Pellet No.	Moisture	Protein	Fat	Crude Fiber	Ash	Ca.	P.
1958	1P	5.6	13.2	1.9	20.5	20.4	3.08	4.29
1960	1P	4.2	13.0	2.2	22.1	22.4	3.18	5.95
Average	1P 2/	4.9	13.1	2.0	21.3	21.4	3.13	5.12
1958	2	7.4	19.4	2.9	6.5	6.4	1.08	0.62
1960	2	5.6	20.0	2.3	7.5	5.4	0.75	0.68
Average	2	6.5	19.7	2.6	7.0	5.9	0.92	0.65
1958	2P	6.6	22.0	2.8	6.3	8.1	1.59	1.15
1960	2P	5.6	21.6	2.3	7.7	8.9	1.38	1.50
Average	2P	6.1	21.8	2.6	7.0	8.5	1.48	1.32
1958	3	7.0	28.4	2.6	6.7	5.5	1.05	0.32
1960	3	5.7	30.2	2.1	6.5	5.4	0.65	0.32
Average	3	6.4	29.3	2.4	6.6	5.4	0.85	0.32
1958	3P	6.5	28.6	1.7	6.7	10.5	1.91	1.57
1960	3P	5.1	32.2	1.9	7.0	9.6	1.45	1.95
Average	3P	5.8	30.4	1.8	6.8	10.6	1.68	1.76
1958	4	6.6	39.2	2.0	7.7	6.5	1.04	0.42
1960	4	4.9	42.3	1.4	7.1	6.4	0.66	0.45
Average	4	5.8	40.8	1.7	7.4	6.4	0.85	0.44
1958	4P	5.9	40.0	1.5	7.5	11.8	1.75	1.36
1960	4P	4.6	43.7	1.5	7.5	10.7	1.50	1.75
Average	4P	5.2	41.8	1.5	7.5	11.2	1.62	1.56

1/ Pellets were chemically analyzed only twice in three years.
2/ Lot 1P received only one-half the amount per day received by the other lots.

Experimental equipment

A portable corral and feed stall arrangement was located at the campsite and consisted of a corral and ten feed stalls. Figures 1, 2, and 3 show this arrangement.

The corral was made of snow fence supported by steel posts. The feeding stalls were made of unplaned, native pine, 1" x 6" lumber and consisted of panels 5'6" x 8', erected in such a manner that individual stalls were eight feet long by thirty-six inches wide. The panels were supported by steel posts. A movable cross-panel, 4' x 5'6", was placed in the front and rear of each stall to secure the cow in position for feeding. There were five stalls on either side of a small work area where feed was stored in covered metal cans. A scale and work table were also conveniently located within this work area. Feed boxes were 12" x 15" x 6".

The entire corral and stall arrangement could be disassembled, placed on a truck, moved to a new campsite and reassembled in about four hours and required the labor of three men. Two men were usually able to gather the cattle from the range and feed them supplement in about two and one-half hours. The time required for feeding, throughout the duration of the experiment, varied as the number of cows varied from fifty-six to eighty-two.

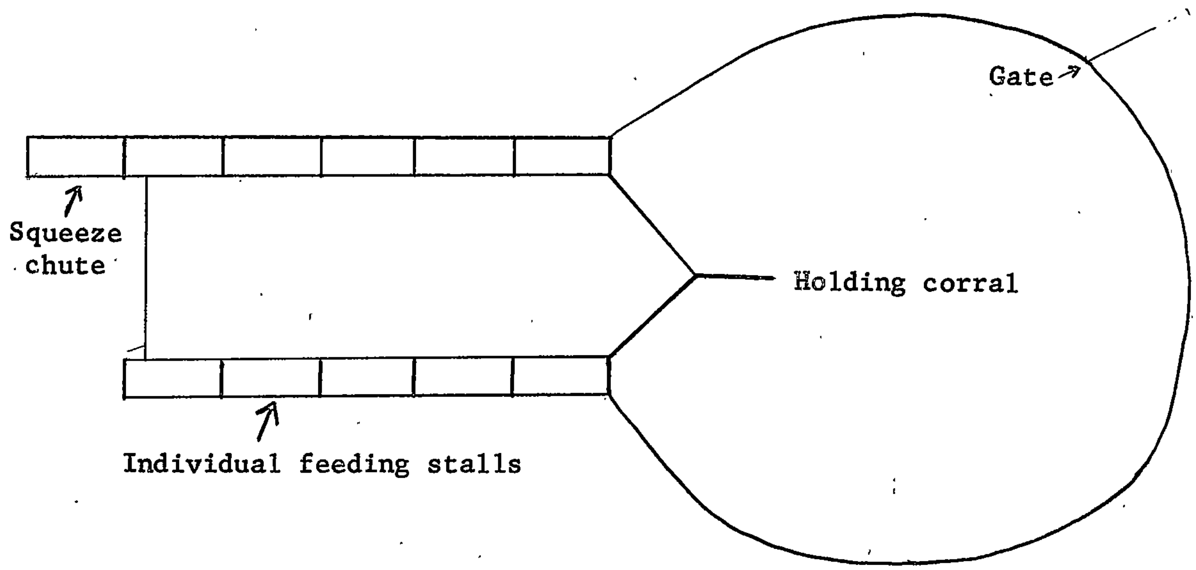


Figure 1. Portable corral.

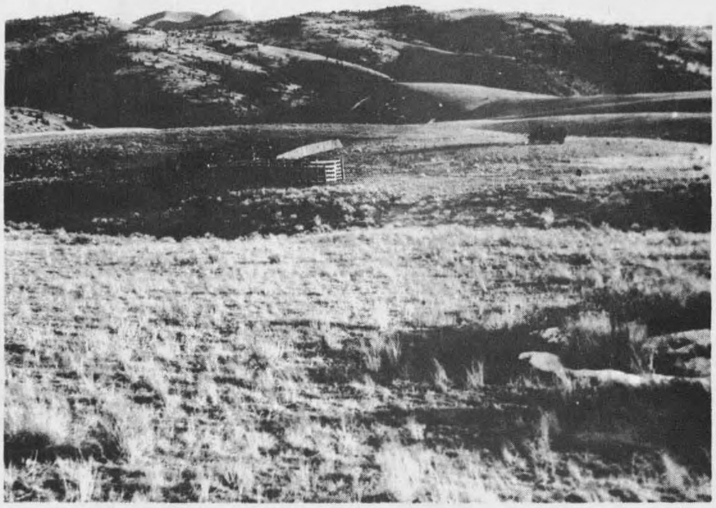


Figure 2. The experimental feeding area at campsite 3.

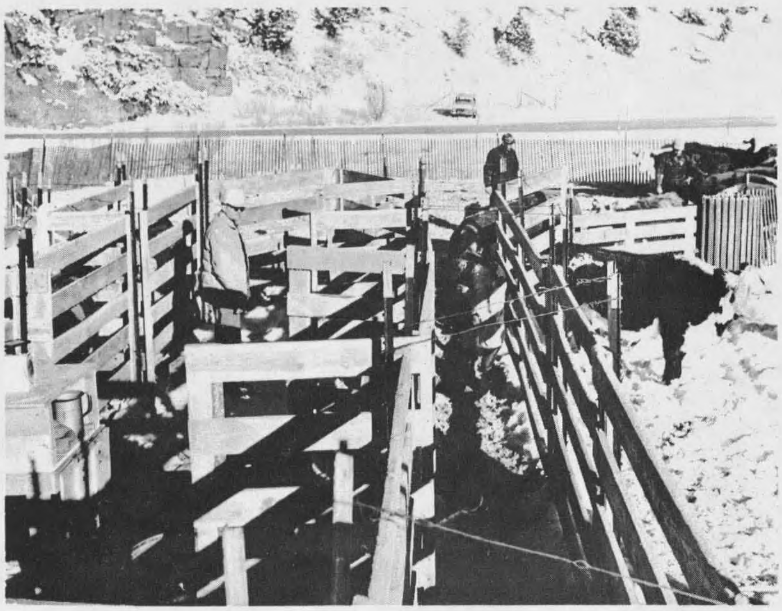


Figure 3. Feeding corral, feeding stalls and the work area.

Handling of experimental cattle

The cattle were all grazed together throughout the experiment. During the winter feeding period, the cows were gathered every-other-day for supplemental feeding. The cattle were moved to different grazing areas periodically. These areas are outlined in Appendix Figure 1. The dates the cattle were grazing these areas are shown in Appendix Table I. The predominant forage species grazed by the cattle are shown in Table IV.

Figure 4 shows some of the experimental cows and the dye brand used on the head to identify their experimental lot number. Eartags and number brands were used on all cows; however, the dye brand used on the head and back the first year and on the back all years made identification much easier for the men who fed the cattle.

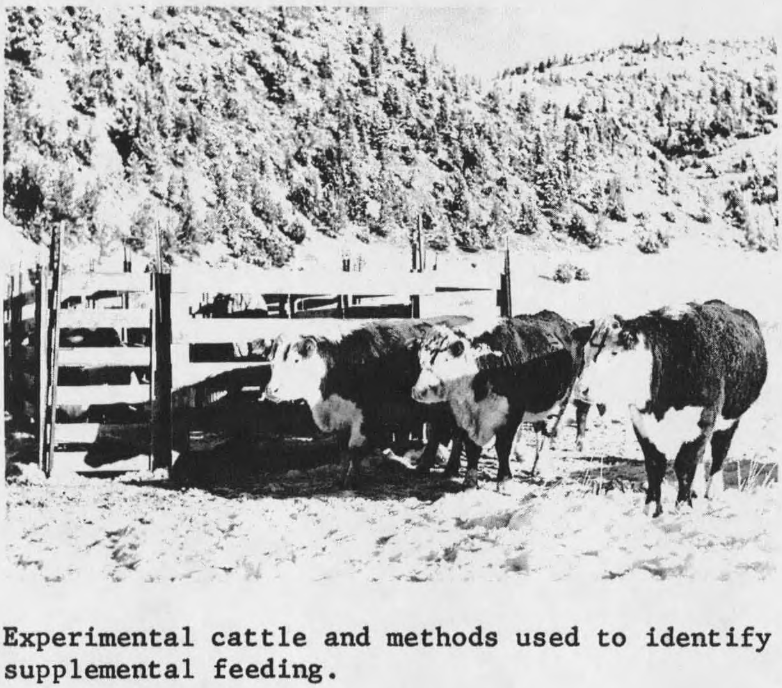


Figure 4. Experimental cattle and methods used to identify the cows for supplemental feeding.

Occasionally, throughout the wintering periods, the range was covered with snow limiting the amount of forage the cows were able to graze. Heavy

TABLE IV. PREDOMINANT FORAGE SPECIES GRAZED BY EXPERIMENTAL CATTLE 1/.

Forage	
Common Name	Scientific Name
Bluebunch wheatgrass 2/	*Agropyron spicatum*
Idaho fescue 3/	*Festuca idahoensis*
Giant wildrye	*Elymus cinereus*
Cheatgrass brome	*Bromus tectorum*
Blue grama	*Bouteloua gracilis*
Prairie junegrass	*Koeleria cristata*
Needle-and-thread	*Stipa comata*
Plains reedgrass	*Calamagrostis montanensis*
Rubber rabbitbrush	*Chrysothamnus nauseosus*
Silky lupine	*Lupinus sericeus*
Fringed sagewort	*Artemisia frigida*
Antelope bitterbrush	*Purshia tridentata*
Common snowberry	*Symphoricarpos albus*
Willows	*Salix* spp.

1/ The experimental area is a foothill range of rather high moisture and there are several species of annual grasses and sedges that are important in spring and early summer but are not important on winter range and are omitted from the list for this reason.
2/ Dominant of all grasses on the ranch.
3/ Co-dominant with Bluebunch wheatgrass at higher elevations.

snow seldom remained for long periods, but when grazing was hampered by this condition the cows were fed about fifteen pounds of grass hay per head, daily. During the winter grazing periods, hay was fed two days in February, 1958; five days in February and one day in March of 1959; and one day in February and two days in March of 1960. The cows were moved from the range to the calving barn at ranch headquarters prior to calving each year and the range forage was replaced by twenty to twenty-five pounds of grass hay per cow, daily. Supplemental pellets were fed throughout calving.

The cattle received supplemental pellets 147, 137, and 158 days during the respective winters 1957-58, 1958-59, and 1959-60.

<u>Cow weights and blood collection</u>

Each year, the cows were weighed on the first day or the day before the supplemental feeding began. This was considered to be the initial weight. Weights were taken about every fifty-six days subsequent to the initial weight. Final winter weights were taken on the last day or the day after supplemental feeding terminated. The very few cows that had not calved before the final winter weigh day were not weighed (six head in three years). Summer weights consisted of: initial--same as final winter weight, and final summer weights were taken at weaning time each year. Appendix Tables II, III, and IV contain these weights. The cattle were not shrunk prior to weighing. Weights were taken on a portable scale thus enabling the weighing of cattle at the feeding campsite as well as at the ranch headquarters.

