MONTANA STATE UNIVERSITY

# Diammonium phosphate as a source of nitrogen and phosphorus for beef cattle

by Gary L Cowman

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Animal Science
Montana State University
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Abstract:
Two experiments were conducted to evaluate the use of diammonium phosphate as a supplemental source of nitrogen and phosphorus for beef cattle.

Experiment I was designed to compare diammonium phosphate with mono-ammonium phosphate, urea, and soybean oil meal, as an added nitrogen source to wintering and fattening rations fed to steers. Thirty-two Hereford steer calves were used in this study. The steers were on the wintering trial for 112 days and the fattening trial 168 days. During the wintering trial, the steers were individually fed a low protein ration once daily.

All of the steers in both trials received the same basal ration, the only difference among treatments being in the added source of nitrogen in each of the eighteen percent protein supplements. Lot 1 received monoammonium phosphate; Lot 2, diammonium phosphate; Lot 3, urea; and Lot 4, soybean oil meal. The basal ration fed during the wintering period consisted of steam-rolled barley, dried molasses beet pulp, and grass hay. During the fattening trial, the high-concentrate basal ration was self-fed, (eighty percent steam-rolled barley, twenty percent dried molasses beet pulp) . In both trials, the steers received one pound of eighteen percent protein supplements furnishing the additional nitrogen. The steers remained in the same lots and on the same sources of -supplemental nitrogen throughout both feeding trials. There were no significant differences among the weight gains made by the four lots of steers, during either the wintering or fattening trial. Only small differences were noted among the four lots of steers during the wintering trial. In the fattening trial, steers fed part of the added nitrogen as soybean oil meal required 7.5 percent less feed per pound of gain and gained 0.26 pound more daily than those steers fed part of the added nitrogen as monoammonium phosphate.

In experiment II, diammonium phosphate and defluorinated phosphate were compared as supplemental sources of phosphorus at three levels of percent phosphorus intake. The levels used were 0.18, 0.24, and 0.30 percent phosphorus of the total ration. The thirty-two Hereford heifer calves used as the experimental animals were divided into eight treatments of four head each. The heifers were individually fed during the 140-day wintering trial. All of the heifers received the same low-phosphorus basal ration, the only difference among treatments being in either the added source or level of phosphorus in each of the twenty percent prothin supplements. The two control lots received a 0.12 percent phosphorus ration.

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# DIAMMONIUM PHOSPHATE AS A SOURCE OF NITROGEN AND PHOSPHORUS FOR BEEF CATTLE

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## ABSTRACT

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Experiment I was designed to compare diammonium phosphate with monoammonium phosphate, urea, and soybean oil meal, as an added nitrogen source to wintering and fattening rations fed to steers. Thirty-two Hereford steer calves were used in this study. The steers were on the wintering trial for 112 days and the fattening trial 168 days. During the wintering trial, the steers were individually fed a low protein ration once daily. All of the steers in both trials received the same basal ration, the only difference among treatments being in the added source of nitrogen in each of the eighteen percent protein supplements. Lot 1 received monoammonium phosphate; Lot 2, diammonium phosphate; Lot 3, urea; and Lot 4, soybean oil meal. The basal ration fed during the wintering period consisted of steam-rolled barley, dried molasses beet pulp, and grass hay. During the fattening trial, the high-concentrate basal ration was self-fed, (eighty percent steam-rolled barley, twenty percent dried molasses beet pulp). In both trials, the steers received one pound of eighteen percent protein supplements furnishing the additional nitrogen. The steers remained in the same lots and on the same sources of supplemental nitrogen throughout both feeding trials. There were no significant differences among the weight gains made by the four lots of steers, during either the wintering or fattening trial. Only small differences were noted among the four lots of steers during the wintering trial. In the fattening trial, steers fed part of the added nitrogen as soybean oil meal required 7.5 percent less feed per pound of gain and gained 0.26 pound more daily than those steers fed part of the added nitrogen as monoammonium phosphate.

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# INTRODUCTION

The lower net returns, commonly experienced in the present day beef cattle industry, greatly emphasizes the importance of providing adequate levels of nutrients for maximum production. In several areas of Montana, phosphorus plays a vital role in limiting the efficiency of beef production. Cattle grazing on many of the state range land require a supplemental source of phosphorus and in some instances additional protein. The problem of phosphorus and protein supplementation also exists when cattle are wintered on high roughage rations, especially when the roughage is grown on low phosphorus soils.

Many of the inorganic phosphorus supplements commonly used are expensive and besides phosphorus, supplies only calcium. There would be a distinct feeding advantage if the inorganic supplement would not only supply phosphorus but also nitrogen. Diammonium phosphate, a non-protein nitrogen compound, contains twenty-three percent phosphorus and twenty-one percent nitrogen. This amount of nitrogen gives a protein equivalent of 131 percent or one-half of that furnished by urea. Diammonium phosphate has been widely used as a phosphorus and nitrogen source in commercial fertilizer. However, very little experimental work has been conducted to determine its use for ruminants.

Because diammonium phosphate may possibly be priced competitively with urea and some sources of phosphorus as a feeding ingredient there is a need to determine its feeding value in beef cattle rations. The objectives of the experiments reported in this manuscript were to evaluate diammonium phosphate as a source of nitrogen and phosphorus for beef cattle.

# REVIEW OF LITERATURE

An extensive amount of research has been conducted on the physiological and economical importance of providing adequate mineral nutrition for farm animals in order to attain maximum production. According to Maynard and Loosli (1956), our specific knowledge of proper mineral nutrition is due primarily to research conducted during the last thirty years.

The functions of mineral nutrients are varied and numerous. Mitchell (1947) conveniently classified the biological functions of minerals under the following four headings: (1) minerals contribute to the structure of the body, (2) they aid in maintaining the status quo of the tissues already formed against the constant erosion of the life processes, (3) minerals participate in the functional activities of the body, such as muscular activities, and (4) as integral parts of enzyme systems in the tissues, minerals aid materially in the metabolizing of organic food nutrients.

## THE BIOLOGICAL FUNCTIONS OF PHOSPHORUS

Among the mineral elements required by animals, phosphorus is foremost in importance (Mitchell, 1947). Bohstedt (1940) stated that if cows need extra minerals, phosphorus is the one element other than salt which they need most. Phosphorus, which is present to the amount of a few tenths percent in non-mineralized tissues, is necessary for all forms of life and is present in all living cells (Greaves et al., 1934, Van Wazer, 1961).

Phosphorus has more functions than any other element in the body; at least fourteen vital functions have been determined for this versatile element. In living systems, phosphorus functions both chemically and physically.

In general, eighty percent of the total phosphorus in the body is found in bone and teeth. One gross physical property of phosphorus is the mechanical strengthening of the body through the formation of mineralized tissues (Harrow and Mazur, 1959 and White, 1959). According to Mitchell (1947), the phosphorus found in the bone is of minor importance in animal economy and it is the phosphorus in the soft tissue that is doing yeoman service.

Through the formation of hexose-phosphates, adenylic acid, and creatin phosphate, phosphorus plays a primary role in carbohydrate metabolism. Phosphorus also is vitally concerned with the metabolism of fat and is involved in some phases of protein metabolism. Hawk et al. (1954) reported that the synthesis of body proteins, involving the linking together of amino acids resulting from protein digestion, occurs only after phosphorylation. Mitchell (1947) stated that there exists a hand-in-hand relationship between phosphorylation and oxidation and he further emphasized the ability of these functions to provide and distribute energy to body tissue. Baremore and Luck (1931) suggested that phosphorus functions as a catalyzing agent for biological oxidation, the degree of catalysis being proportional to the phosphate concentration.

Phosphorus is essential in muscular contractions and in the functioning of the central nervous system. It enters into the buffering powers of the blood and other tissues. Phosphates have also been shown to be involved with vitamin and enzyme activity (Greaves et al., 1934, Hawk et al., 1954 and Harrow and Mazur, 1959).

PHOSPHORUS REQUIREMENTS OF BEEF CATTLE

The requirement of farm animals for calcium and phosphorus has become much greater, as their rates of production have increased through breeding and through more intensive methods of feeding and management (Morrison, 1956).

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 tables are not entirely consistent.

Van Wazer (1961) suggests that, in considering the requirement of beef cattle for phosphorus, needs for maintenance, growth and fattening under many different conditions must be taken into account.