Blood samples were taken from the cows during the experiment. Fifty cc. blood tubes containing one cc. of sodium citrate were used to collect forty to forty-five cc. of blood by venous puncture. Inorganic plasma phosphorus, plasma carotene and plasma vitamin A levels were determined by the colorimetric methods of Fiske and Subbarow (1925) for phosphorus and Kimble (1938) for carotene and vitamin A. The methods used were modified for the Bausch and Lomb "Spectronic 20" colorimeter. The results of analyses for the year 1958-59 were not available for this report. Blood data of the other years are shown in Appendix Tables V and VI. All experimental cattle were bled during 1957-58. Approximately one-half of the cows were bled in 1959-60.

Breeding

The cows were pasture bred each year. Table V shows the dates of breeding and bulls used.

TABLE V. BREEDING.

Year	Bulls In	Bulls Out	Bulls Used
1957	6-7-57	8-16-57	Three yearling purebred Herefords. Breeder--W. B. Ellis, Cascade, Montana.
1958	6-8-58	8-18-58	Same bulls as above. Two-year-olds this year.
1959	6-8-59	8-18-59 (about)	Three two-year-old purebred Herefords. Breeder--Montana Agr. Exp. Sta.

Calving

The cows were taken to the calving barn about five to seven days before the first calves were expected each year. The respective dates the cattle left the winter grazing area for calving were March 3, 1958; March 4, 1959; and March 7, 1960. The portable corrals and stalls were moved to the calving barn and supplemental feeding continued through calving. Grass hay (twenty to twenty-five pounds per head, daily) replaced range forage during calving.

The calving barn (identified in Appendix Figure 1 as CB) was located at the Red Bluff Ranch between Warm Springs Creek and Highway 289. Wire corrals were arranged in conjunction with the calving barn so the cows could be sorted. Usually, the cows that seemed nearest their parturition time were allowed access to the calving barn. The barn was of stone construction approximately twenty by sixty feet. One end of the barn was partitioned to form a small maternity pen and holding chute. A sling with a chain hoist to facilitate handling weak or sick cows was situated in the opposite end of the barn. Medical supplies were available at the ranch house near the calving barn.

The cows were observed periodically each day. As the calves were born, they were eartagged, weighed and the weight and date of birth recorded. Calves that were born dead but appeared normal otherwise were also weighed and recorded. One deformed calf was born; its birth weight was not taken. All calves were weighed within eight hours of birth, although the length of time between birth and weighing was not closely controlled. Most calves had opportunity to nurse before their birth weights were taken. Appendix Tables II, III, and IV contain birth weights and dates..

The calves were branded, dehorned and castrated prior to the time the cows were turned out for summer grazing. The respective dates that grazing began following calving were May 3, 1958; May 5, 1959; and May 23, 1960; however, due to the fact that supplemental feeding began late in 1957-58, supplemental feeding was continued while cows grazed spring range until June 2, 1958.

Weaning

The cows and calves were removed from summer pasture each fall (November 3, 1958, October 29, 1959 and October 28, 1960) and taken to the ranch headquarters where the calves were separated from the cows for weaning. At this time, final summer cow weights were taken and the calves were weighed and scored. As the calves were individually weighed, three scorers consisting of two experiment station staff members and an extension livestock specialist, gave the calves a numerical score. The average of the three scores given each calf was recorded and is shown in Appendix Tables II, III, and IV as are the weaning weights. The scoring was not done by the same individuals every year.

The actual weaning weights of the calves were adjusted for age of dam and sex of calf to 180-days of age. The method of adjusting follows. Each calf's weaning weight was first adjusted to a 180-day weight by computing the average daily gain from birth to weaning. The average daily gain from birth to weaning was multiplied by 180 and the birth weight added to this product. Correction for age of dam was made by multiplying the 180-day adjusted weaning weight times a percentage factor corresponding to the age of the dam. These factors consisted of 110 percent for calves from two-year-old cows, 105 percent for calves from three-year-old cows, 102 percent for calves from four-year-old cows and 100 percent for calves from five to ten-year-old cows. No corrections for dams beyond ten years of age were necessary in this experiment. To correct for sex of calf, the average weight adjusted for age of dam for steer calves was divided by the average weight adjusted for age of dam for heifer calves and the result multiplied by the weight adjusted for age of dam for each heifer. Adjustment for sex of calf was necessary each year of this experiment since the average weaning weight of the steer calves was greater than the average weaning weight of the heifer calves all three years. The method used for adjusting calf weights is based on data reported by Knapp _et al._ (1942) and Clark _et al._ (1958).

RESULTS AND DISCUSSION

Production of cows wintered on the range

Individual cow weights and the measurements and observations of their offspring are recorded in Appendix Tables II, III, and IV. Production measurements by lot are shown in Table VI. A summary of cow production is shown in Table VII.

Cow weights

The effect of supplementation on cow weights was inconsistent between years. Cows supplemented with higher protein levels lost less weight through the wintering period than cows receiving a lesser protein level, except at the thirty percent level. In 1957-58 and 1959-60, cows receiving thirty percent protein pellets lost more weight than the cows receiving twenty percent protein pellets. Van Horn *et al*. (1959) found that the higher levels of protein produced more gain on ewes grazing winter range.

The effect of adding additional phosphorus was inconsistent on weight gains of cows except at the thirty percent protein level. At this protein level, additions of phosphorus resulted in cows losing less weight during each of the three years. There was no predictable effect of additional phosphorus on weight gains of cows.

Blood analyses

The results of blood analyses for inorganic plasma phosphorus, plasma carotene and plasma vitamin A are shown in Appendix Tables V and VI. Values received for plasma vitamin A levels were not considered accurate. Extremely low values and the inconsistency of the values within a given treatment and analysis would seem to lend support to this line of reasoning. Values

TABLE VI. PRODUCTION OF COWS WINTERED ON THE RANGE, 1957-1960.

Treatment	1	1P	2	2P	3	3P	4	4P
No. cows 1957-58	7	7	7	7	7	7	7	7
Avg. wt. (lbs.)								
Initial (1-7-58)	1004	962	1007	987	994	1006	989	1019
Final (6-2-58)	985	918	1016	984	986	1000	1027	1030
Gain	-19	-44	9	-3	-8	-6	38	11
No. calves born alive	6	7	7	7	7	7	6	7
Avg. calving date	4-24	4-21	4-21	4-16	4-8	4-21	4-26	4-4
Avg. birth wt.	76	80	79	84	76	79	76	74
Avg. weaning wt.	409	423	408	426	406	433	387	443
Avg. adj. weaning wt. 1/	391	408	398	398	381	411	382	404
No. cows 1958-59	9	9 2/	10	9	10 2/	9 2/	10	9 3/
Avg. wt. (lbs.)								
Initial (12-18-58)	974	1004	972	1032	961	988	1014	1063
Final (5-4-59)	903	938	952	970	941	982	1004	1048
Gain	-71	-66	-20	-62	-20	-6	-10	-15
No. calves born alive	8	9	7	9	10	8	10	10 4/
Avg. calving date	4-1	4-16	3-29	4-12	4-7	4-16	4-1	4-15
Avg. birth wt.	74	71	79	90	72	82	71	76
Avg. weaning wt.	389	367	385	418	362	366	388	389
Avg. adj. weaning wt. 1/	377	391	374	434	369	379	385	410
No. cows 1959-60	10	10	10	11	11	10	10	10
Avg. wt. (lbs.)								
Initial (12-16-59)	1006	1060	1111	1010	1072	1094	1089	1109
Final (5-23-60)	900	947	995	918	962	987	996	1032
Gain	-106	-113	-116	-92	-110	-107	-93	-77
No. calves born alive	9	9	10	10	9	10	10	10
Avg. calving date	4-24	4-14	3-31	4-10	3-30	3-28	4-8	4-5
Avg. birth wt.	79	78	71	77	78	77	76	80
Avg. weaning wt.	370	403	406	372	427	420	394	416
Avg. adj. weaning wt. 1/	355	387	382	358	391	366	373	389

1/ Weaning weights were adjusted for age of dam and sex of calf to 180 days.

2/ One cow within the lot had not calved on the date final weights were taken, therefore the average weight of the cows for each of such lots was computed on one fewer than the total number in the lot indicates.

3/ Two cows within the lot had not calved on the date final weights were taken, therefore the average weight of the cows for this lot was computed on two fewer than the total number in the lot indicates.

4/ One cow in this lot had twins. The record of her calves was not included in computations this year.

TABLE VII. SUMMARY OF THE PRODUCTION OF COWS WINTERED ON THE RANGE, 1957-1960.

Treatment	1	1P	2	2P	3	3P	4	4P
Total No. cows 1/	26	26	27	27	28	26	27	26
Avg. wt. of cows (lbs.)								
Initial	995	1009	1030	1010	1009	1029	1031	1064
Final	929	934	988	957	963	990	1009	1037
Gain	-66	-75	-42	-53	-46	-39	-21	-27
No. calves born alive	23	25	24	26	26	26	26	27 2/
Percent of cows having live calves	88.5	96.2	88.9	96.3	92.9	100	96.3	103.8 2/
Percent of cows weaning live calves	88.5	92.3	85.2	85.2	89.3	100	96.3	92.3 4/
Avg. calving date	4-17	4-17	4-7	4-13	4-5	4-11	4-12	4-8
Avg. birth wt. (lbs.)	76.3	76.3	76.3	83.7	75.3	79.3	74.3	76.7
Avg. weaning wt. (lbs.)	389	398	400	405	398	406	390	416
Avg. adj. weaning wt. 3/	374	395	384	396	380	385	380	401

1/ The figure does not indicate the number of different cows but only the total number of observations of cows within treatment over the three year period.

2/ One set of twins were born in this lot during 1959.

3/ Calf weaning weights were adjusted for age of dam and sex of calf to 180 days.

below twenty micrograms per one hundred milliliters of plasma are not often reported in the literature except when the vitamin A content has been intentionally lowered. All cattle in this experiment, except lot 1 cows, received supplemental vitamin A. The low levels of vitamin A, reported in Appendix Tables V and VI of this paper, probably resulted from excessive oxidation of vitamin A during analysis. The phosphorus levels and carotene levels reported in Appendix Tables V and VI were assumed to be reasonably accurate. The level of significance of differences in carotene and vitamin A levels between treatments was not tested statistically.

The difference in plasma inorganic phosphorus levels of cows between phosphorus levels within protein level were statistically significant ($P < .01$) for 1959-60, but not for 1957-58. Table VIII and Table IX show the analysis of variance for blood plasma inorganic phosphorus for years 1957-58 and 1959-60.

TABLE VIII. ANALYSIS OF VARIANCE FOR BLOOD PLASMA INORGANIC PHOSPHORUS LEVEL (1957-58).

Variation	D.F.	S.S.	M.S.	F
Between protein levels/year	3	8.92	2.97	2.06
Between phosphorus levels/ protein level/year	4	8.83	2.21	1.53
Error	102	157.18	1.44	
Total	109	174.93		

According to the analyses, plasma inorganic phosphorus levels increased from December 16, 1959 to April 21, 1960 in cows of all treatment groups. The levels of inorganic phosphorus in plasma from cows receiving additional phosphorus was higher than for cows receiving no additional phosphorus, however.

TABLE IX. ANALYSIS OF VARIANCE FOR BLOOD PLASMA INORGANIC PHOSPHORUS LEVEL (1959-60).

Variation	D.F.	S.S.	M.S.	F
Between protein levels/year	3	2.04	0.68	0.80
Between phosphorus levels/ protein level/year	4	14.01	3.50	4.17**
Error	94	80.30	0.85	
Total	101	96.35		

**Significant at the 1 percent level.

Calves born and weaned

These data indicate a possible advantage from feeding additional phosphorus in terms of live calves born. The number of live calves born to cows receiving additional phosphorus was equal to or greater than the number of live calves born to cows receiving no additional phosphorus except at the thirty percent protein level of the year 1958-59 and at the twenty percent level of year 1959-60. The level of protein did not seem to have a consistent effect upon number of live calves born, but in general, the cows receiving higher protein levels tended to have greater calving percentages. The advantage in the number of living calves born to the phosphorus supplemented cows had been partially overcome by weaning time. Cows receiving twenty percent protein pellets without additional phosphorus, weaned the same number of calves over three years as the cows receiving the same level of protein with additional phosphorus. Cows receiving forty percent protein pellets, without additional phosphorus, weaned four percent (about one calf) more calves than cows receiving forty percent protein with additional phosphorus. Cows receiving additional phosphorus at the zero and thirty percent protein levels weaned four percent and eleven percent more calves than cows receiving the same protein levels without additional phosphorus. Knox and Watkins (1942) and Reynolds et al. (1953) reported an increased number of calves and an increased weight of calves at weaning from cows fed supplemental phosphorus while grazing winter range known to be deficient in the element.

Calving date

Cows receiving the higher percent protein supplements tended to calve earlier than those receiving the lower percent protein supplements; however, the number of days in which the earlier calving lots of cows exceeded the later calving lots of cows was not significant. The control lot of cows calved later than most of the treated lots of cows each year. The control lot had the latest three-year-average calving date.

There was no predictable effect of phosphorus treatment on calving date of the cows. Analysis of variance for calving date is shown in Table X.

TABLE X. ANALYSIS OF VARIANCE FOR CALVING DATE.