Comparisons of phosphorus retention in dairy calves fed phosphorus, at the rate of 1.8 and 3.25 grams per one hundred pounds of live weight, made by Archibald and Bennett (1935), showed that the higher intake of phosphorus resulted in greater retention. These findings are comparable to those of Huffman et al. (1933), who found that 10 to 21 grams of phosphorus daily were adequate for young dairy cattle from eighteen months to first calving.

Forbes et al. (1929) conducted a balance study with 1,000-pound beef steers and showed that an intake of 10.84 grams daily was necessary to produce a positive phosphorus balance for maintenance. In contrast to this study, Watkins (1933) showed that 500-pound steers ingesting 11.03 grams of feed phosphorus had a negative balance, but the steers receiving 14.7 grams of feed phosphorus, furnished either by natural feeds or disodium phosphate, showed uniformily positive phosphorus balances. He found also that growing steers of eighteen months of age could not satisfy their phosphorus needs with a daily intake of 8.5 grams of phosphorus.

In studying the effect of adding phosphorus supplements to beet by-product rations, Maynard et al. (1936) found that yearling steers showed definite symptoms of aphosphorosis with a daily intake of 1.96 grams of phosphorus per one hundred pounds of live weight daily. Their investigation also indicated that both calves and yearlings met their daily requirement by receiving, respectively, 18.0 and 24.0 grams of phosphorus per steer daily; however, they emphasized that these values are not necessarily the minimum requirement. In a preliminary report, Beeson et al. (1937) demonstrated that the minimum daily phosphorus requirement for fattening six hundred pound steer calves is slightly less than twelve grams of phosphorus daily or an intake of about two grams daily per one hundred pounds of live weight. Later, Beeson (1940) concluded that the minimum physiological phosphorus requirement is possibly near 1.80 grams per one hundred pounds of live weight; however, he suggested that even though the recommendation of two grams per hundred pounds of body weight is not necessarily the minimum requirement necessary to support normal nutrition and health of the animal, it is as low a level as should be fed under practical feeding conditions.

Tillman et al. (1959) observed that two grams of phosphorus per hundred pounds of live weight did not meet the phosphorus requirement for four hundred pound steers, when the response was measured by weight gains, feed consumption, or feed efficiency. If bone growth and plasma-inorganic phosphorus data were the response criteria, it was found that two grams per hundred weight net the phosphorus requirement for these functions. These results are in agreement with those of Burroughs et al. (1956) and suggest that phosphorus requirement for weight gains and feed response is greater than for bone growth or maintenance of plasma-inorganic phosphorus level. Both Burroughs et al. (1956) and Tillman et al. (1959) indicated that the phosphorus requirement may be higher than that reported by Beeson (1941).

According to Hagg (1940), rations for cattle are not likely to be seriously deficient in calcium and phosphorus, unless its dry matter contains less than about 0.3 to 0.4 percent calcium and 0.2 to 0.3 percent phosphorus.

The National Research Council (1958) suggested that for high rates of live weight gains a minimum of 0.20 percent phosphorus in fattening rations and 0.15 percent phosphorus in other rations be fed to beef cattle. These are minimum requirements and allow no margin of safety. Wise et al. (1958) recommended an increase in the phosphorus level of the ration of 0.08 percent phosphorus over the minimum requirements. Wise stated that this would appear to be a reasonable safety factor under most conditions.

FACTORS AFFECTING THE UTILIZATION OF PHOSPHORUS

Calcium-phosphorus ratio

Most literature pertaining to calcium and phosphorus indicates that these two elements not only need to be present in sufficient amounts in livestock rations, but also present in the proper proportion.

Meigs et al. (1926) reported that phosphorus assimilation may be interfered with by an excess of calcium in the ration. These workers emphasized that two parts or more by weight of calcium to one of phosphorus constitute an excess. Likewise, Turner et al. (1927) obtained better assimilation of calcium and phosphorus when the calcium-phosphorus ratio of the feed was 1.25 than when it was 2.5. Otto (1938) reported that varying the intakes of calcium and phosphorus from the optimum resulted in less efficient retention of both elements by growing calves.

Experimental data reported by Theiler et al. (1927) indicate that the minimum requirements for growth of cattle are higher in the case of phosphorus than calcium and a ratio of CaO to $P_2O_5$ as high as one to three is not necessarily disadvantageous.

Working with steers fed wintering rations, Dowe et al. (1957) found that when phosphorus was adequate, a high ratio of calcium to phosphorus resulted in lower gains. They suggested that if gains are used as a criterion, a critical calcium-phosphorus ratio may exist between four to one and nine to one. It was observed that the feed required per pound of gain increased as the calcium to phosphorus ratio became greater.

Beeson et al. (1945) reported that a calcium-phosphorus ratio as wide as nine to one was satisfactory for sheep when the ration was adequately supplied with calcium, phosphorus, and vitamin D.

According to Fairbanks (1939), factors other than the ratio of calcium and phosphorus must be considered. He stated that the presence of calcium and phosphorus in a ration does not assure availability of either, although the ratio of these elements might be optimum.

Vitamin D

The animal body can use calcium and phosphorus independently of each other only to a limited extent. The utilization of both calcium and phosphorus is intimately tied up with Vitamin D (Maynard and Loosli, 1956).

According to Hagg (1940), an ample supply of vitamin D (or its equivalent in sunshine) is necessary for the proper utilization of the calcium and phosphorus contained in the ration. Results obtained by Bethke (1932) showed that vitamin D has a marked influence on the retention of calcium and phosphorus. Wallis (1935) reported that the average calcium retention by dairy calves may be increased fourteen-fold and the phosphorus retention eleven-fold by vitamin D therapy.

Bethke et al. (1932) and Shohl (1936) studied the relationship between vitamin D and calcification and concluded that wider calcium-phosphorus ratios could be utilized by animals when ample vitamin D was present.

Trace minerals

Large intakes of iron, aluminum, magnesium, and zinc have been found to reduce phosphorus absorption in monogastric animals by forming insoluble phosphates in the intestinal tract (Maynard and Loosli, 1956).

Thomas (1951) observed that varying the amount of trace minerals in beef steer rations containing 0.20 percent phosphorus had an effect on rate of gain.

Recent results with lambs by Thompson et al. (1959) showed that dietary aluminum had a negligible effect on phosphorus absorption, although zinc was found to reduce phosphorus retention.

MTHEODS OF DETERMINING THE AVAILABILITY OF PHOSPHORUS FOR BEEF CATTLE

Blood levels

The inorganic phosphorus content of blood of cattle has been studied for several years as a measure of the adequacy of this mineral.

Palmer and Eckles (1927) and Green and DuToit (1927) reported work demonstrating that the blood of cattle suffering from phosphorus deficiency is very low in inorganic phosphorus. Henderson and Weakely (1930) reported that a low concentration of inorganic phosphorus in the blood is reliable indication of a ration inadequate in this element.

Van Landingham et al. (1935) found that the concentration of inorganic phosphorus in the blood was an important index of the severity of phosphorus deficiency in the ration of dairy heifers. These workers observed that, when heifers were fed low-phosphorus rations, the lowering of the blood phosphorus levels were roughly proportional to the severity of phosphorus deficiency. This is in agreement with work reported by Greaves et al. (1934), who demonstrated that there is a close correlation between phosphorus intake and inorganic phosphorus of the blood.

Malan et al. (1928) showed that the less pronounced phosphorus deficiency symptoms, manifested as malnutrition and stunting of growth, can be detected by blood analysis with a reasonable degree of certainty.

A study with lambs by Beeson et al. (1944) indicated that the inorganic phosphorus in the blood of sheep remains remarkably constant when the phosphorus content of the diet is unchanged. They found that a change in the dietary phosphorus intake causes an immediate change in the blood phosphorus level.

Two-year-old heifers showed a normal level of five mg. of inorganic phosphorus per 100 ml. of whole blood according to Malan et al. (1928). Normal levels for blood serum inorganic phosphorus of 7.30, 4.76, 5.07, and

4.89 percent were reported by Payne et al. (1946) for yearling bulls, herd bulls, two-year-old heifers, and aged cows, respectively.

Payne et al. (1946) showed that the inorganic phosphorus level of blood fluctuates with age and to a lesser extent with sex. Anderson et al. (1930) and Palmer et al. (1930) observed that the plasma-inorganic phosphorus content of calves increases until about six months of age, after which a decrease sets in which a decrease sets in which continues until the normal range for mature cattle is reached.