Variation	D.F.	S.S.	M.S.	F
Between years	2	3686	1843	5.60**
Between protein levels/year	9	5450	606	1.84 1/
Between phosphorus levels/ protein level/year	12	6226	519	1.58
Error	180	59261	329	
Total	203	74623		
Interactions				
Years X phosphorus	2	2671	1335	4.06*
Years X protein	6	2849	475	1.44
Phosphorus X protein	3	574	191	0.58
Years X phosphorus X protein	6	2585	431	1.31
Error	180	59261	329	

* Significant at the 5 percent level.
** Significant at the 1 percent level.
1/ Approaches significance at the 5 percent level.

Birth weights

The effect of treatments was more consistent for birth weights than any other factor except weaning weights. The effect of treatment on weaning weights was similar to that of birth weights. Table XI shows the analysis of variance for birth weights.

TABLE XI. ANALYSIS OF VARIANCE FOR BIRTH WEIGHT.

Variation	D.F.	S.S.	M.S.	F
Between years	2	76	38	0.78
Between protein levels/year	9	2242	249	5.08**
Between phosphorus levels/ protein level/year	12	1468	122	2.48**
Error	177	8583	49	
Total	200	12369		
Interactions				
Years X phosphorus	2	126	63	1.29
Years x protein	6	1774	296	6.04**
Phosphorus X protein	3	318	106	2.16
Years X phosphorus X protein	6	295	49	1.00
Error	177	8583	49	

** Significant at the 1 percent level.

A summary of the birth weights of calves is shown in Table XII.

The difference in birth weights of calves between years, between protein levels within years, and between phosphorus levels within protein level within year was highly significant ($P < .01$).

Cows receiving twenty percent protein with additional phosphorus had the heaviest calves at birth in years 1957-58 and 1958-59. This lot had the heaviest average birth weights for the three-year-period. The average birth weights of calves from cows in lot 1 (these cows received no supplemental pellets) were neither the lightest nor heaviest during a given year. Over the three-year-period, birth weights in two other lots were equal to lot 1, three lots had heavier birth weights, and two lots had lighter birth weights than lot 1.

TABLE XII. SUMMARY OF BIRTH WEIGHTS (Average weight in pounds).

Year	Lot or Treatment							
	1	1P	2	2P	3	3P	4	4P
1957-58	76	80	79	84	76	79	76	74
Average of all lots -								78.0
Average of lots receiving additional phosphorus - - - - - - - -								79.2
Average of lots receiving no additional phosphorus- - - - - -								76.7
Phosphorus treated lots exceeded non-phosphorus treated lots-								2.5
1958-59	74	71	79	90	72	82	71	76
Average of all lots -								76.8
Average of lots receiving additional phosphorus - - - - - - - -								79.7
Average of lots receiving no additional phosphorus- - - - - -								74.0
Phosphorus treated lots exceeded non-phosphorus treated lots-								5.7
1959-60	79	78	71	77	78	77	76	80
Average of all lots -								77.0
Average of lots receiving additional phosphorus - - - - - - - -								78.0
Average of lots receiving no additional phosphorus- - - - - -								76.0
Phosphorus treated lots exceeded non-phosphorus treated lots-								2.0
Three-year averages								
	76.3	76.3	76.3	83.7	75.3	78.3	74.3	76.7
Average of all lots -								77.1
Average of lots receiving additional phosphorus - - - - - - - -								78.7
Average of lots receiving no additional phosphorus- - - - - -								75.5
Phosphorus treated lots exceeded non-phosphorus treated lots-								3.2

Weaning weights

All weaning weights were adjusted for age of dam and sex of calf to a 180-day weight. Analysis for effect of ration on weaning weights was made with this consideration. Table XIII shows analysis of variance for adjusted weaning weights.

The effect of supplementing cows with phosphorus during the winter on the weaning weight of calves was evident. Calves from phosphorus supplemented cows were significantly heavier at weaning time than calves from cows receiving no phosphorus supplement ($P < .05$). The advantage of feeding supplemental phosphorus occurred in nine out of twelve comparisons.

TABLE XIII. ANALYSIS OF VARIANCE FOR ADJUSTED WEANING WEIGHT.

Variation	D.F.	S.S.	M.S.	F
Between years	2	13532	6766	5.20**
Between protein levels/year	9	11337	1260	0.97
Between phosphorus levels/ protein level/year	12	36732	3061	2.35*
Error	170	221089	1301	
Total	193	282690		
Interactions				
Years X phosphorus	2	8243	4172	3.21*
Years X protein	6	10106	1684	1.29
Phosphorus X protein	3	4530	1510	1.16
Years X phosphorus X protein	6	17417	2903	2.23*
Error	170	221089	1301	

* Significant at the 5 percent level.
** Significant at the 1 percent level.

The difference in weaning weights of calves from cows fed different levels of protein was not significant within year. Table XIV shows a summary of the weaning weights of the calves.

Addition of phosphorus at the twenty and forty percent protein level had a greater effect on weaning weight than addition of phosphorus at the thirty percent protein level. Over the three-year-period, cows in lot 1P (additional phosphorus at the zero percent protein level) weaned calves about the same weight as lot 2P.

Supplemental feeding was continued throughout calving; however, over the three-year-period, a total of six cows calved late and supplemental feeding was terminated prior to the parturition date of these cows. It is

TABLE XIV. SUMMARY OF WEANING WEIGHTS (Average weight in pounds).

Year	Lot or Treatment							
	1	1P	2	2P	3	3P	4	4P
1957-58	391	408	398	398	381	411	382	404
Average of all lots								396.5
Average of lots receiving additional phosphorus								405.0
Average of lots receiving no additional phosphorus								388.0
Phosphorus treated lots exceeded non-phosphorus treated lots								17.0
1958-59	377	391	374	434	369	379	385	410
Average of all lots								389.5
Average of lots receiving additional phosphorus								403.0
Average of lots receiving no additional phosphorus								376.0
Phosphorus treated lots exceeded non-phosphorus treated lots								27.0
1959-60	355	387	382	358	391	366	373	389
Average of all lots								375.0
Average of lots receiving additional phosphorus								375.0
Average of lots receiving no additional phosphorus								375.0
Phosphorus treated lots exceeded non-phosphorus treated lots								-----
Three-year averages								
	374	395	384	396	380	385	380	401
Average of all lots								386
Average of lots receiving additional phosphorus								394
Average of lots receiving no additional phosphorus								379
Phosphorus treated lots exceeded non-phosphorus treated lots								15

possible that supplemental feeding had a greater effect on weaning weight by stimulating lactation, than it did on gestation--especially for those cows that calved early and received supplement during several days of lactation (as much as fifty-three days for cows in lot 3 in year 1959-60). Although the possibility of such a stimulating effect on lactation occurred, the evidence of its effect on the weaning weights is not strong. During the year 1958-59, cows in lots receiving no additional phosphorus calved earlier than cows receiving additional phosphorus. The cows in lots receiving the additional phosphorus had heavier average adjusted weaning weights.

During year 1959-60, cows in lot 3P calved earlier than cows in lot 3. The adjusted weaning weights of calves from the earlier calving cows (lot 3P) were lighter than those of the calves from cows calving later (lot 3).

These data suggest that the difference in adjusted weaning weights was due to treatment.

Average daily gain from birth to weaning

The difference between treatments for average daily gain to weaning was similar to the difference between treatment for adjusted weaning weight. The average daily gain from birth to weaning of calves was different between treatments. The lots of cows receiving additional phosphorus had calves that gained faster from birth to weaning. Treatment differences for birth weight were highly significant ($P < .01$) and difference in adjusted weaning weight between phosphorus levels within protein level within year was significant ($P < .05$). Analysis of variance for average daily gain to weaning is shown in Table XV.

TABLE XV. ANALYSIS OF VARIANCE FOR AVERAGE DAILY GAIN TO WEANING.

Variation	D.F.	S.S.	M.S.	F
Between years	2	1.27	0.64	12.80**
Between protein levels/year	9	0.32	0.04	0.80
Between phosphorus levels/ protein level/year	12	0.81	0.07	1.40
Error	170	9.13	0.05	
Total	193	11.53		
Interactions				
Years X phosphorus	2	0.16	0.08	1.60
Years X protein	6	0.13	0.02	0.40
Phosphorus X protein	3	0.00	0.00	----
Years X phosphorus X protein	6	0.50	0.08	1.60
Error	170	9.13	0.05	

** Significant at the 1 percent level.

The average daily gain to weaning for phosphorus supplemented lots and non-phosphorus supplemented lots were as follows: (comparisons are averages of the three years). Lot 1, 1.64; lot 1P, 1.74; lot 2, 1.65; lot 2P, 1.70; lot 3, 1.64; lot 3P, 1.67; lot 4, 1.65; and lot 4P, 1.75. These differences were not statistically significant, but for this experiment the average daily gains of calves from phosphorus treated cows, along with the differences in birth weights, were sufficient to cause a significant difference in the weaning weights of calves from cows between phosphorus treatments. The greater daily gains of calves from phosphorus supplemented cows was probably the result of more milk produced by the phosphorus supplemented cows. Other researchers have reported a stimulated milk flow due to phosphorus supplementation of cows deficient in the element. (Becker et al., 1927; Eckles et al. 1933, and Maynard and Loosli, 1956).

Calf score

Analysis of variance for calf score is shown in Table XVI.

TABLE XVI. ANALYSIS OF VARIANCE FOR CALF SCORE.

Variation	D.F.	S.S.	M.S.	F
Between years	2	98.64	49.32	1.25
Between protein levels/year	9	446.00	49.56	1.26
Between phosphorus levels/ protein level/year	12	389.90	32.49	0.83
Error	163	6412.03	39.34	
Total	186	7346.57		
Interactions				
Years X phosphorus	2	33.70	16.85	0.43
Years X protein	6	377.87	62.98	1.60
Phosphorus X protein	3	108.87	36.29	0.92
Years X phosphorus X protein	6	212.14	35.36	0.90
Error	163	6412.03	39.34	

Individual calf scores differed widely but the variation between treatments and years was not greater than the variation within treatment and years.

Economic value of the experimental supplements

The actual value of the supplements used in this experiment could not be determined because the calves were not sold at weaning time. An estimate of the value of these supplements is based on an assumed calf price of twenty-eight dollars per hundred pounds of live weight. The price represents an average for steer and heifer calves over the three-year-period of this experiment.

The cost of supplemental pellets fed throughout the experiment is shown in Table XVII as price per ton and cost per cow per wintering period.

Table XVIII shows the estimated returns per cow from supplemental feeding.

A possible advantage to be gained from feeding supplements is greater calving percentages. A value was not given this factor because all death losses could not be associated with the treatment. One cow in each of lots 1, 2P, and 3 died of causes not associated with treatment. One calf from lot 2 died of urinary calculi. One calf from each of lots 2P, 4, and 4P died of unknown causes. These losses lowered the weaning percentages of the respective lots. Considering the deaths not due to treatment, these data indicate that lot 3P, had the highest weaning percent. Weaning percentages in lots 1P, 2P, 3, 4, and 4P were about equal to each other but lower than lot 3P. Lots 1 and 2 had the lowest calving percentages. The actual calving percentages are shown in Table VII but the values listed

TABLE XVII. COSTS OF WINTERING SUPPLEMENTS 1957-60.

Treatment	1	1P	2	2P	3	3P	4	4P
Cost of supplement per ton $ 1/								
1957-58	---	$61.16	$67.29	$71.60	$80.94	$76.25	$95.64	$98.90
1958-59	---	64.00	63.00	63.00	72.00	78.00	86.00	89.00
1959-60	---	63.75	61.00	64.20	68.00	72.55	78.40	80.90
Average	---	62.97	63.76	66.27	73.65	75.60	86.68	89.60
Cost of supplement per cow								
1957-58 2/	---	$4.50	$4.95	$5.26	$5.95	$5.60	$7.03	$7.27
1958-59 3/	---	4.38	4.32	4.32	4.93	5.34	5.89	6.10
1959-60 4/	---	5.04	4.82	5.07	5.37	5.73	6.19	6.39
Average cost	---	4.64	4.70	4.88	5.42	5.56	6.37	6.59

1/ The specifications for the pellets were sent to three local feed manufacturers who submitted bids. The lowest bidder was awarded the contract.
2/ Cows were fed supplement 147 days.
3/ Cows were fed supplement 137 days.
4/ Cows were fed supplement 158 days.

in the table were calculated with no consideration for deaths due to factors other than treatment; all cows were pregnancy tested before each winter feeding period started.

TABLE XVIII. ESTIMATED RETURNS FROM SUPPLEMENTAL FEEDING (per cow per year)

	Lot number							
	1	1P	2	2P	3	3P	4	4P
Cost of supplement per cow ($) 1/	---	4.64	4.70	4.88	5.42	5.56	6.37	6.59
Return per cow above control ($) 2/	---	5.88	2.80	6.16	1.68	3.08	1.68	7.56
Returns per cow above cost of supplement ($)	---	1.24	-1.90	1.28	-3.74	-2.48	-4.69	0.97

1/ Average cost over the three-year period.
2/ The control group (lot 1) had the lightest three-year average adjusted weaning weight. Return per cow above the controls was determined as follows: average three-year weaning weight minus the average three-year weaning weight of controls times $28. per cwt. The estimated average value per calf from the control lot was $104.72.