Long et al. (1952) noted a decline in plasma-inorganic phosphorus in heifers from a high of 7.5 mg. percent at approximately six months of age to 4.5 mg. percent two years later. Milligram percent is the number of milligrams per 100 cc. of blood or plasma.

Weight gains and feed utilization

Results obtained by Beeson et al. (1944) showed that, when phosphorus was fed at a suboptimal level, the rate of growth of lambs was closely correlated with phosphorus intake.

Kleiber et al. (1936) found that beef heifers fed a phosphorus-deficient ration (0.13 percent phosphorus) ceased to grow, and when the same heifers were fed a ration still lower in phosphorus (0.068 percent phosphorus), they lost weight. These authors reported that the control heifers fed the same ration but supplemented with dicalcium phosphate, so that the phosphorus content was about 0.4 percent, gained weight.

Lewis (1950) reported that in a study with beef steers, where the calcium to 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.

Similar results were obtained with steers by Long et al. (1956). These workers observed that feed intake, weight gains, and plasma-inorganic phosphorus levels increased in a linear manner (statistically significant, ($P < .05$)) with increased amounts of supplemental phosphorus over the range of 0.07, 0.11, and 0.15 percent.

Hughes et al. (1933) and Riddell et al. (1934) reported that a shortage of phosphorus in the ration becomes a limiting factor in the economical utilization of feeds.

Kleiber et al. (1936) found that phosphorus deficiency in beef heifers decreases the efficiency of energy utilization. Work conducted earlier by Eckles and Gullickson (1927) also indicated that cattle receiving rations inadequate in phosphorus utilize their feed less efficiently than animals on adequate phosphorus rations. These workers suggest that at least twenty percent more digestible nutrients are required in rations for cattle under phosphorus-deficient conditions.

Beeson et al. (1944) reported that lambs receiving a low-phosphorus ration required 20.6 percent more air-dry feed to grow and fatten than lambs receiving rations containing ample phosphorus. They emphasized that lambs are similar to steers in their reaction to low-phosphorus diets in that a phosphorus inadequency interfers more with the utilization of food than amount eaten.

Bone studies

The influence of feed on the bone strength of cattle has been studied by Becker and Neal (1930). They found that breaking strength determinations on the bones were reliable measures of the extent of calcium and phosphorus deficiency in cattle. Shrewbury and Vestal (1943) demonstrated that total weight of bone ash, percentage of ash, and bone wall thickness were significantly related to the amount of calcium and phosphorus in the rations. They found that the amount of calcium and phosphorus in the ration had no significant effect upon the length of the bones. These findings are further substantiated by Maynard and Loosli (1956). They reported that the measurement of density, hardness, and determination of breaking strength are useful measures in detecting the degree of calcium and phosphorus utilization.

Wise et al. (1960) found that bone growth, as measured by autoradiographs of femurs and ribs, was a sensitive method of determining the amount of phosphorus supplied by various phosphorus sources. They reported that calves fed rations supplemented with either dicalcium phosphate or defluorinated phosphate exhibited significantly more rib and femur growth than calves fed soft phosphate.

Balance studies

Balance studies involve a quantitative accounting for the intake of a given nutrient in the food and for its outgo in the excreta (Maynard and Loolsi, 1956). Van Wazer (1961) stated that much useful information may be obtained by the balance method, for it provides a means of measuring the availability of a specific nutrient to the animal body.

Van Wazer emphasized that, in phosphorus balance studies, it is important that the level of dietary phosphorus not exceed more phosphorus than the animal can utilize. Archibald and Bennett (1935) found that there is lower efficiency of utilization with higher intakes even though the total retention is greater.

Laboratory methods

The advantages would be quite apparent, if the results obtained from laboratory determinations of phosphorus availability could serve as a reliable index of phosphorus availability of supplements fed to ruminants.

Reynolds et al. (1944) developed a procedure to test the solubility of phosphate materials using 0.25 percent hydrochloric acid as a solvent for the phosphate.

Working with poultry, Bird and Mattingly (1945) concluded that the parallelism between availability and solubility was such that a determination of solubility could be used as a quick approximate measure of availability.

According to Gillis et al. (1948), the solubility test, developed by Reynolds, is useful only in that the insoluble compounds may be eliminated. They emphasized that the solubility of a compound is no indication of its biological availability.

Anderson et al. (1956) described an artificial rumen technique adapted for measuring phosphorus availability of supplements used in ruminant rations. Results obtained by Long et al. (1956) indicate close agreement between phosphorus availability studies with cattle involving growth, blood and bone analysis and the laboratory method of determinating phosphorus availability reported by Anderson.

BIOLOGICAL AVAILABILITY OF DIFFERENT SOURCES OF PHOSPHORUS

The question of availability of phosphorus from different sources for ruminant animals is one that has not been completely answered. The recommended allowances of phosphorus of various feeding standards are stated in terms of total phosphorus with no consideration being given to availability. Chemical analysis for phosphorus is meaningless if animals can not assimilate the phosphate.

Gillis et al. (1954) indicated that equivalent amounts of phosphorus from different sources are not necessarily of equal nutritional value. He emphasized that the content of availability rather than total phosphorus determines the usefulness of a phosphorus supplement.

Van Wazer (1961) reported that the only true measure of a feed phosphate compound is a test which determines how much of the phosphorus in the compound can be used by animals for its calcification and other life-sustaining processes.

Defluorinated products

Perhaps one of the earliest evaluations of phosphorus supplements was that of Theiler (1927) who observed that bone meal, sodium phosphate, calcium phosphate, phosphoric acid, and wheat bran were effective in alleviating the osteophagia of phosphorus deficient cattle, whereas ground rock phosphate had little curative effect.

Differences in availability of inorganic phosphorus are attributable in large part to the variation of pyrophosphate, metaphosphate, and orthophosphate (Beeson, 1960).

Gillis et al. (1948) reported that the meta- and pyro-forms of phosphates are likely to occur in the defluorination process of rock phosphate. They indicated that all three chemical forms of phosphorus are capable of existing singly or together in the end product of defluorination.

In a series of studies with either rats or chicks, Ellis et al. (1945) and Bird et al. (1945) have shown that the calcium metaphosphate and calcium pyrophosphate are less available than the orto form of phosphate. In other studies also with rats and chicks, Barrentine et al. (1944), Cabell et al. (1950), and Gillis et al. (1948) revealed that although most pyro- and metaphosphates were poorly utilized or completely unavailable, all orthophosphates such as bone meal, mono-, di-, and tricalcium phosphates were excellent sources for animal feeding.

In a study of availability to lambs of phosphorus from different sources using the balance technique, Ammerman et al. (1957) found that calcium pyrophosphate was essentially unavailable for lambs. They reported that the phosphorus from monocalcium phosphate, calcium metaphosphate, and calcium pyrophosphate was absorbed to the extent of sixty-three, thirty-four, and zero percent, respectively. Ammerman et al. suggested that some of the calcium metaphosphate may be hydrolyzed to calcium monophosphate in the intestinal fluids and thus become available. Further evidence of this chemical reaction taking place is indicated by Van Wazer (1961).

Ellis and Cabell (1944) indicated that the temperature of the defluorination process was a critical factor in reducing the availability of phosphorus to the animal. They observed a wide range in feeding value of defluorinated superphosphate, when the defluorination process was conducted under varying degrees of temperatures. The feeding values ranged from relatively poor in the case of the lowest to very good for the highest temperature.

Results obtained by Ammerman et al. (1957) showed that calcinedprocessed, defluorinated products were equal to dicalcium phosphate in promoting phosphorus retention and maintaining phosphorus blood levels in yearling steers. However, these workers observed in balance studies with lambs that the phosphorus from dicalcium phosphate and defluorinated phosphate did not exhibit equal availability. They reported that one-hundred percent of the phosphorus from dicalcium phosphate was absorbed, whereas only fifty-four percent of the phosphorus in defluorinated phosphate was utilized by lambs.

Experimental results reported by Wentworth et al. (1960) involving feeding trials with dairy heifers indicated that the phosphorus from dicalcium phosphate was the most available, followed closely by defluorinated phosphate and Curacao Island phosphate. However, from a series of studies with dairy calves, Wise et al. (1961) concluded that the phosphorus in the defluorinated phosphate tested was only slightly less available to the calf than that in chemically pure dicalcium phosphate. Availability of the phosphorus in Curoacao Island phosphate appeared to closely approach that of defluorinated phosphate.

Gullickson and Olsen (1946) reported that no significant difference was observed between defluorinated phosphate and bone meal in available phosphorus for dairy calves.