SUMMARY

During the winters of 1957-58, 1958-59, and 1959-60, fifty-six, seventy-five, and eighty-two Hereford cows were wintered on the range. Eight lots of cows comparable in breeding, age and weight were fed seven different supplements. (Lot 1 cows, controls, did not receive a supplement). Lots 2, 2P, 3, 3P, 4, and 4P received two pounds of supplement per head, every-other-day for 147, 137, and 158 days during the respective winters 1957-58, 1958-59, and 1959-60. The supplements were pelleted and contained four different protein levels. Additional phosphorus was added to four of the seven supplements. Cows in lots 2, 3, and 4 received pellets containing approximately twenty, thirty, and forty percent protein. Cows in lots 1P, 2P, 3P and 4P received pellets containing approximately zero, twenty, thirty and forty percent protein with additional phosphorus added to give an additional 4.6 grams of phosphorus per day or about one-half of the cow's daily phosphorus requirement. All cows were grazed together. During calving, the range forage was replaced by twenty to twenty-five pounds of grass hay per head, daily, and supplemental pellet feeding continued.

The difference in inorganic plasma phosphorus levels between treatments was not significant during the winter of 1957-58. Cows receiving additional phosphorus had significantly higher inorganic plasma phosphorus levels during the winter of 1959-60 ($P < .01$). The protein levels fed had no significant effect on inorganic phosphorus levels. Blood data were not available for the year of 1958-59.

More live calves were born in the lots of cows receiving additional

phosphorus. The level of protein fed did not seem to affect the number of live calves born. The number of calves weaned differed between lots, but due to deaths of cows and calves not associated with treatment, and the fact that all cows were pregnancy tested each fall, the weaning percentages of the respective lots could not be accurately compared.

Cows receiving higher protein supplements tended to calve earlier than cows receiving lower protein supplements. These differences were not statistically significant. There was no significant difference in calving date associated with feeding additional phosphorus.

There was a significant effect ($P < .01$) of both protein and phosphorus supplementation on birth weight of calves. Lot 2P had the heaviest calves at birth and lot 4, had the lightest calves at birth. Cows receiving additional phosphorus had heavier calves at birth than the cows receiving no additional phosphorus except at the zero percent protein level.

Cows receiving additional phosphorus weaned heavier calves than cows receiving no additional phosphorus. These differences were statistically significant ($P < .05$). There was no significant effect of protein level on weaning weight.

There was a consistent trend for calves from cows receiving additional phosphorus to gain more weight from birth to weaning. The differences in average daily gain from birth to weaning between treatments were not statistically significant; however.

Cows in lots 1P, 2P, and 4P annually returned (above feed cost) an estimated \$1.24, \$1.28, and \$0.97 per cow more than the controls (lot 1). Cows in lots 2, 3, 3P, and 4 annually returned (above feed costs) an estimated \$1.90, \$3.74, \$2.48, and \$4.69 per cow less than the controls.

These data indicate that the range grazed by the experimental cows was not seriously deficient in protein or phosphorus. The cows receiving additional phosphorus during the winter produced more calves that were significantly heavier at birth and weaning than cows receiving no additional phosphorus, indicating the winter range was borderline or slightly deficient in phosphorus. The response to phosphorus treatment by the cows on this experiment was not as great as that reported by other researchers when cows were grazed on ranges known to be deficient in the element.

Under the conditions of this experiment, feeding a protein supplement with additional phosphorus to cattle grazing winter range was profitable, but feeding protein supplement without additional phosphorus was not profitable. The cows receiving twenty percent protein plus additional phosphorus returned the greatest estimated profit.

LITERATURE CITED

Anderson, R., E. Cheng and Wise Burroughs. 1956. A laboratory technique for measuring phosphorus availability of feed supplements fed to ruminants. J. Animal Sci. 15:489.

Anonymous. 1955. Sources of phosphorus for beef heifer calves on dry bluestem pasture. Kansas State College. Dept. of An. Hus.

Auchinachie, O. W. and J. S. Emslie. 1934. The effects of diet on the plasma phosphatase of sheep. Biochem. J. 27:351.

Barmore, Mark and J. M. Luck. 1931. The role of phosphate in biological oxidation. J. Gen. Physiol. 15:97.

Becker, R. B., C. H. Eckles, and L. S. Palmer. 1927. Effect of mineral deficiency on the yield and composition of cow's milk. J. Dairy Sci. 10:169.

Beeson, W. M., D. W. Bolin, C. W. Hickman, and R. F. Johnson. 1941. The phosphorus requirement of growing and fattening beef steers. Idaho Agr. Expt. Sta. Bul. 240.

Black, W. H., J. R. Quesenberry, and A. L. Baker. 1938. Wintering beef cows on the range with and without a supplement of cottonseed cake. U. S. D. A. Tech. Bul. 603.

Black, W. H., L. H. Tash, J. M. Jones, and R. J. Klegerg, Jr. 1949. Comparison of methods of supplying phosphorus to range cattle. U. S. D. A. Tech. Bul. 981.

Blum, J. K. 1931. The relation of lime and phosphoric acid in the feed to the growth and development of bone of white rats. Texas Agr. Expt. Sta. Bul. 441.

Burroughs, W., A. Raun, E. Cheng, and C. C. Culbertson. 1956. Different kinds and amounts of phosphorus in fattening cattle rations. Iowa State College, An. Hus. Leaflet 209.

Clark, R. T., C. E. Shelby, J. R. Quesenberry, R. R. Woodward, and F. S. Willson. 1958. Production factors in range cattle under northern great plains conditions. U. S. D. A. Tech. Bul. 1181.

Colovas, N. F., H. W. Keener, A. E. Terri, and H. A. Davis. 1952. Limestone lowers digestibility of silage. Report of the Director of the New Hampshire Expt. Sta., Bul. 394.

Colovas, N. F., H. A. Keener, A. E. Terri, and H. A. Davis. 1953. Too much limestone lowers digestibility of both protein and energy in silage. Report of the Director of the New Hampshire Expt. Sta. Bul. 402.

Dowe, T. W., J. Matsushima, and V. H. Arthaud. 1957. The effects of adequate and excessive calcium when fed with adequate phosphorus in growing rations for beef calves. J. Animal Sci. 16:811.

Eckles, C. H. and T. W. Gullickson. 1927. The relation of phosphorus deficiency to the utilization of feed. Proc. Am. Soc, Anim. Prod. p. 6.

Eckles, C. H., T. W. Gullickson, and L. S. Palmer. 1933. Phosphorus deficiency in the rations of cattle. Minn. Agr. Expt. Sta. Tech. Bul. 91.

Eckles, C. H., L. S. Palmer, T. W. Gullickson, C. P. Fitch, W. L. Boyd, L. Bishop, and J. W. Nelson. 1935. Effects of uncomplicated phosphorus deficiency on estrus cycle, reproduction and composition of tissues of mature dairy cows. Cornell Vet. 25:22.

Eveleth, D. F., M. W. Eveleth, and F. E. Walsh. 1937. Inorganic phosphorus of the serum of dairy cattle. North Am. Vet. 18:18.

Fairbanks, B. W. 1939. The calcium-phosphorus ratio. North Am. Vet. 20:17.

Fiske, C. H. and Y. Subbarow. 1925. The colorimetric determination of phosphorus. J. Biol. Chem. 66:375.

Gallup, W. D. and H. M. Briggs. 1950. The minimum phosphorus requirements of lambs for phosphorus equilibrium. J. Animal Sci. 9:426.

Gallup, Willis D., H. M. Briggs, L. S. Pope, and James Tucker. 1951. Comparative effect on vitamin A metabolism in sheep of urea, soybean oil meal and cottonseed meal as sources of protein. J. Animal Sci. 10:251.

Greaves, J. E., E. J. Maynard, and W. Reeder. 1934. Influence of calcium and phosphorus intake on bovine blood. J. Agr. Res. 48:1033.

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. J. Agr. Sci. 18:384.

Haag, J. R. and I. R. Jones. 1935. The calcium and inorganic phosphorus content of the blood plasma of normal dairy cattle. J. Biol. Chem. 110:439.

Haag, J. R. 1951. Minerals for livestock. Oregon Agr. Expt. Bul. 503.

Hartman, A. M. and E. B. Meigs. 1931. Calcium assimilation as indicated by bone analysis in long time experiments. J. Dairy Sci. 14:322.

Henderson, H. O. and C. E. Weakley. 1930. The effect of feeding different amounts of calcium and phosphorus upon the growth and development of dairy animals. West Virginia Agr. Expt. Sta. Bul. 231.

Holmes, A. D. and M. Pigott. 1931. The calcium-phosphorus ratio of Tibiae of growing chicks. J. Biol. Chem. 92:187.

Hopper, T. H. and L. L. Nesbitt. 1930. The chemical composition of some North Dakota pasture and hay grasses. N. Dak. Agr. Expt. Sta. Bul. 236.

Huffman, C. G., C. S. Robinson, C. W. Duncan, L. W. Lamb, and M. F. Mason. 1933. A study of the phosphorus requirement of dairy cattle. 1. Phosphorus requirements for growth and reproduction from three months of age to first calving. J. Dairy Sci. 16:203.

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. p. 241.

Kimble, M. S. 1939. Photocolorimetric determination of vitamin A and carotene in human plasma. J. Lab. and Clin. Med. 24:1055.

Kleiber, M., H. Goss, and H. R. Builbert. 1936. Phosphorus deficiency, metabolism, and food utilization in beef heifers. J. Nutrition. 12:121.

Knapp, Bradford Jr., A. L. Baker, and J. R. Quesenberry. 1942. Growth and production factors in range cattle. Mont. Agr. Expt. Sta. Bul. 400.

Knox, J. H. and P. E. Neale. 1937. Mineral supplements for cattle on phosphorus-deficient range. New Mex. Agr. Expt. Sta. Bul. 249.

Knox, J. H., J. W. Benner, and W. E. Watkins. 1941. Seasonal calcium and phosphorus requirements of range cattle, as shown by blood analysis. New Mex. Agr. Expt. Sta. Bul. 282.

Knox, J. H. and W. E. Watkins. 1942. The use of phosphorus and calcium supplements for range livestock in New Mexico. New Mex. Agr. Expt. Sta. Bul. 287.

Kolari, D. E. and L. E. Hanson. 1961. Factors affecting the digestibility of flax plant product by sheep. J. Animal Sci. 20:58.

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. Expt. Tech. Bul. T-43.

Long, T. A., A. D. Tillman, A. B. Nelson, W. D. Gallup, and B. Davis. 1957. Availability of phosphorus in mineral supplements for beef cattle. J. Animal Sci. 16:444.

Malan, A. I., H. H. Green and P. J. Du Toit. 1928. Studies in mineral metabolism. V. Composition of bovine blood on phosphorus deficient pasture. J. Agr. Sci. 18:376.

Marsh, H., K. F. Swingle, R. R. Woodward, G. F. Payne, E. E. Frahm, L. H. Johnson, and J. C. Hide. 1959. Nutrition of cattle on an eastern Montana range as related to weather, soil, and forage. Mont. Agr. Expt. Sta. Bul. 549.

Marsh, H. and K. F. Swingle. 1960. Calcium, phosphorus, magnesium, carotene, and vitamin A content of the blood of range cattle in eastern Montana. Am. Vet. M. Assn. J. 137:378. (Abstract).

Maynard, E. J. and J. K. Loosli. 1956. The inorganic elements and their metabolism. Animal Nutrition fourth ed. McGraw-Hill Book Co. Inc., New York.

McCall, R. 1940. The digestibility of mature range grasses and range mixture fed alone and with supplements. J. Agr. Res. 60:39.

Mitchell. 1947. The mineral requirements of farm animals. J. Animal Sci. 6:365.

Morris, S. and S. C. Ray. 1939. The effect of a phosphorus deficiency on the protein and mineral metabolism of sheep. Biochem. J. 33:1209.

Moustgaard, J. 1956. Protein requirement and protein synthesis in cows and sows during foetal development. III. International Congress on Animal Reproduction. p. 123.

National Research Council. 1958. Nutrient requirements of beef cattle--revised. National Academy of Sciences--National Research Council. Pub. 579.

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. Expt. Sta. Tech. Bul. No. T 54.

Otto, J. S. 1938. The assimilation of calcium and phosphorus by the growing bovine. Ondersspoort J. Vet. Sci. and Anim. Ind. 10:282.

Palmer, L. S., W. S. Cunningham, and C. H. Eckles. 1930. Normal variation in the inorganic phosphorus of the blood of dairy cattle. J. Dairy Sci. 13:174.

Palmer, L. S., R. A. Gortner, and R. Rude. 1930. The biometry of calcium and inorganic phosphorus in the blood plasma of dairy cattle. J. Dairy Sci. 13:360.

Palmer, L. S., C. P. Fitch, T. W. Gullickson, and W. L. Boyd. 1935. Supplementary report on an experiment to determine the effect of a low calcium ration on reproduction in cattle. Cornell Vet. 25:229.

Payne, M. G., A. C. Clark, H. E. Kingman, and W. M. Stansbury. 1946. Blood levels of calcium and inorganic phosphorus in Hereford Cattle. J. Agr. Res. 72:357.

Pope, L. S. 1960. Okla. Agr. Expt. Sta. Misc. Pub. M-P. 57, pp. 60-81. J. E. Zimmerman Ph.D. Thesis, 1960. Okla. State Univ.

Repp, W. W. and W. E. Watkins. 1958. Carotene, vitamin A, and inorganic phosphorus in the blood plasma of range cows. New Mex. Agr. Expt. Sta. Bul. 420.