Other inorganic phosphates

The main phosphatic mineral supplement for animal feeds is dicalcium phosphate (Van Wazer, 1961). He emphasized that soft phosphate with colloidal clay is by far the poorest phosphorus supplement. Although there are some contradictory results reported, most experimental data coincides with Van Wazer's conclusion. Soft phosphate with colloidal clay is a mixture of fine particles of rock phosphate and clay.

Working with poultry, Gillis et al. (1954) determined the biological values of several inorganic phosphates. The biological values, expressed as the percentage of the value of 100, assigned tricalcium phosphate, were as follows: dicalcium phosphate, 98; steamed bone meal, 70 to 100; defluorinated phosphate, 82 to 89; Curacao Island phosphate, 87; and soft phosphate with colloidal clay less than 50.

Results obtained with cattle seem to indicate that several of the sources of phosphorus exhibit relatively similar biological availability.

In studies with growing beef cattle, Beeson et al. (1946), Hodgson et al. (1947) and Plumlee and Beeson (1953) failed to show any significant difference in the availability of phosphorus from steamed bone meal, dicalcium phosphate, defluorinated phosphate, and Curacao Island phosphate.

Ammerman et al. (1957), using phosphorus balance and blood phosphorus levels as criteria reported no significant differences between the availability of the phosphorus in soft phosphate and that in bone meal, defluorinated phosphate, and imported rock phosphate. In contrast, Long et al. (1956) found that the availability of phosphorus, as measured by bone ash, plasma-inorganic phosphorus levels, and weight gain, was greater from dicalcium phosphate than that from soft phosphate. Likewise, Raun et al. (1956a) and Burroughs et al. (1956) reported that cattle gained more rapidly when supplemented with dicalcium phosphate than when fed soft phosphate.

Watkins (1933) reported that disodium phosphate was superior to bone meal as a source of phosphorus for yearling steers. Green (1936) found that phosphorus from monocalcium phosphate was retained better than phosphorus from bone meal.

Tillman and Brethour (1958b) reported the availability of phosphorus supplied by phosphoric acid to be in the same order of magnitude as that supplied by dicalcium phosphate when fed to beef cattle. Likewise, Richardson et al. (1957) and (1961) concluded that phosphoric acid is an acceptable source of phosphorus for cattle.

Phytin phosphorus

The available evidence indicates that ruminants have the ability to make use of phytin phosphorus more effectively than do monogastric animals.

Reid et al. (1947) have shown that rapid hydrolysis of phytin phosphorus occurs in the rumen, and Raun et al. (1956b) found that phytase was produced by rumen microorganisms. The conclusion is drawn that rumen microorganisms produce phytase in sufficient quantities to hydrolyze the phytate present in the plant feedstuffs.

Beeson et al. (1941) and (1944) reported that steers and lambs receiving cottonseed meal as a source of phosphorus grew and fattened as rapidly and efficiently as steers and lambs receiving bone meal as a source of phosphorus.

Lofgreen and Kleiber (1953) found the digestibility of alfalfa hay in their lamb experiment to be ninety-one percent in virtue of which they concluded that the phosphorus in alfalfa hay appeared to be highly available.

Tillman and Brethour (1958a) found no significant differences between calcium phytate and mono-calcium phosphate as sources of phosphorus for lambs.

## PALATABILITY OF PHOSPHORUS SUPPLEMENTS

Becker et al. (1944) reported that defluorinated superphosphate proved to be unpalatable for cattle to the extent that it was necessary to mix it with common salt to get them to eat it. Consumption of the mixtures was directly in proportion to the salt content. They found that the dairy heifers chose a seven to one mixture of salt and defluorinated superphosphate over mixtures containing progressively lesser mixtures of salt.

Gullickson and Olsen (1946) found no differences in the palatability of supplements containing steamed bone meal or defluorinated phosphate.

Hodgson et al. (1948) demonstrated that both steam bone meal and defluorinated superphosphate proved to be satisfactory supplements when force-fed by mixing with the feed. However, when fed free choice bone meal was far more palatable than superphosphate, either alone or mixed with salt, anise, or licorice. Both minerals were eaten more readily when mixed with salt at the rate of one to two parts mineral to one part salt than when fed alone. The addition of anise or licorice did not appear to have any advantage over the mineral-salt mixture from the standpoint of increasing the rate of mineral intake.

Richardson et al. (1961) observed that steer wintering and fattening rations containing six grams of phosphorus as phosphoric acid were as highly palatable as when bone meal supplied six grams of phosphorus.

## UTILIZATION OF NON-PROTEIN NITROGEN BY RUMINANTS

The digestive tract of a ruminant differs from other classes of animals because a highly symbiotic relationship exists between the host animal and the microorganisms which are found in the digestive tract. The distinguishing feature of the alimentary tract of a ruminant is the large rumen or paunch located in the anterior portion of the digestive tract.

The microbes found in the rumen make it possible for ruminants to use low-quality roughages and synthetic compounds such as urea. Some classes of bacteria are able to obtain part or all of their protein requirements through the use of ammonia and other forms of nitrogen. Protein synthesis by the microorganisms in the rumen of cattle and sheep make it possible for these animals to utilize non-protein nitrogen and proteins of low biological value.

Looper et al. (1959) reported that the utilization of nitrogen compounds in ruminants is influenced by three processes: (1) the conversion of dietary protein to microbial protein; (2) the release of ammonia from dietary protein and non-protein nitrogen sources and the subsequent absorption of a portion of ammonia through the rumen; and (3) the synthesis of microbial protein from non-protein nitrogen sources.

Urea

There is a considerable amount of literature published pertaining to the utilization of urea by ruminants. It is the author's opinion that a certain amount of care must be taken in interperting the data reported on the utilization of different non-protein nitrogen compounds. Factors such as energy intake, fiber, and protein content of the basal ration are but a few of the factors which may affect non-protein nitrogen utilization and thus must be given consideration when comparing the utilization of different sources of nitrogen.

Mills et al. (1942) reported that only when adequate fermentable carbohydrates are included in the ration can urea be utilized at a maximum rate and efficiency in the rumen of the cow. These workers found that, when timothy hay was fed as the sole ingredient of the basal ration, utilization of added urea took place only partially, if at all. In the presence of starch, a suitable substate was provided for the development of an active flora, and urea was efficiently utilized. Lofgreen et al. (1951) and Bell et al. (1953) reveal further evidence of the influence of energy intake on utilization of non-protein nitrogenous compounds.

Johnson et al. (1942) and Arias et al. (1951) observed that small amounts of a readily available carbohydrate aided cellulose digestion, which in turn increased urea utilization, whereas large amounts of such materials inhibited cellulose digestion.

Some of the first work conducted to investigate the hypothesis that protein in useful amounts could be synthesized from non-protein nitrogen sources through microbial action was reported by Voltz (1922). He observed that lambs receiving a low-protein basal ration made satisfactory growth when the ration was supplemented with urea.

Work and Henke (1939) reported that growth obtained on a ration for dairy heifers in which four precent urea was substituted for the protein supplement was inferior to growth obtained by heifers on a normal protein ration but was superior to that on a low-protein, eight percent, ration.

Using yearling steers in nitrogen balance studies, Weber and Hughes (1942) found that the retention of urea nitrogen was equal to that of cottonseed meal nitrogen. Briggs et al. (1947) reported that urea alone was a poor supplement to prairie hay fed to yearling and two-year-old steers. However, steers fed rations containing not more than fifty percent of the total nitrogen from urea and the remainder from cottonseed meal gained as well as steers fed rations of straight cottonseed meal. Briggs et al. (1948) demonstrated that pelleted wintering rations for lambs with four percent urea permitted about the same storage of nitrogen as was stored from cottonseed meal. Nitrogen storage was decreased as the proportion of total nitrogen supplied by urea increased in the pellet to fifty and seventy-five percent.

Miller and Morrison (1942) found that lambs receiving a low-quality roughage ration (six percent protein) in which urea furnished more than one-half of the total nitrogen were distinctly less efficient than lambs fed similar rations containing linseed meal mixtures or mixtures of linseed meal and smaller proportions of urea. Except when urea furnished over one-half of the total nitrogen, lambs stored approximately thirty-two percent of the digested nitrogen, and the biological value was reported to be around sixty-two.