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. Expt. Bul. 773.

Riddell, W. H., J. S. Hughes, and J. B. Fitch. 1934. The relation of phosphorus deficiency to the utilization of feed in dairy cattle. Kans. Agr. Expt. Sta. Tech. Bul. 36.

Rittenberg, D. and D. Sheman. 1946. The metabolism of proteins and amino acids. Annual Revs. Biochem. 15:247.

Robinson, C. S. and C. F. Huffman. 1926. Studies on the chemical composition of beef blood. I. The concentrations of certain constituents in normal beef plasma. J. Biol. Chem. 67:245.

Ross, O. B. and W. D. Gallup. 1949. The effect of phosphorus deficiency on blood plasma carotene. J. Animal Sci. 8:628. (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. Expt. Sta. Bul. B-359.

Smith, S. L. 1935. A comparison of the values of cottonseed cake and corn for the supplemental feeding of range ewes. Natl. Wool Grower 25(10): 21.

Smith, E. F., F. W. Boren, and B. A. Koch. 1960. A comparison of salt-protein loose mixtures with and without additional phosphorus. Forty-Seventh Annual Livestock Feeder's Day. Circular 378. Kan. Agr. Expt. Sta.

Sutton, T. A. and P. A. Soldner. 1943. The effect of parturition and beginning of lactation on the level of carotene and vitamin A in the blood plasma of dairy cows. J. Dairy Sci. 26:40 (Abstract).

Taylor, B. E. and F. Hubbert, Jr. 1960. Trends in phosphorus for beef cattle and sheep. Trends in Phosphorus. Smith-Douglass Co. Inc., Norfolk, Virginia.

Thieler, A., H. H. Green, and P. J. Du Toit. 1927. Minimum mineral requirements in cattle. J. Agr. Sci. 17:291.

Thieler, A. and H. H. Green. 1932. Aphosphorosis in ruminants. Nutr. Abstr. and Rev. 1:359.

Tillman, A. D., J. R. Brethour, and S. L. Hansard. 1959. Comparative procedures for measuring the phosphorus requirement of cattle. J. Animal Sci. 18:249.

Thomas, O. O. 1951. I. Relation of nutrition and age at first calving to lifetime performance of beef cows. II. The effect of low phosphorus rations upon carotene metabolism in ruminants. Doctor of Philosophy Thesis. Okla. A. and M. College.

Thomas, O. O. 1952. I. Mineral nutrition studies. Mont. Agr. Expt. Sta. (Unpublished).

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. J. Animal Sci. 12:372.

Van Arsdell, W. J., O. B. Ross and R. W. MacVicar. 1950. Effect of ration upon some constituents of blood and milk of Hereford cows and the blood of their calves. J. Animal Sci. 9:545.

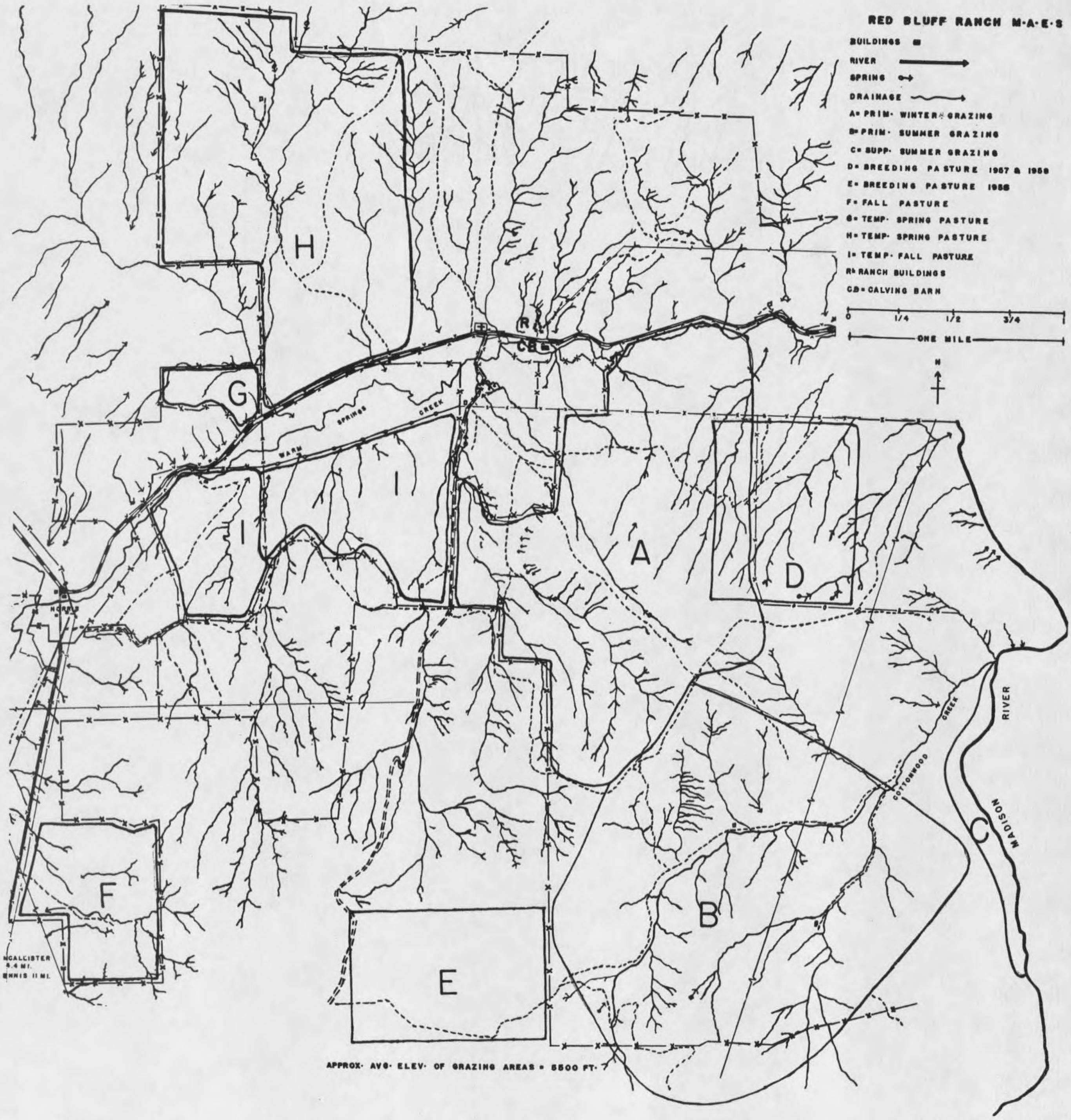
Van Horn, J. L., O. O. Thomas, J. Drummond, A. S. Hoversland, and F. S. Willson. 1959a. Range ewe production as affected by winter feed treatments. Mont. Agr. Expt. Sta. Bul. 548.

Van Horn, J. L., G. F. Payne, F. S. Willson, J. Drummond, O. O. Thomas, and F. A. Branson. 1959b. Protein supplementation of range sheep. Mont. Agr. Expt. Sta. Bul. 547.

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. J. Dairy Sci. 18:557.

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

Yeager, R. and J. C. Winters. 1935. The effect on different diets of the total ash, calcium and phosphorus content of bones. J. Nutrition. 10:389.



Appendix Figure 1. The experimental area, Red Bluff Ranch, Montana Agricultural Experiment Station.

APPENDIX TABLE I. AREAS GRAZED AND BEGINNING AND ENDING DATES OF VARIOUS PHASES OF THE RANGE CATTLE NUTRITION STUDY (1957-1960).

Area being grazed 1/	Dates (inclusive)	Area being grazed 1/	Dates (inclusive)
D	6- 7-57 5/ to 6-30-57	A	12-18-58 2/ to 3- 3-59
C	7- 1-57 to 7- 9-57	CB	3- 4-59 4/ to 5- 3-59 3/
B	7-10-57 to 10-15-57	H	5- 4-59 to about 6-1-59
B	7-16-57 6/	E	about 6-2-59 to 7- 6-59
D	10-16-57 to late Oct., 1957 7/	E	6-8-59 5/
F	late Oct., 1957 to 1- 6-58	C	7- 7-59 to about 7-15-59
A	1- 7-58 2/ to about 2-6-58	B	about 7-16-59 to 10-28-59
I	2- 7-58 to 3- 3-58	B	8-18-59 5/
CB	3- 4-58 to 5- 2-58	I	10-29-59 7/ to about 11-14-59
G	5- 3-58 to 5-20-58	F	about 11-15-59 to 12-15-59
H	5-21-58 to 6- 2-58 3/	A	12-16-59 2/ to 4- 6-60
D	6- 3-58 to 6-30-58	CB	4- 7-60 4/ to 5-22-60
D	6-8-58 5/	G	5-23-60 to 6- 1-60
C	7- 1-58 to about 7-10-58	E	6- 2-60 to about 7-1-60
B	about 7-11-58 to 8-31-58	E	6- 7-60 5/
B	8-18-58 6/	C	about 7-2-60 to about 7-12-60
H	about 9-1-58 to 11- 2-58	B	about 7-13-60 to 10-27-60
I	11- 3-58 7/ to about 11-15-58	B	late Aug., 1960 6/
F	about 11-16-58 to 12-17-58	I	10-28-60 7/

1/ Areas outlined in Appendix Figure 1.
2/ Supplemental feeding began.
3/ Supplemental feeding ended.
4/ Hay replaced range forage during calving.
5/ Breeding began.
6/ Breeding ended.
7/ Weaning date.

APPENDIX TABLE II. PERFORMANCE OF INDIVIDUAL COWS AND THEIR CALVES BY TREATMENT (1957-1958).

Cow No.	Age	Init. Wt. 1/ 1-7-58	Final Wt. 2/ 6-2-58	Gain	Summer Wt. 3/ 11-3-58	Gain	Calving 4/ Date	Sex	Birth Wt.	Weaning Wt.	Adj. Wean 5/ Wt.	A.D.G. to Weaning	Score 6/
						Lot or Treatment 1 (1957-58)							
2	4	1125	1125	--	1230	105	138	F	65	390	440	1.92	84.3
29	4	955	960	5	1140	180	86	F	75	410	374	1.52	85.0
50	4	900	870	-30	1030	160	101	M	70	410	374	1.65	82.7
85	4	955	980	25	1105	125	132	M	90	390	406	1.71	72.7
97	5	920	905	-15	1025	120	104	M	70	380	347	1.54	80.3
902	5	955	980	25	1150	170	150	-	Dead at birth, deformed				----
937	5	1215	1075	-140	1235	160	87	M	84	475	404	1.78	83.0
Avg.	4+	1004	985	-19	1131	146	114		75	409	391	1.69	81.3
						Lot or Treatment 1P (1957-58)							
16	4	1185	1075	-110	1235	160	89	M	100	485	426	1.77	92.0
20	4	815	795	-20	900	105	123	M	65	390	392	1.77	83.7
52	4	1020	990	-30	1165	175	115	F	78	405	430	1.80	82.7
87	4	860	785	-75	925	140	89	F	70	440	387	1.62	88.3
910	5	1070	1040	-30	1160	120	131	M	90	430	437	1.93	80.0
947	5	985	950	-35	1080	130	82	F	78	490	427	1.87	83.7
43	4	800	790	-10	900	110	148	M	80	320	359	1.51	81.7
Avg.	4+	962	918	-44	1052	134	111		80	423	408	1.75	84.6

APPENDIX TABLE II. (CONTINUED).

Cow No.	Age	Init. Wt. 1/ 1-7-58	Final Wt. 2/ 6-2-58	Gain	Summer Wt. 3/ 11-3-58	Gain	Calving 4/ Date	Sex	Birth Wt.	Weaning Wt.	Adj. Wean 5/ Wt.	A.D.G. to Weaning	Score 6/
						Lot or Treatment 2 (1957-58)							
3	4	980	1000	20	1100	100	107	M	78	410	384	1.66	72.0
26	4	980	970	-10	1090	120	121	M	80	420	436	1.93	83.0
56	4	1060	1105	45	1155	50	148	F	85	360	424	1.73	72.0
82	5	880	915	35	1085	170	118	M	80	395	381	1.67	74.0
89	4	1050	1040	-10	1195	155	93	F	82	430	401	1.63	80.0
915	5	1075	1045	-30	1180	135	83	M	77	440	367	1.62	80.3
934	5	1025	1040	15	1115	75	109	F	74	400	390	1.65	80.3
Avg.	4+	1007	1016	9	1131	115	111		79	408	398	1.70	77.4
						Lot or Treatment 2P (1957-58)							
33	4	1210	1215	5	1300	85	131	M	85	385	401	1.71	79.7
39	4	985	940	-45	1105	165	85	M	90	495	426	1.82	83.3
64	4	900	930	30	1240	310	97	F	75	Died 5/26		----	----
83	5	875	865	-10	1035	170	91	M	75	455	392	1.76	81.0
91	4	890	925	35	1065	140	97	M	80	425	382	1.64	79.0
935	5	975	1035	60	1190	155	152	F	85	320	377	1.52	73.0
963	5	1075	980	-95	1115	135	89	M	95	475	408	1.74	76.3
Avg.	4+	987	984	-3	1150	166	106		84	426	398	1.70	78.7

APPENDIX TABLE II. (CONTINUED).

Cox No.	Age	Init. Wt. 1/ 1-7-58	Final Wt. 2/ 6-2-58	Gain	Summer Wt. 3/ 11-3-58	Gain	Calving 4/ Date	Sex	Birth Wt.	Weaning Wt.	Adj. Wean 5/ Wt.	A.D.G. to Weaning	Score 6/
						Lot or Treatment 3 (1957-58)							
14	4	1095	1145	50	1250	105	128	F	85	400	430	1.76	83.3
48	4	945	970	35	1110	140	127	F	85	395	423	1.72	82.7
57	4	1030	930	-100	1090	160	76	F	68	430	376	1.57	83.0
79	5	940	955	15	1150	195	76	M	69	365	299	1.28	71.3
84	4	885	915	30	1060	145	101	F	65	390	374	1.58	78.7
904	5	1025	990	-35	1160	170	86	F	75	390	349	1.40	74.7
930	5	1040	1000	-40	1140	140	95	M	85	475	416	1.84	84.3
Avg.	4+	994	986	-8	1137	151	98		76	406	381	1.60	79.7
						Lot or Treatment 3P (1957-58)							
6	4	1105	1150	45	1230	80	132	F	80	350	382	1.54	73.0
12	4	1065	1085	20	1215	130	95	M	76	490	436	1.95	90.7
73	4	915	920	5	1070	150	117	M	85	395	386	1.63	74.0
90	4	940	820	-120	1055	235	83	F	75	500	446	1.90	88.0
917	5	1115	1130	15	1300	170	129	M	80	425	429	1.94	73.3
944	5	980	920	-60	1005	85	82	M	80	510	424	1.91	90.3
953	5	925	975	50	1070	95	136	M	80	360	375	1.64	65.3
Avg.	4+	1006	1000	-6	1135	135	111		79	433	411	1.80	79.2

APPENDIX TABLE II. (CONTINUED).

Cow No.	Age	Init. Wt. 1/ 1-7-58	Final Wt. 2/ 6-2-58	Gain	Summer Wt. 3/ 11-3-58	Gain	Calving 4/ Date	Sex	Birth Wt.	Weaning Wt.	Adj. Wean 5/ Wt.	A.D.G. to Weaning	Score 6/
						Lot or Treatment 4 (1957-58)							
24	4	1210	1265	55	1300	35	136	F	70	360	403	1.70	71.7
47	4	935	935	0	1130	195	91	M	82	470	414	1.80	88.0
71	4	1035	1060	25	1245	185	123	F	75	310	326	1.28	71.7
86	4	780	810	30	915	105	117	F	75	370	379	1.55	81.0
914	5	900	950	50	930	-20	134	F	65	305	331	1.39	63.7
916	5	1030	1200	170	1425	225	Cow did not calve			---	---	----	----
921	5	1030	970	-60	1140	170	95	M	87	505	442	1.97	84.3
Avg.	4+	989	1027	38	1155	128	116		76	387	382	1.62	76.7
						Lot or Treatment 4P (1957-58)							
13	4	1115	1175	60	1300	125	105	F	63	415	403	1.74	83.7
34	4	1040	1080	40	1220	140	95	M	68	450	400	1.80	82.7
42	4	955	955	0	1215	260	93	M	77	Calf died 4/15		----	----
77	5	915	960	45	1150	190	83	M	78	460	386	1.71	84.3
88	4	995	985	-10	1110	125	87	F	78	470	426	1.78	79.0
901	5	1130	1125	-5	1210	85	110	F	76	430	420	1.80	82.0
961	5	985	930	-55	1065	135	85	F	78	435	386	1.61	74.7
Avg.	4+	1019	1030	11	1181	151	94		74	443	404	1.74	81.1

1/ Date supplemental feeding began.
2/ Date supplemental feeding terminated.
3/ End of summer grazing; also weaning date.
4/ Chronological day of the year in which birth occurred.
5/ Adjusted for age of dam and sex of calf to 180 days of age.
6/ The average of scores given by three persons at time of weaning.

APPENDIX TABLE III. PERFORMANCE OF INDIVIDUAL COWS AND THEIR CALVES BY TREATMENT (1958-1959).

Cow No.	Age	Init. Wt. 1/ 12-18-58	Final Wt. 2/ 5-4-59	Gain	Summer Wt. 3/ 10-29-59	Gain	Calving 4/ Date	Sex	Birth Wt.	Weaning Wt.	Adj. Wean 5/ Wt.	A.D.G. to Weaning	Score 6/
					Lot or Treatment 1 (1958-59)								
2	5	1095	990	-105	1185	195	86	M	83	450	423	1.96	80.6
29	5	1000	1005	-5	1210	205	99	M	69	380	383	1.81	82.0
50	5	960	905	-55	1100	195	83	F	85	425	403	1.81	84.0
85	5	1010	940	-70	1150	210	93	F	70	395	391	1.83	81.0
97	6	935	835	-100	1050	215	87	M	76	385	367	1.68	78.0
902	6	1080	985	-95	1190	205	89	F	68	360	348	1.60	79.0
937	6	1170	1055	-115	1275	220	85	M	90	440	416	1.88	82.0
931	3	810	745	-65	920	175	93	M	57	280	288	1.25	69.0
741	2	710	670	-40	850	180	107	F	66	Calf born dead		----	----
Avg.	4+	974	903	-71	1103	200	91		74	389	377	1.73	79.4
					Lot or Treatment 1P (1958-59)								
16	5	1100	1045	-55	1300	255	100	F	83	390	395	1.80	79.0
20	5	790	7/	--	970	---	166	F	65	335	511	2.57	----
52	5	1095	1080	-15	1225	145	104	F	90	375	386	1.71	77.0
87	5	820	770	-50	920	150	96	F	66	385	382	1.82	78.0
722	2	715	690	-25	885	195	101	F	62	335	379	1.61	75.0
910	6	1075	1030	-45	1215	185	90	F	70	430	415	1.99	82.0
925	6	1035	825	-210	1050	225	101	F	62	270	274	1.22	72.0
947	6	990	965	-25	1175	210	96	F	67	400	396	1.90	82.0
957	6	1205	1100	-105	1240	140	98	F	75	380	380	1.76	73.0
Avg.	5	1004	938	-66	1126	188	106		71	367	391	1.82	77.2

APPENDIX TABLE III. (CONTINUED).

Cow No.	Age	Init. Wt. 1/ 12-18-58	Final Wt. 2/ 5-4-59	Gain	Summer Wt. 3/ 10-29-59	Gain	Calving 4/ Date	Sex	Birth Wt.	Weaning Wt.	Adj. Wean 5/ Wt.	A.D.G. to Weaning	Score 6/
					Lot or Treatment 2 (1958-59)								
3	5	1040	960	-80	1150	190	80	M	87	395	366	1.61	81.0
26	5	1020 8/	990 8/	-30	Died 6/20 -- Cow had a normal calf that died of urinary calculi								
56	5	1020	1155	135	1425	270	Cow did not calve ---				---	----	----
78	6	1060	990	-70	1280	290	98	M	85	350	350	1.53	73.0
82	6	945	920	-25	1105	185	84	M	75	370	349	1.58	80.0
89	5	1060	1010	-50	1225	215	98	M	81	405	405	1.87	81.0
725	2	675	675	0	850	175	82	F	66	375	388	1.63	----
729	2	765	735	-30	1105	370	Calf died at birth---				---	----	----
915	6	1070	1060	-10	1285	225	88	M	80	385	370	1.67	81.0
934	6	1070	1025	-45	1175	150	84	M	80	415	390	1.79	81.0
Avg.	4+	967	948	-19	1178	230	88		79	385	374	1.67	79.5
					Lot or Treatment 2P (1958-59)								
33	5	1220	1190	-30	1360	170	109	M	98	400	420	1.86	82.0
39	5	1010	955	-55	1150	195	118	M	82	Died at birth		----	----
64	5	1120	985	-135	1110	125	98	M	108	450	451	1.98	81.0
83	6	935	965	30	1125	160	116	F	95	400	441	1.97	81.0
91	5	920	885	-35	1065	180	92	M	85	415	404	1.84	80.0
705	2	805	725	-80	840	115	108	F	85	395	460	1.90	----
935	6	1035	980	-55	1175	195	96	F	80	425	426	1.97	82.0
960	6	1215	1075	-140	1230	155	95	M	86	440	434	2.01	86.0
963	6	995 8/	970 8/	-25 8/	Died 6/12 8/		83	M	87	Cow died 6/12		----	----
Avg.	5	1032	970	-62	1132	162	102		90	418	434	1.93	82.0

APPENDIX TABLE III. (CONTINUED).

Cow No.	Age	Init. Wt. 1/ 12-18-58	Final Wt. 2/ 5-4-59	Gain	Summer Wt. 3/ 10-29-59	Gain	Calving 4/ Date	Sex	Birth Wt.	Weaning Wt.	Adj. Wean 5/ Wt.	A.D.G. to Weaning	Score 6/
					Lot or Treatment 3 (1958-59)								
14	5	1085	1135	50	1325	190	84	M	78	380	357	1.61	81.0
48	5	975	7/	--	1220	---	132	M	85	355	421	1.99	----
57	5	1020	945	-75	1190	245	90	M	74	425	410	1.94	82.0
79	6	1020	1025	5	1185	160	79	M	69	360	331	1.51	77.0
84	5	960	915	-45	1125	210	91	F	71	340	332	1.49	77.0
709	2	780	760	-20	1000	240	93	M	68	385	415	1.78	80.0
717	2	795	750	-45	980	230	95	F	55	340	374	1.62	75.0
904	6	1070	1070	0	1180	110	88	F	70	395	383	1.78	81.0
927	6	835	815	-20	975	160	119	M	80	255	279	1.15	----
930	6	1080	1055	-25	1220	165	99	F	72	385	392	1.82	80.0
Avg.	4+	962	941	-20	1140	190	97		72	362	369	1.67	79.1
					Lot or Treatment 3P (1958-59)								
6	5	1105	1100	-5	1325	225	108	F	112	385	406	1.67	80.0
12	5	1080	1025	-55	1295	270	105	M	76	395	406	1.90	78.0
73	5	935	925	-10	1095	170	110	F	85	360	326	1.37	80.0
90	5	915	890	-25	1175	285	101	M	66	365	371	1.76	79.0
706	2	795	785	-10	935	150	95	M	68	345	374	1.57	78.0
713	2	710	7/	--	890	---	132	F	85	220	281	0.97	72.0
917	6	1030	1150	120	1295	145	95	M	86	450	445	2.07	82.0
944	6	1005	965	-40	1150	185	88	F	85	440	425	1.94	85.0
953	6	965	1020	55	1130	110	119	F	73	335	375	1.72	77.0
Avg.	4+	949	982	-6	1143	193	106		82	366	379	1.66	79.0

APPENDIX TABLE III. (CONTINUED).

Cow No.	Age	Init. Wt. 1/ 12-18-58	Final Wt. 2/ 5-4-59	Gain	Summer Wt. 3/ 10-29-59	Gain	Calving 4/ Date	Sex	Birth Wt.	Weaning Wt.	Adj. Wean 5/ Wt.	A.D.G. to Weaning	Score 6/
					Lot or Treatment 4 (1958-59)								
24	5	1220	1160	-60	1330	170	91	M	90	490	475	2.22	86.0
47	5	990	1020	30	----	---	95	F	80	445	443	2.07	78.0
61	5	1050	1050	0	1105	55	93	F	64	415	410	1.97	82.0
71	5	1125	1140	15	1370	230	90	F	65	340	332	1.52	76.0
86	5	805	800	-5	970	170	88	F	70	360	347	1.58	80.0
702	2	830	855	25	995	140	88	F	55	345	366	1.58	----
704	2	820	830	10	1045	215	81	M	64	305	312	1.27	72.0
914	6	940	935	-5	1100	165	99	M	63	285	287	1.29	71.0
916	6	1325	1220	-105	1335	115	90	F	80	440	429	1.99	85.0
921	6	1030	1025	-5	1180	155	91	M	80	460	446	2.11	86.0
Avg.	4+	1014	1004	-10	1159	157	91		71	388	385	1.76	71.6
					Lot or Treatment 4P (1958-59)								
13	5	1215	1150	-65	1445	295	88	F	82	435	419	1.92	84.0
34	5	1105	1140	35	1285	145	83	M	86	500	468	2.20	88.0
42	5	1115	1100	-15	1250	150	82	F	66	390	366	1.71	88.0
77 9/	6	1025	965	-60	1200	235	73 8/	F	60 8/	---	---	----	----
--	-	----	----	---	----	---	--	M	50 8/	360 8/	324 8/	1.52 8/	77.0 8/
88	5	1015	7/	---	1225	---	144	M	80	335	428	2.01	81.0
701	2	855	860	5	900	40	115	M	72	340	405	1.71	----
730	2	675	7/	---	820	---	144	M	80	280	387	1.57	75.0
901	6	1125	1135	10	1275	140	87	F	77	400	386	1.76	77.0
961	6	1000	985	-15	----	---	95	M	62	430	424	2.09	84.0
Avg.	4+	1014	1048	-15	1175	168	105		76	389	410	1.87	82.4

1/ Date supplemental feeding began.
2/ Date supplemental feeding terminated.
3/ End of summer grazing; also weaning date.
4/ Chronological day of the year in which birth occurred.
5/ Adjusted for age of dam and sex of calf to 180 days of age.
6/ The average of scores given by three persons at time of weaning.
7/ Had not calved as of final weight and no weight was taken. The corresponding initial weight and summer weight was subtracted for purposes of computing averages.
8/ Individual weights not used in computing averages.
9/ Not included in statistical analysis because of twin birth.