Johnson et al. (1942) reported that the products formed in the rumen from urea are as well utilized in metabolism as the nitrogen of soybean oil meal. Similar observations were noted by Gallup et al. (1954) with yearling steers fed a basal ration (five percent protein) supplemented with either two percent urea or thirteen percent soybean oil meal. Steers fed only the basal ration lost an average of sixty pounds over a period of three months. Those fed the supplemented ration maintained their weight and retained similar amounts of nitrogen. Contrary to these reports, Light et al. (1956) found that lambs fed a soybean oil meal ration gained twenty percent faster and consumed twelve percent more feed than those fed the urea supplement. Urea made up approximately forty-one percent of the protein equivalent of the ration. The faster gains made on the soybean oil meal supplemented ration was significant ($P < .01$) when compared to gains made on the urea supplemented ration.

Ammoniated products

An important problem in the feeding of non-protein nitrogen compounds is the production of ammonia in the rumen at a rate greater than that of effective utilization by rumen microorganisms. Several attemps have been made to chemically bind ammonia with many feeds and industrial by-products in order to reduce the release of ammonia in the rumen.

For some reason, which is as yet not fully understood, animals fed ammoniated molasses develop a nervous condition, and it appears that ammoniated molasses products tested thus far are of limited value as protein extenders in ruminant feeds.

Tillman et al. (1957) found that yearling steers fed a basal ration plus two pounds daily of ammoniated cane molasses (thirty-two percent protein equivalent) showed severe signs of a nervous disorder within five to six days. The steers reacted with violence and in several instances injured themselves by charging into gates and fences in a manner of extreme excitement. Similar observations were noted with dairy calves according to Bartlett and Broster (1958). These workers noticed symptoms of toxicity when the ammoniated molasses was fed at the rate of one pound per day. Parham et al. (1955) observed no physiological effects in dairy cows due to feeding of ammoniated molasses in the twelve percent protein concentrate mixture. The ammoniated molasses replaced thirty percent of the protein.

Knodt et al. (1951) reported that calves fed an eleven percent protein ration in which twenty-two percent of the total nitrogen was from ammoniated molasses (twenty-six percent protein equivalent) that the nitrogen from the ammoniated molasses was as digestible as equivalent amounts of nitrogen from soybean oil meal. Tillman and Swift (1953) conducted a nitrogen balance study with lambs and found that lambs receiving equivalent amounts of nitrogen from urea or soybean oil meal stored significantly ($P < .05$) more nitrogen than did lambs receiving ammoniated cane molasses. Feedlot trials conducted by Tillman et al. (1957) with yearling steers fed fattening rations containing ammoniated cane molasses indicated that the nitrogen of this product is not well utilized. The results were confirmed in digestion and nitrogen balance trials with fattening type rations.

Repp et al. (1955a) reported that growth data obtained from a lamb-feeding experiment suggested a period of two to three weeks was required for the lambs to become fully adapted to non-protein nitrogen compounds. According to these investigators in-vitro studies in which rumen microorganisms from lambs previously fed propionamide released significantly more ammonia nitrogen from propionamide than did the rumen microorganisms from lambs which had not been so fed. These findings may explain why there is a period of adaptation.

Urea toxicity

Dinning et al. (1948) were the first to make a study of the manifestations of urea overdosing. They reported that the entrance of large quantities of urea into the rumen and its subsequent rapid hydrolysis results in the release of ammonia at a rate which does not permit complete use of the nitrogen by rumen microorganisms for the synthesis of cellular protein. They found that ammonia, not utilized by the rumen flora, is rapidly absorbed into the blood stream where it may reach toxic level.

Repp et al. (1955b) suggested that animals actually succumb to an ammonia toxicity. Repp's work showed blood ammonia is a valid measurement of the toxicity of non-protein nitrogen compounds. Lambs in this study were able to endure blood ammonia-nitrogen values of about 1 mg. per 100 ml. of whole blood without showing outward symptoms of toxicity. When lambs were drenched with toxic doses of urea, it was possible to measure an increase in the blood ammonia fifteen minutes after dosing. The first clinical symptoms appeared at approximately thirty to forty-five minutes after dosing.

Different values for the toxic level of single doses of urea may be found in the literature. Clark et al. (1951) found it to be as low as eighteen grams per one-hundred pounds body weight for lambs. Repp et al. (1955b) reported ataxia in lambs given thirty-five grams per one-hundred pounds of body weight but no death loss below forty grams. Davis and Roberts (1959) found the toxic dose level of urea to be between fifteen and twenty grams per one-hundred pounds body weight for cattle.

Urea and diammonium phosphate were compared with respect to their toxicity to lambs by Russell et al. (1962). Much higher nitrogen equivalent doses of diammonium phosphate than of urea were required to produce adverse effects in lambs. In this experiment, diammonium phosphate could be given via stomach tube at levels up to fifty grams, urea-equivalent, per one-hundred pounds body weight, with no adverse effects attributable to diammonium phosphate. They reported that one lamb died after a dose of fifteen grams of urea and urea doses above twenty grams had to be discontinued because of the severe incidence of urea toxicity.

UTILIZATION OF DIAMMONIUM PHOSPHATE IN RUMINANT RATIONS

It was mentioned previously that Russell et al. (1962) found that urea nitrogen appeared to be more toxic than diammonium phosphate. Using nitrogen balance studies with lambs, these workers found no significant difference in the retention of nitrogen supplied by either urea or diammonium phosphate. In the balance studies, the basal ration contained ten percent with thirty-one percent of the nitrogen from non-protein origin.

The results of a digestion and nitrogen balance trial with dairy heifers indicated that diammonium phosphate was utilized as well as a nitrogen source as urea or soybean oil meal (Lassiter et al., 1962). It was also demonstrated by these workers that dairy heifers fed grain rations in which diammonium phosphate supplied thirty-five percent of the nitrogen grew at a rate comparable to heifers fed rations in which urea supplied a similar level of nitrogen.

Shaw et al. (1946) conducted some limited palatability studies and found that dairy cows would consume rations containing one percent diammonium phosphate. The palatability trials reported by Lassiter et al. (1962) indicated that some problem with palatability exists when diammonium phosphate is incorporated into grain rations at levels higher than two percent.

## EXPERIMENT I -- DIAMMONIUM PHOSPHATE AS A NITROGEN SOURCE FOR BEEF CATTLE

Experiment I was designed to evaluate the use of diammonium phosphate as a supplemental source of nitrogen to wintering and fattening type rations for steers. The experiment consisted of a 112-day wintering trial and a 168-day fattening trial.

### PROCEDURE

#### Wintering trial

The wintering trial was designed to compare diammonium phosphate and monoammonium phosphate as a source of nitrogen for steer calves receiving a wintering ration. The experimental animals used in the experiment consisted of thirty-two head of Hereford steer calves weighing approximately four hundred and forty pounds. The steers were bred and raised by the Montana Experiment Station, Red Bluff Ranch, Norris, Montana. The steers were weaned October 28, 1960 and trucked to the steer barn, located on the Montana State College Campus, Bozeman, Montana, on December 8, 1960. On arrival at the steer barn, the steers were grouped into two pens and fed native grass hay until the wintering trial was initiated.

The experimental area used at the steer barn consisted of four separate but adjoining, dry-lot pens, each having an adjoining loafing shed. Individual feeding stalls were located within each shed. Each pen contained a common water tank, and salt and mineral boxes were located inside the sheds.

On December 22, 1960, the thirty-two head of steers were allotted to their respective lots. The steers were stratified according to individual weights and randomly assigned to one of the four lots. Each lot was randomly assigned to receive one of the four treatments. The eight steers assigned to each treatment were randomly assigned to individual feed stalls within their respective lots. Each steer was fed in its respective feeding stall throughout the wintering period. All of the steers were ear-tagged for identification and numbered with a black livestock dye which corresponded to the respective feeding stall within each lot.

The steers were individually weighed, December 27, 1960, and started on their respective experimental rations. All of the calves received the same basal ration, the only difference among treatments being the source of supplemental nitrogen. The sources of added nitrogen in each treatment are as follows-- Lot 1 received monoammonium phosphate; Lot 2, diammonium phosphate; Lot 3, urea; and Lot 4, soybean oil meal. The design of the experiment is given in Table I.

Table I. Experimental Design and Sources of Supplemental Nitrogen Fed During Wintering Trial of Experiment I.

| Lot No. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Supplemental source of nitrogen | Monoammonium phosphate | Diammonium phosphate | Urea | Soybean oil meal |
| No. of animals | 8 | 8 | 8 | 8 |

The supplemental protein pellet was calculated to furnish one and one-half percent phosphorus, two and one-half percent calcium and eighteen percent protein. Vitamin A was added to supply 5,000 I. U. per pound of feed. Sodium sulfate was added to supplements 158, 159, and 160, so the sulfur content of the four supplements was equal. The composition of the supplemental pellets are shown in Table II.