APPENDIX TABLE IV. PERFORMANCE OF INDIVIDUAL COWS AND THEIR CALVES BY TREATMENT (1959-1960).

Cow No.	Age	Init. Wt. 1/ 12-16-59	Final Wt. 2/ 5-23-60	Gain	Summer Wt. 3/ 10-28-60	Gain	Calving 4/ Date	Sex	Birth Wt.	Weaning Wt.	Adj. Wean 5/ Wt.	A.D.G. to Weaning	Score 6/
Lot or Treatment 1 (1959-60)													
29	6	1140	1145	5	1225	80	183	M	not taken	315 7/	---	----	----
50	6	1050	960	-90	1075	115	132	F	84	370	405	1.68	68.3
85	6	1085	1010	-75	1125	115	120	F	85	385	401	1.65	77.7
97	7	1020	920	-100	1110	190	124	F	80	355	375	1.54	76.0
741	3	850	725	-125	905	180	80	M	65	415	366	1.58	82.0
810	2	825	715	-110	860	145	122	M	75	310	267	1.31	67.7
887	2	800	660	-140	Cow died prior to calving-cause unknown						---	----	----
902	7	1130	990	-140	1150	160	93	F	74	355	331	1.34	70.7
931	4	880	800	-80	970	170	93	M	77	330	300	1.21	71.0
937	7	1280	1070	-210	1260	190	92	M	90	445	394	1.69	79.0
Avg.	5	1006	900	-106	1076	149	115		79	370	355	1.50	74.0
Lot or Treatment 1P (1959-60)													
16	6	1245	1090	-155	1320	230	115	F	90	415	423	1.74	84.0
20	6	955	880	-75	960	80	116	M	75	410	399	1.80	83.0
52	6	1220	1050	-170	1260	210	92	F	98	440	410	1.63	81.3
87	6	965	780	-185	955	175	78	M	64	440	366	1.68	87.3
722	3	825	810	-15	970	160	86	F	64	390	371	1.51	78.3
847	2	740	670	-70	870	200	---	-	Born dead		---	----	----
910	7	1230	1030	-200	1200	170	98	M	80	440	397	1.76	84.0
925	7	1025	950	-75	1100	150	97	M	85	290	270	1.00	62.3
947	7	1125	1115	-10	1180	65	153	F	75	325	396	1.68	68.7
957	7	1265	1095	-170	1260	165	109	M	70	480	451	2.12	85.7
Avg.	5+	1060	947	-113	1108	160	105		78	403	387	1.66	79.4

APPENDIX TABLE IV. (CONTINUED).

Cow No.	Age	Init. Wt. 1/ 12-16-59	Final Wt. 2/ 5-23-60	Gain	Summer Wt. 3/ 10-28-60	Gain	Calving 4/ Date	Sex	Birth Wt.	Weaning Wt.	Adj. Wean 5/ Wt.	A.D.G. to Weaning	Score 6/
					Lot or Treatment 2 (1959-60)								
3	6	1100	1005	-95	1150	145	82	M	72	415	445	1.56	85.7
56	6	1400	1235	-165	1295	60	78	F	60	440	384	1.70	81.7
78	7	1170	1045	-125	1220	175	109	F	70	425	380	1.84	82.3
82	7	1085	1020	-65	1125	105	77	F	68	395	345	1.45	76.0
89	6	1170	1080	-90	1200	120	76	F	60	440	380	1.68	76.7
729	3	1105	880	-225	1075	195	78	M	64	490	426	1.90	85.7
819	2	825	735	-90	865	130	98	M	70	340	339	1.32	70.3
831	2	820	705	-115	915	210	109	F	67	320	350	1.31	66.7
915	7	1240	1245	5	1270	25	93	F	82	380	356	1.43	81.0
934	7	1195	1000	-195	1225	225	112	F	93	415	417	1.69	82.0
Avg.	5+	1111	995	-116	1134	139	91		71	406	382	1.59	78.8
					Lot or Treatment 2P (1959-60)								
33	6	1325	1190	-135	1370	180	115	F	83	345	352	1.40	71.7
39	6	1135	1000	-135	1200	200	82	M	72	415	353	1.56	85.3
64	6	1120	1000	-120	1125	125	100	M	95	430	394	1.66	85.3
83	6	1105	980	-125	1115	135	91	F	80	445	410	1.73	84.3
91	6	1020	935	-85	1075	140	97	M	80	405	366	1.59	78.0
811	2	765	660	-105	860	200	132	F	60	225	271	0.97	51.7
832	2	825	775	-50	945	170	116	F	60	305	344	1.32	64.3
835	2	680	775	95	935	160	Born dead		--	---	---	----	----
841	2	775	690	-85	925	235	93	F	65	305	314	1.15	65.7
935	7	1150	990	-160	1135	145	90	M	90	430	378	1.60	80.3
960	7	1215	1100	-115	1230	130	93	F	82	420	393	1.62	80.3
Avg.	4+	1010	918	-92	1083	165	101		77	372	358	1.46	74.7

APPENDIX TABLE IV. (CONTINUED).

Cow No.	Age	Init. Wt. 1/ 12-16-59	Final Wt. 2/ 5-23-60	Gain	Summer Wt. 3/ 10-28-60	Gain	Calving 4/ Date	Sex	Birth Wt.	Weaning Wt.	Adj. Wean 5/ Wt.	A.D.G. to Weaning	Score 6/
					Lot or Treatment 3 (1959-60)								
14	6	1275	1090	-185	1270	180	83	M	95	490	419	1.80	83.3
48	6	1175	1065	-110	1225	160	90	M	90	455	455	2.03	90.7
57	6	1125	1060	-65	1155	95	95	M	72	410	365	1.63	81.3
79	7	1170	1065	-105	1235	170	85	F	75	370	336	1.36	75.3
84	6	1065 7/	Cow died 5/15		----	---	94	F	70	Cow died calf was raised by cow 42			
709	3	980	865	-115	985	120	83	M	79	470	421	1.79	82.7
717	3	975	885	-90	1080	195	Cow did not calve			---	---	----	----
904	7	1175	1085	-90	1170	85	88	M	75	425	370	1.64	88.0
930	7	1225	1045	-180	1175	130	103	F	75	390	377	1.58	81.3
827	2	790	670	-120	815	145	75	F	68	405	385	1.48	67.0
886	2	825	790	-35	1065	275	100	M	Born dead		---	----	----
Avg.	5+	1072	962	-110	1118	156	90		70	427	391	1.66	81.2
					Lot or Treatment 3P (1959-60)								
6	6	1260	1075	-185	1240	165	88	M	85	465	400	1.75	84.0
12	6	1245	1140	-105	1335	195	86	F	70	450	383	1.64	82.0
73	6	1080	985	-95	1150	165	86	M	60	385	301	1.34	79.3
706	3	945	845	-100	940	95	80	M	66	390	328	1.37	75.7
710	3	1225	1075	-150	1220	145	78	M	75	480	415	1.78	83.7
713	3	910	830	-80	945	115	89	F	70	360	326	1.25	72.0
840	2	785	740	-45	925	185	87	M	78	320	299	1.08	67.3
917	7	1250	1160	-90	1295	135	93	M	100	495	453	1.96	85.7
944	7	1125	975	-150	1165	190	87	F	78	440	388	1.62	85.0
953	7	1115	1045	-70	1120	75	103	M	90	420	371	1.56	85.7
Avg.	5	1094	987	-107	1134	146	88		77	420	366	1.54	80.0

APPENDIX TABLE IV. (CONTINUED).

Cow No.	Age	Init. Wt. 1/ 12-16-59	Final Wt. 2/ 5-23-60	Gain	Summer Wt. 3/ 10-28-60	Gain	Calving 4/ Date	Sex	Birth Wt.	Weaning Wt.	Adj. Wean 5/ Wt.	A.D.G. to Weaning	Score 6/
					Lot or Treatment 4 (1959-60)								
24	6	1280	1210	-70	1315	105	91	F	68	405	374	1.60	80.0
47	6	1150	1075	-75	1180	105	143	M	85	385	425	1.89	82.0
61	6	1105	1015	-90	1115	100	86	M	80	490	422	1.90	89.3
71	6	1290	1190	-100	1335	145	96	F	78	345	328	1.30	72.3
86	6	970	825	-145	940	115	79	F	73	460	405	1.74	83.3
702	3	985	920	-65	1110	190	78	F	67	435	399	1.64	84.3
704	3	1000	945	-55	1190	245	106	M	75	330	324	1.30	64.7
829	2	780	750	-30	865	115	101	F	70	340	359	1.34	72.0
914	7	1175	1000	-175	1145	145	111	M	80	335	321	1.34	73.3
921	7	1155	1035	-120	1185	150	99	M	80	415	377	1.65	82.0
Avg.	5+	1089	996	-93	1138	142	99		76	394	373	1.57	78.3
					Lot or Treatment 4P (1959-60)								
13	6	1450	1335	-115	1425	90	80	M	80	530	445	2.03	85.7
34	6	1225	1155	-70	1260	105	94	F	84	440	412	1.71	82.3
42	6	1225	1120	-105	1205	85	90	F	100	Calf died, cow raised cow 84's calf			
77	7	1150	1090	-60	1225	135	88	F	65	375	342	1.45	77.7
88	6	970	1055	85	1200	145	93	M	84	455	404	1.78	80.3
723	3	1150	1030	-120	----	---	102	F	80	395	401	1.58	79.3
730	3	800	725	-75	910	185	114	M	80	360	368	1.50	79.3
813	2	800	690	-110	845	155	117	M	70	320	344	1.35	63.3
901	7	1210	1140	-70	1240	100	91	F	95	445	414	1.66	85.0
961	7	1110	985	-125	1135	150	87	M	67	425	368	1.67	85.0
Avg.	5+	1109	1032	-77	1161	128	96		80	416	389	1.64	79.8

1/ Date supplemental feeding began.
2/ Date supplemental feeding terminated.
3/ End of summer grazing; also weaning date.
4/ Chronological day of the year in which birth occurred.
5/ Adjusted for age of dam and sex of calf to 180 days of age.
6/ The average of scores given by three persons at time of weaning.
7/ Individual weights not used in computing averages.

APPENDIX TABLE V. PHOSPHORUS, CAROTENE, AND VITAMIN A BLOOD LEVELS OF COWS FED VARIOUS SUPPLEMENTS ON WINTER RANGE (1957-1958).

Milligrams of inorganic phosphorus/100 ml. plasma

Lot	Cow No.	1-7-58 1/	2-27-58 2/
1	2	4.92	3.44
	29	4.56	2.44
	50	5.43	3.64
	85	4.61	3.20
	97	3.16	2.67
	902	4.78	3.28
	937	5.15	2.97
Lot Average		4.66	3.09
Lot 1P	16	5.52	4.39
	20	3.60	4.70
	52	7.56	4.88
	87	6.61	4.92
	910	5.71	5.81
	947	5.81	2.88
	43	----	3.44
Lot Average		5.80	4.43
Lot 2	3	6.72	4.05
	26	6.00	4.92
	56	6.36	4.97
	82	6.20	5.48
	89	3.92	2.82
	915	4.09	3.88
	934	6.61	5.01
Lot Average		5.70	4.45
Lot 2P	33	6.77	4.48
	39	6.05	3.93
	64	7.36	4.18
	83	4.83	5.38
	91	6.72	2.82
	935	5.34	4.52
	963	3.80	4.35
Lot Average		5.84	4.24

APPENDIX TABLE V. (CONTINUED).

Lot	Cow No.	1-7-58 1/	2-27-58 2/
	Milligrams of inorganic phosphorus/100 ml. plasma		
3	14	4.60	4.61
	48	4.88	4.22
	57	6.46	4.22
	79	4.52	3.88
	84	5.71	4.14
	904	6.66	3.84
	930	7.14	3.40
Lot Average		5.71	4.04
Lot 3P	6	6.15	3.60
	12	4.22	4.70
	73	4.26	9.96
	90	4.52	3.24
	917	7.14	4.52
	944	7.25	4.70
	953	3.44	3.88
Lot Average		5.28	4.94
Lot 4	24	3.36	4.92
	47	4.04	4.44
	71	3.28	3.60
	86	6.82	3.48
	914	5.15	3.97
	916	4.31	5.20
	921	5.86	4.44
Lot Average		4.69	4.29
Lot 4P	13	4.26	4.88
	34	4.26	4.44
	42	4.78	4.44
	77	4.39	3.24
	88	3.20	4.26
	901	5.76	3.88
	961	5.15	4.31
Lot Average		4.54	4.21

APPENDIX TABLE V. (CONTINUED).