Approximately one-third equivalent crude protein was from a non-protein nitrogen source in supplements 158 and 159. Monoammonium phosphate supplied one-sixth of the protein equivalent in supplement 160. About sixty percent of the phosphorus was supplied by either defluorinated phosphate, diammonium phosphate or monoammonium phosphate in the four supplements.

Table II. Composition of the Supplemental Pellets Containing the Different Sources of Supplemental Nitrogen Fed During the Wintering Trial of Experiment I.

| Lot No. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| MSC Formula No. | 160 (MAP) | 159 (DAP) | 158 (UREA) | 157 (SBOM) |
| Ingredients: | | Percent of Ration | | |
| Barley | 75 | 85 | 86.5 | 69 |
| Molasses | 5 | 5 | 5 | 5 |
| Soybean oil meal | 11 | -- | -- | 20 |
| Urea | -- | -- | 2.5 | -- |
| Defluorinated phosphate | -- | -- | 6 | 6 |
| Diammonium phosphate | -- | 5 | -- | -- |
| Monoammonium phosphate | 4 | -- | -- | -- |
| Limestone | 5 | 5 | -- | -- |
| Trace mineral supplement | 0.1 | 0.1 | 0.1 | 0.1 |
| Vitamin A 1/ | X | X | X | X |
| Sodium sulfate 2/ | 1.50 | 3.35 | 3.15 | -- |

1/ Vitamin A was added to supply 5,000 I.U. per pound of feed.
2/ Sodium sulfate was added so the sulfur content of the four supplements were equal.

The steers were started on one pound of the concentrate mixture, one-half pound of the eighteen percent protein pellet, and eight pounds of native grass hay. The concentrate mixture consisted of equal parts of steam-rolled barley with molasses added and dried molasses beet pulp. The steam-rolled barley contained five percent molasses, which was added during the rolling process.

Each steer was hand-fed once daily in its respective feeding stall. The steers were put into their feeding stalls at approximately eight o'clock every morning and allowed to eat the feed allotted them. The daily ration was weighed out and put into the feeding boxes each afternoon. At approximately one o'clock every day the calves were turned out of their stalls and remained out until the following morning. Feed not consumed was weighed back and recorded.

The level of concentrate feeding was gradually increased as the calves would accept it and the hay feeding was simultaneously decreased. When the calves had been on the trial fifty-six days, the daily ration was increased to five pounds of concentrate mixture and one pound of protein supplement and the hay was decreased to five pounds daily. This level of feeding was then maintained throughout the remainder of the trial without further alteration. According to the feeding standards of Morrison (1956) and the National Research Council (1958), the daily ration fed in this trial should produce approximately one pound of gain per day.

The steers were given an overnight shrink prior to the initial and final weighing. The wintering period terminated April 18, 1960. Every twenty-eight days throughout the 112-day wintering period, the calves were individually weighed and blood samples from the jugular vein were taken. Plasma-inorganic phosphorus, plasma carotene, and plasma vitamin A levels were determined by the colorimetric methods of Fiske and Subbarow (1925) for phosphorus and Kimble (1939) for carotene and vitamin A. The methods used were modified for the Bausch and Lomb "Spectronic 20" colorimeter.

Fattening trial

The thirty-two head of Hereford steers previously wintered for 112-days on the diammonium phosphate trial were used in a fattening trial. The steers remained in the same lots and on the same sources of nitrogen they received during the wintering trial. On April 18, 1961, the final weights for the wintering trial were taken, these weights being used as the initial weights for the fattening trial.

The same experimental area was used as had been used during the wintering period. The eight steers per treatment were group-fed the concentrate ration in a conventional feed bunk. At the beginning of the fattening trial, the steers were hand-fed a ration consisting of five pounds of concentrates, five pounds of native grass hay, and one pound of an eighteen percent protein pellet. The supplemental pellet served as a carrier for the various sources of nitrogen and phosphorus being evaluated. Each lot of calves received the same supplemental pellet as they had during the wintering period, with the exception that the phosphorus and calcium content were increased to two and three percent respectively and the level of vitamin A was increased to 30,000 I. U. per pound of supplement. The composition of the protein supplements is given in Table III.

The concentrate mixture used during this trial consisted of eighty percent steam-rolled barley, with five percent molasses added and twenty percent dried molasses beet pulp. The concentrate mixture was gradually increased until the steers reached a full-feed. The hay feeding was gradually decreased and was discontinued after the 28th day of the trial.

On June 3, 1961, the steers were changed from hand-feeding twice daily to a self-feeder. At this time, the steers were consuming sixteen pounds of concentrates and one pound of the supplemental protein pellet per head daily. The protein pellets were self-fed with the concentrates and mixed so the steers would receive approximately one pound per head daily.

Table III. Composition of the Protein Supplements Containing the Different Sources of Supplemental Nitrogen Fed During the Fattening Trial of Experiment I.

| Lot No. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| MSC Formula No. | 164 (MAP) | 163 (DAP) | 162 (UREA) | 161 (SBOM) |
| Ingredients: | | Percent of Ration | | |
| Barley | 73 | 83 | 84.5 | 67.5 |
| Molasses | 5 | 5 | 5 | 5 |
| Soybean oil meal | 11 | -- | -- | 20 |
| Urea | -- | -- | 2.5 | -- |
| Defluorinated phosphate | -- | -- | 7.5 | 7.5 |
| Diammonium phosphate | -- | 5 | -- | -- |
| Monammonium phosphate | 4 | -- | -- | -- |
| Limestone | 7 | 7 | -- | -- |
| Monosodium phosphate | -- | -- | .5 | -- |
| Trace minerals | 0.1 | 0.1 | 0.1 | 0.1 |
| Vitamin A 1/ | X | X | X | X |

1/ Vitamin A was added to supply 30,000 I.U. per pound of supplement. Sodium sulfate was added to supplements 162, 163, and 164, so the sulfur content of the four supplements was equal.

Individual weights were obtained every twenty-eight days throughout the experiment. The steers were shrunk overnight prior to the initial and final weighing. The steers were weighed off the experiment, October 3, 1961, after a 168-day fattening period. The steers were sold on the basis of carcass grade and yield to a slaughtering plant at Butte, Montana. Carcass weights and federal carcass grades were obtained at the time of slaughter.

# RESULTS AND DISCUSSION

## Wintering trial

The pertinent data of this 112-day wintering trial, concerning the average daily gains, feed consumption, and feed utilization are summarized in Table IV.

Table IV. Average Weight Gains, Daily Feed Intake, and Feed Efficiency of Steers Wintered on Rations Differing in Sources of Supplemental Nitrogen. Experiment I. (December 27, 1960 to April 18, 1961 -- 112 days).

| Lot No. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Treatment | Monoammonium phosphate | Diammonium phosphate | Urea + defluor-inated phosphate | Soybean oil meal + defluorinated phosphate |
| No. Steers | 8 | 8 | 8 | 8 |
| Average weights (lbs.) | | | | |
| Initial | 439 | 436 | 455 | 450 |
| Final | 562 | 563 | 563 | 560 |
| Gain | 123 | 127 | 108 | 110 |
| Avg. daily gain | 1.10 | 1.14 | 0.97 | 0.98 |
| Average daily feed consumption (lbs.) | | | | |
| Concentrates | 3.7 | 3.7 | 3.5 | 3.6 |
| Supplement | 0.88 | 0.89 | 0.87 | 0.91 |
| Hay | 5.7 | 5.7 | 5.7 | 5.5 |
| Total | 10.28 | 10.29 | 10.07 | 10.01 |
| Feed required/cwt. gain | | | | |
| Concentrates | 318 | 323 | 351 | 364 |
| Supplement | 80 | 78 | 90 | 93 |
| Hay | 526 | 500 | 594 | 561 |
| Total | 924 | 901 | 1035 | 1018 |
| Feed cost/cwt. gain 1/ | $15.80 | $15.54 | $17.58 | $17.75 |

1/ The cost of feeds used in this experiment is given in Appendix Table XI.

The steers used in this experiment were of relatively similar size and age at the initiation of the trial. Table IV shows that there existed a nineteen pound spread between the average initial weights of the four lots of steers. When the average initial weights of the steers for all lots were subjected to analysis of variance, the differences among treatments were not significant (P<.05).

The total weight gains made by the steers receiving either monoammonium or diammonium phosphate as a partial source of nitrogen in an eighteen percent protein supplement, (Lots 1 and 2, respectively) were slightly greater than the gains made by steers receiving either urea or soybean oil meal, (Lots 3 and 4, respectively). Table IV shows that the average total gain made by the steers in Lot 2 (diammonium phosphate), the highest gaining group, was only 21 pounds greater than the average gains made by the steers in Lot 3 (urea), the lowest gaining lot of steers. The two lots of steers receiving the ammoniated products as sources of nitrogen made similar gains during the wintering period. The steers receiving diammonium phosphate made 0.04 pounds greater average daily gain than the Lot 1 steers on monoammonium phosphate. An analysis of variance showed no statistically significant differences in the weight gains made by the four lots during the 112-day wintering period. The analysis of variance for total weights gains is shown on Table V.

Table V. Analysis of Variance of Total Weight Gains of Steers Wintered on Rations Differing in Sources of Supplemental Nitrogen.

| Variation | D.F. | S.S. | M.S. | F-Value |
|---|---|---|---|---|
| Between treatments | 3 | 2,102 | 700.7 | 2.08 |
| Within treatments | 28 | 9,441 | 337.2 | |
| Total | 31 | 11,543 | | |

At the beginning of this winter trial, it was observed that some of the steers in Lots 3 and 4 were very slow in learning to eat their experimental ration. It was also noted that the calves in these two lots were considerably more nervous and more difficult to put into their individual feeding stalls as compared to the calves in Lots 1 and 2, especially during the first 28-days of the experiment. This may explain in part the lesser gains made by the steers in Lots 3 and 4 during the wintering period. Appendix Table I and Table VI shows that the calves in these two lots lost on the average of 0.05 pounds per head daily during the first 28 days of the experiment. An analysis of variance revealed that the gains made by the steers in Lots 3 and 4 during the first 28-day period were significantly smaller ($P < .05$) than the gains made by the steers in Lots 1 and 2 for the same period. However, there were no significant differences among treatments in total gains in the subsequent three 28-day periods.

Table VI. Average Daily Gains of Steers by 28-day Periods of Steers Fed Different Sources of Supplemental Nitrogen During the Wintering Trial of Experiment I.

| Lot No.<br>Treatment | 1<br>(MAP) | 2<br>(DAP) | 3<br>(UREA) | 4<br>(SBOM) |
|---|---|---|---|---|
| Average daily gain by 28-day periods (lbs.) | | | | |
| 1st | 0.36 | 0.40 | -0.05 | -0.05 |
| 2nd | 1.14 | 1.21 | 1.36 | 1.34 |
| 3rd | 1.42 | 1.63 | 1.23 | 1.27 |
| 4th | 1.49 | 1.27 | 1.35 | 1.39 |
| Average daily gain for 112-day period (lbs.) | 1.10 | 1.14 | 0.97 | 0.98 |

The difficulty encountered in getting some of the calves in Lots 3 and 4 started to eat their experimental ration did not appear to be due to the palatability of any one ingredient in the ration. Once the calves became accustomed to the concentrate mixture, they readily accepted the one pound of protein supplement. There were no significant differences in the total amount of feed consumed among the steers on the four treatments, either by 28-day periods or for the entire 112-day feeding period. Individual steer feed records are given in Appendix Table II. The average daily feed intake by periods is shown in Table VII.

Table VII. Average Daily Feed Intake by 28-day Periods of Steers Fed Different Sources of Supplemental Nitrogen During the Wintering Trial of Experiment I.

| Lot No.<br>Treatment | 1<br>(MAP) | 2<br>(DAP) | 3<br>(UREA) | 4<br>(SBOM) |
|---|---|---|---|---|
| Average daily gain intake by 28-day periods (lbs.) | | | | |
| 1st | 9.5 | 9.4 | 8.8 | 9.3 |
| 2nd | 10.0 | 10.0 | 9.9 | 9.7 |
| 3rd | 10.7 | 10.6 | 10.8 | 10.4 |
| 4th | 10.6 | 10.8 | 10.8 | 10.6 |
| Average daily gain for 112-day period (lbs.) | 10.3 | 10.3 | 10.1 | 10.0 |

Table IV shows that the average daily feed consumption was approximately 3.7, 5.7, and 0.90 pounds for the concentrate mixture, hay, and protein supplement, respectively. Using the average daily feed consumption figures from Table IV and the proximate chemical analysis of the feed ingredients used in this experiment, (see Table VIII), the average daily intake of the various nutrients were estimated. The proximate chemical analysis of the feed ingredients fed during this wintering trial are shown in Table VIII.

When the one-pound of protein supplement was added to the basal ration, the phosphorus and calcium requirements of the steers were adequately met, according to the recommended nutrient allowances purposed by the National

Table VIII. Proximate Chemical Analysis of the Feeds Fed During the Wintering Trial of Experiment I. 1/

| | Moisture | Crude Protein | Ether Extract | Crude Fiber | Ash | Phosphorus | Calcium |
|---|---|---|---|---|---|---|---|
| Ingredient: | | | | Percent | | | |
| Dried molasses beet pulp | 6.4 | 8.6 | 0.6 | 11.3 | 1.5 | 0.15 | 0.68 |
| Steam-rolled barley | 9.6 | 11.6 | 2.4 | 5.2 | 4.2 | 0.37 | 0.32 |
| Grass hay | 5.8 | 8.1 | 3.2 | 25.6 | 7.4 | 0.14 | 0.64 |
| Supplements | | | | | | | |
| MSC 157 (Lot 4, SBOM) | 8.3 | 18.5 | 2.2 | 5.6 | 11.4 | 1.55 | 2.70 |
| MSC 158 (Lot 3, Urea) | 9.6 | 18.6 | 2.2 | 5.0 | 9.9 | 1.40 | 2.88 |
| MSC 159 (Lot 2, DAP) | 9.0 | 19.6 | 2.2 | 4.9 | 11.5 | 1.70 | 2.33 |
| MSC 160 (Lot 1, MAP) | 8.5 | 19.5 | 2.1 | 5.4 | 11.0 | 1.80 | 2.38 |

1/ The feed analysis was conducted by the Montana State College Chemistry Department -- Station.

Research Council (1958), (see Table IX). The phosphorus from defluorinated phosphate supplied approximately 34 percent of the total daily phosphorus intake for the steers in Lots 3 and 4. Likewise, monoammonium and diammonium phosphate furnished about 30 and 33 percent of the daily phosphorus intake for the steers in Lots 1 and 2, respectively. The total daily intake of protein, phosphorus, and calcium furnished by the wintering ration is shown in Table IX.

The experimental ration fed during this trial supplied approximately 78 percent of the amount of protein required by the experimental animals in Lots 1 and 2 and about 76 percent of the protein requirement in Lots 3 and 4. Table X gives the average daily pounds of crude protein consumed during each of the 28-day periods. The smaller amounts of protein consumed daily by the steers in Lots 3 and 4 during the first 28 days resulted primarily from the smaller amounts of total ration eaten during this period.

Because the ration fed during this wintering period was apparently adequate in all nutrients except protein, it would appear that any measurable

Table IX. Total Daily Protein, Phosphorus, and Calcium Intake of Steers Wintered on Rations Differing in Sources of Supplemental Nitrogen.

| Lot No. | NRC Requirements 1/ | 1 (MAP) | 2 (DAP) | 3 (UREA) | 4 (SBOM) |
|---|---|---|---|---|---|
| Average daily intake: | | | | | |
| Protein | | | | | |
| Pounds | 1.3 | 1.01 | 1.01 | 0.97 | 0.99 |
| Percent of ration | 10.3 | 9.8 | 9.8 | 9.6 | 9.9 |
| Phosphorus | | | | | |
| Pounds | 0.02 | 0.035 | 0.034 | 0.031 | 0.033 |
| Grams | 10.0 | 16.1 | 15.6 | 14.3 | 14.9 |
| Percent of ration | 0.17 | 0.34 | 0.33 | 0.31 | 0.33 |
| Calcium | | | | | |
| Pounds | 0.03 | 0.076 | 0.075 | 0.081 | 0.079 |
| Grams | 13.0 | 34.4 | 34.2 | 36.7 | 35.9 |
| Percent of ration | 0.22 | 0.74 | 0.73 | 0.80 | 0.79 |

1/ Nutrient requirements based on those reported by the National Research Council for wintering a 500 pound weanling calf.