	Micrograms of carotene/100 ml. plasma		
Lot	Cow No.	1-7-58 1/	2-27-58 2/
1	2	98.74	72.32
	29	123.49	104.78
	50	80.12	80.12
	85	140.52	98.74
	97	95.22	109.65
	902	124.75	162.67
	937	136.49	100.00
Lot Average		114.19	104.04
	Micrograms of vitamin A/100 ml. plasma 3/		
Lot	2	33.63	7.66
1	29	12.26	9.10
	50	25.62	5.17
	85	7.87	----
	97	31.35	----
	902	41.79	17.08
	937	28.01	16.69
Lot Average		25.79	11.14
	Micrograms of carotene/100 ml. plasma		
Lot	16	114.68	88.17
1P	20	110.91	95.22
	52	151.43	75.59
	87	151.43	109.73
	910	139.18	65.69
	947	131.29	98.74
	43	------	95.22
Lot Average		133.15	89.76
	Micrograms of vitamin A/100 ml. plasma 3/		
Lot	16	31.70	2.67
1P	20	13.88	0.63
	52	31.52	4.22
	87	34.51	8.40
	910	18.48	37.53
	947	15.32	7.34
	43	-----	5.48
Lot Average		24.24	9.47

APPENDIX TABLE V. (CONTINUED).

Lot	Cow No.	1-7-58 1/	2-27-58 2/
	Micrograms of carotene/100 ml. plasma		
2	3	113.42	72.32
	26	83.30	61.33
	56	180.12	118.46
	82	186.07	52.83
	89	124.75	109.73
	915	120.97	77.85
	934	101.17	46.56
Lot Average		129.97	77.01
	Micrograms of vitamin A/100 ml. plasma 3/		
Lot 2	3	34.72	8.47
	26	24.00	20.77
	56	31.84	41.08
	82	23.12	1.55
	89	13.95	22.91
	915	28.89	-----
	934	15.32	39.33
Lot Average		24.55	22.35
	Micrograms of carotene/100 ml. plasma		
Lot 2P	33	118.46	88.17
	39	214.51	70.05
	64	169.80	11.92
	83	189.18	132.55
	91	118.46	108.47
	935	136.44	104.78
	963	90.52	68.96
Lot Average		148.19	83.56
	Micrograms of vitamin A/100 ml. plasma 3/		
Lot 2P	33	35.95	2.28
	39	29.31	----
	64	31.94	10.33
	83	30.82	48.88
	91	14.30	6.36
	935	14.13	22.28
	963	12.05	12.05
Lot Average		24.07	17.03

APPENDIX TABLE V. (CONTINUED).

Lot	Cow No.	1-7-58 1/	2-27-58 2/
	Micrograms of carotene/100 ml. plasma		
3	14	90.52	68.96
	48	126.04	63.51
	57	106.04	82.38
	79	164.09	119.72
	84	87.00	61.33
	904	158.39	89.35
	930	169.95	39.43
Lot Average		128.86	74.95
	Micrograms of vitamin A/100 ml. plasma 3/		
Lot 3	14	24.49	18.98
	48	27.13	12.37
	57	34.69	10.86
	79	15.18	39.43
	84	27.06	9.98
	904	28.64	6.68
	930	39.29	18.94
Lot Average		28.07	16.75
	Micrograms of carotene/100 ml. plasma		
Lot 3P	6	120.97	63.51
	12	174.16	131.29
	73	158.40	83.56
	90	165.52	104.78
	917	135.24	64.60
	944	161.24	97.57
	953	175.59	109.73
Lot Average		155.87	93.58
	Micrograms of vitamin A/100 ml. plasma 3/		
Lot 3P	6	25.51	-----
	12	40.98	17.54
	73	16.41	34.02
	90	38.34	3.73
	917	28.08	9.77
	944	12.93	38.17
	953	14.51	20.17
Lot Average		25.25	20.57

APPENDIX TABLE V. (CONTINUED).

Lot	Cow No.	1-7-58 1/	2-27-58 2/
	Micrograms of carotene/100 ml. plasma		
4	24	119.72	80.87
	47	127.35	67.87
	71	124.75	117.20
	86	135.24	144.55
	914	113.42	59.23
	916	122.23	54.95
	921	141.86	73.41
Lot Average		126.37	85.44
	Micrograms of vitamin A/100 ml. plasma 3/		
Lot 4	24	20.95	16.52
	47	29.94	5.90
	71	17.50	14.23
	86	35.99	31.42
	914	30.29	50.96
	916	14.06	27.97
	921	38.66	5.55
Lot Average		26.77	21.79
	Micrograms of carotene/100 ml. plasma		
Lot 4P	13	124.75	85.91
	34	186.07	98.74
	42	107.22	61.33
	77	122.25	84.73
	88	151.43	97.57
	901	81.29	53.86
	961	95.22	70.05
Lot Average		124.03	78.88
	Micrograms of vitamin A/100 ml. plasma 3/		
Lot 4P	13	19.29	2.81
	34	43.50	14.58
	42	44.39	4.67
	77	19.43	30.54
	88	20.00	3.97
	901	33.14	7.94
	961	28.92	35.78
Lot Average		29.81	14.33

1/ Initial cow weights and blood taken this date and supplemental feeding began.
2/ Blood taken 51 days after supplemental feeding began.
3/ The values listed are probably not valid. Those values below 20 mcg./100 ml. are probably the result of excessive oxidation during analysis.

APPENDIX TABLE VI. PHOSPHORUS, CAROTENE, AND VITAMIN A BLOOD LEVELS OF COWS FED VARIOUS SUPPLEMENTS ON WINTER RANGE (1959-1960).

	Milligrams of inorganic phosphorus/100 ml. plasma			
Lot	Cow No. 1/	12-16-59 2/	3-10-60	4-21-60 3/
1	29	4.52	4.65	----
	50	3.80	3.44	----
	97	2.08	2.48	----
	810	4.57	4.74	----
	937	3.05	5.01	4.39
Lot Average		3.60	4.06	4.39
Lot 1P	16	3.97	6.41	----
	52	2.55	5.38	3.24
	87	4.35	4.92	5.52
	910	3.48	----	----
Lot Average		3.59	5.57	4.38
Lot 2	3	---- 4/	3.44	4.22
	82	---- 4/	4.09	4.22
	819	2.48	3.12	4.22
	915	---- 4/	5.06	4.35
	934	3.05	4.70	----
Lot Average		2.76	4.08	4.25
Lot 2P	33	3.72	6.21	----
	39	4.22	5.15	5.76
	83	4.01	3.68	4.88
	811	4.18	6.10	----
	841	3.20	4.97	5.71
	960	3.36	3.97	4.26
Lot Average		3.78	5.01	5.15

APPENDIX TABLE VI. (CONTINUED).

Lot	Cow No. 1/	12-16-59 2/	3-10-60	4-21-60 3/
		Milligrams of inorganic phosphorus/100 ml. plasma		
3	48	2.48	3.28	3.72
	57	3.12	3.89	5.06
	79	2.52	2.48	----
	930	3.93	3.12	3.84
	827	4.01	4.35	4.97
Lot Average		3.21	3.42	4.40
Lot 3P	12	2.67	3.40	4.88
	73	4.35	4.74	4.26
	840	---- 4/	5.06	5.62
	917	4.74	4.01	5.34
	944	2.82	4.70	4.31
Lot Average		3.64	4.38	4.88
Lot 4	24	2.23	3.01	3.97
	71	4.22	3.16	3.56
	829	---- 4/	4.13	4.57
	914	2.93	2.89	----
	921	3.24	3.68	3.64
Lot Average		3.16	3.37	3.93
Lot 4P	13	3.44	5.01	5.96
	34	3.84	5.76	4.74
	77	3.20	3.84	4.76
	813	3.48	5.24	----
	961	2.55	4.88	5.06
Lot Average		3.30	4.95	5.13

APPENDIX TABLE VI. (CONTINUED).

Lot	Cow No. 1/	12-16-59 2/	3-10-60	4-21-60 3/
		Micrograms of carotene/100 ml. plasma		
1	29	136.49	70.05	------
	50	122.23	18.71	------
	97	106.04	23.57	------
	810	187.58	98.74	------
	937	114.68	36.41	243.54
Lot Average		133.40	49.50	243.54
		Micrograms of vitamin A/100 ml. plasma 5/		
Lot 1	29	16.80	32.33	------
	50	20.35	1.23	------
	97	14.16	18.59	------
	810	-----	5.27	------
	937	20.35	13.95	36.94
Lot Average		17.92	14.27	36.94
		Micrograms of carotene/100 ml. plasma		
Lot 1P	16	171.23	40.44	------
	52	158.39	55.96	401.01
	87	203.19	70.05	415.27
	910	165.52	-----	------
Lot Average		174.58	55.48	408.12
		Micrograms of vitamin A/100 ml. plasma 5/		
Lot 1P	16	70.46	47.27	------
	52	18.24	11.14	30.93
	87	15.60	4.15	24.21
	910	18.73	-----	------
Lot Average		30.76	20.85	27.57

APPENDIX TABLE VI. (CONTINUED).

Lot	Cow No. 1/	12-16-59 2/	3-10-60	4-21-60 3/
		Micrograms of carotene/100 ml. plasma		
2	3	------ 4/	38.42	267.62
	82	------ 4/	9.23	409.40
	819	133.89	39.43	250.84
	915	------ 4/	46.56	333.89
	934	221.14	57.05	------
Lot Average		177.53	38.14	315.44
		Micrograms of vitamin A/100 ml. plasma 5/		
Lot 2	3	------ 4/	44.74	22.21
	82	------ 4/	15.57	20.91
	819	------ 4/	9.95	20.28
	915	------ 4/	22.95	22.81
	934	22.03	18.80	-----
Lot Average		22.03	22.40	21.55
		Micrograms of carotene/100 ml. plasma		
Lot 2P	33	119.72	50.76	------
	39	80.12	21.56	282.72
	83	174.16	37.42	307.89
	811	203.19	95.22	------
	841	119.72	47.65	276.85
	960	221.14	64.60	359.90
Lot Average		153.01	52.87	306.84
		Micrograms of vitamin A/100 ml. plasma 5/		
Lot 2P	33	18.66	24.53	-----
	39	22.81	12.72	17.92
	83	19.57	5.27	23.83
	811	5.03	7.98	-----
	841	1.23	2.64	14.51
	960	10.93	17.47	18.27
Lot Average		13.04	11.77	18.63

APPENDIX TABLE VI. (CONTINUED).

Lot	Cow No. 1/	12-16-59 2/	3-10-60	4-21-60 3/
		Micrograms of carotene/100 ml. plasma		
3	48	152.77	40.44	250.84
	57	42.87	38.42	250.84
	79	372.48	24.50	------
	930	136.78	36.41	243.54
	827	117.20	8.31	------
Lot Average		164.42	29.62	248.41
		Micrograms of vitamin A/100 ml. plasma 5/		
Lot 3	48	25.09	12.90	19.43
	57	19.79	3.20	22.70
	79	20.03	6.40	-----
	930	27.06	13.53	16.94
	827	13.49	19.89	-----
Lot Average		21.09	11.18	19.69
		Micrograms of carotene/100 ml. plasma		
Lot 3P	12	241.78	52.85	291.11
	73	164.09	42.37	345.64
	840	------ 4/	42.37	288.59
	917	165.42	30.37	238.26
	944	141.86	64.60	421.14
Lot Average		178.31	46.51	316.95
		Micrograms of vitamin A/100 ml. plasma 5/		
Lot 3P	12	16.59	58.62	29.91
	73	25.87	4.74	18.63
	840	----- 4/	4.53	24.42
	917	17.82	17.29	18.17
	944	11.18	12.30	25.97
Lot Average		17.86	19.50	23.42

APPENDIX TABLE VI. (CONTINUED).

Lot	Cow No. 1/	12-16-59 2/	3-10-60	4-21-60 3/
	Micrograms of carotene/100 ml. plasma			
4	24	129.95	82.38	219.46
	71	196.90	34.40	249.16
	829	------ 4/	43.46	201.59
	914	133.89	26.43	------
	921	180.12	26.43	245.30
Lot Average		160.22	42.62	228.88
	Micrograms of vitamin A/100 ml. plasma 5/			
Lot 4	24	24.04	38.10	24.07
	71	17.78	20.14	21.37
	829	----- 4/	22.25	21.75
	914	14.30	13.71	-----
	921	11.11	11.60	23.05
Lot Average		16.81	21.16	22.56
	Micrograms of carotene/100 ml. plasma			
Lot 4P	13	189.18	33.39	295.30
	34	193.79	67.87	309.57
	77	154.20	35.07	292.79
	813	127.35	38.42	------
	961	143.21	35.40	250.84
Lot Average		161.55	42.03	287.12
	Micrograms of vitamin A/100 ml. plasma 5/			
Lot	13	23.41	38.90	30.71
	34	14.34	15.11	26.25
	77	16.66	16.52	21.23
	813	1.97	17.26	-----
	961	13.74	18.31	22.70
Lot Average		14.02	21.22	25.22

1/ Approximately one-half of the cows in each treatment or lot were bled.
2/ Initial weights for the wintering period were taken; cows were bled and supplemental feeding began.
3/ Final bleeding occurred during calving. Any cow that was in the bleeding schedule and had not calved before this date was not used for collection.
4/ Not included in the initial bleeding but was included for the two subsequent bleedings.
5/ The values listed are probably not valid. These values below 20 mcg./ 100 ml. plasma are probably the result of excessive oxidation of vitamin A during analysis.