Table X. Average Daily Crude Protein Consumption During Each 28-day Period of Steers Wintered on Rations Differing in Sources of Supplemental Nitrogen.

| 28-day periods<br>Daily protein requirement (lbs.) | 1st<br>1.1 | 2nd<br>1.1 | 3rd<br>1.3 | 4th<br>1.3 | Average for<br>112-days |
|---|---|---|---|---|---|
| | | | Pounds Consumed | | |
| Lot No. 1 (MAP) | 0.91 | 0.98 | 1.04 | 1.08 | 1.01 |
| Lot No. 2 (DAP) | 0.90 | 0.98 | 0.99 | 1.09 | 1.01 |
| Lot No. 3 (UREA) | 0.81 | 0.98 | 1.06 | 1.07 | 0.97 |
| Lot No. 4 (SBOM) | 0.86 | 0.91 | 1.00 | 1.07 | 0.99 |

differences among the steers fed the various sources of nitrogen might be attributed to differences in nitrogen utilization. When weight gains were used as the criteria for comparing the different nitrogen sources in this experiment, it appeared that the additional supplemental nitrogen supplied by the ammoniated products, mono- and diammonium phosphate, were utilized by the steers as well as the nitrogen from urea or soybean oil meal.

Similar results were reported by Lassiter et al. (1962). These workers concluded, from a growth study with dairy heifers, that the animals efficiently utilized diammonium phosphate as a partial source of nitrogen. Russell et al. (1962), with lambs, found that diammonium phosphate was utilized as well as urea.

An analysis of covariance revealed that the plasma-inorganic phosphorus levels of the steers in Lot 1 were significantly higher ($P<.05$) than were the plasma-inorganic phosphorus levels of the steers in Lot 3, at the conclusion of the 112-day wintering period. There were no significant differences in the final plasma-inorganic phosphorus levels among the steers in Lots 1, 2, and 4. Table XI shows the analysis of plasma-inorganic phosphorus levels.

Table XI. Analysis of Covariance for Final (Y) and Initial (X) Plasma-Inorganic Phosphorus Levels for Steers During Wintering Trial of Experiment I.

| | | Sum of Products | | | Y Adjusted for X | | | |
|---|---|---|---|---|---|---|---|---|
| Variation | df. | XX | XY | YY | df. | SS. | MS. | F. |
| Total | 31 | 21.06 | 4.57 | 24.37 | | | | |
| Treatment | 3 | 7.49 | 2.69 | 6.62 | | | | |
| Error | 28 | 13.57 | 1.88 | 17.75 | 27 | 17.49 | 0.65 | |
| Treatment & error | 31 | 21.06 | 4.57 | 24.37 | 30 | 23.38 | | |
| Treatments adjusted | | | | | 3 | 5.89 | 1.96 | 3.02* |

* Significant ($P<.05$).

The average plasma-inorganic phosphorus levels of the steers for each 28-day period is shown in Table XII and individual steer plasma-phosphorus levels are given in Appendix Table III.

The plasma-inorganic phosphorus levels recorded during this experiment

Table XII. Average Plasma-inorganic Phosphorus Levels of Steers During Wintering Trial of Experiment I.

| | Mg. phosphorus per 100 ml. blood | | | | |
|---|---|---|---|---|---|
| 28-Day Period | 12-27-60 | 1-24-61 | 2-21-61 | 3-23-61 | 4-18-61 |
| Lot No. 1 (MAP) | 7.76 | 7.79 | 8.57 | 7.57 | 7.89 |
| Lot No. 2 (DAP) | 6.78 | 8.15 | 9.04 | 7.74 | 7.61 |
| Lot No. 3 (UREA) | 7.46 | 7.67 | 8.32 | 7.73 | 6.82 |
| Lot No. 4 (SBOM) | 6.66 | 7.97 | 8.04 | 7.90 | 6.98 |

indicated that the ration furnished adequate amounts of phosphorus. The plasma-inorganic phosphorus levels obtained during this experiment were within the normal range reported by Long et al. (1952).

Plasma carotene and plasma vitamin A levels were determined the first three 28-day periods. Individual steer plasma carotene and vitamin A levels for the first three periods are represented in Appendix Table IV. The vitamin A levels of the calves on this experiment were well above the minimum of 16 mcg. of vitamin A per 100 cc. of plasma and 25 mcg. of carotene per 100 cc. of plasma, as reported by Davis et al. (1941).

Fattening trial

Table XIII summarizes the pertinent data of this 168-day fattening trial concerning the average daily weight gains, feed consumption, efficiency of feed utilization, and carcass grades of the experimental animals. Individual steer performance records are given in Appendix Table V.

The steers receiving soybean oil meal as a partial source of the supplemental nitrogen made the greatest weight gains during the 168-day fattening period. The steers receiving the soybean oil meal (Lot 4) averaged approximately 45 pounds more gain than did the lowest gaining group of steers fed monoammonium phosphate, (Lot 1). However, when the total gains

Table XIII. Weight Gains, Feed Consumption, and Feed Costs of Steers Fattened on Rations Differing in Sources of Supplemental Nitrogen. (April 18, 1961 to October 3, 1961 -- 168 Days).

| Lot No. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Treatment | Monoammonium phosphate | Diammonium phosphate | Urea & Defl. phosphate | Soybean oil meal & Defl. phosphate |
| No. of Steers | 8 | 8 | 8 | 8 |
| Average weights (lbs.) | | | | |
| Initial | 562 | 563 | 563 | 560 |
| Final | 1034 | 1059 | 1063 | 1076 |
| Gain | 472 | 496 | 500 | 516 |
| Avg. daily gain | 2.81 | 2.95 | 2.97 | 3.07 |
| Average daily feed consumption (lbs.) | | | | |
| Concentrates | 17.30 | 18.20 | 18.10 | 17.60 |
| Supplement | 1.08 | 1.10 | 1.10 | 1.10 |
| Hay 1/ | 0.58 | 0.58 | 0.58 | 0.58 |
| Total | 18.96 | 19.88 | 19.78 | 19.28 |
| Feed required/cwt. gain | | | | |
| Concentrates | 616 | 615 | 609 | 574 |
| Supplement | 38.3 | 37.5 | 37.3 | 35.7 |
| Hay | 20.5 | 20.5 | 19.0 | 18.8 |
| Total | 647.8 | 673.0 | 665.3 | 628.5 |
| Feed cost/cwt. gain | $15.46 | $15.51 | $14.38 | $14.61 |
| Labor and yardage cost/cwt. gain (9¢ /head per day) 2/ | $3.20 | $3.05 | $3.02 | $2.93 |
| Total cost/cwt. gain | $18.66 | $18.56 | $18.40 | $17.54 |
| Carcass grades | | | | |
| Choice | 8 | 7 | 6 | 6 |
| Good | - | 1 | 2 | 2 |

1/ Hay feeding was discontinued after the 28th day of the experiment.
2/ The labor and yardage cost per day is based on the costs reported by Snapp and Neumann (1960).

made by the steers were subjected to an analysis of variance, the differences among treatments were not significant. The steers receiving diammonium phosphate or urea made similar total gains for the 168-day feeding period.

Because the steers within each lot were group-fed in a self-feeder, a statistical analysis of the amount of feed required to produce 100 pounds of gain could not be conducted. However, as shown in Table III, approximately fifty pounds less feed were required to produce 100 pounds of gain for the steers in Lot 4, than was required by the steers in Lot 1. On a percentage basis, the steers in Lot 4 required 7.5 percent less feed to produce a pound of gain than the steers in Lot 1. Only slight differences were noted in the feed requirement per 100 pounds of gain amont the steers receiving either monosammonium phosphate (Lot 1), diammonium phosphate (Lot 2), or urea (Lot 3).

The hay feeding was discontinued after the first 28-days of the experiment. Following the removal of the hay from the ration, no digestive disturbances or particular craving for hay was observed during the remainder of the experiment. Similar observations have been reported by Thomas et al. (1961).

The average daily feed consumption for the 168-day feeding period was approximately nineteen pounds of total feed for the steers on all treatments. The average daily intakes of protein, phosphorus, and calcium are given in Table XIV. This table shows that requirements for protein, calcium, and phosphorus were met by the rations fed during the trial. The four rations contained approximately the same levels of calcium and phosphorus. The basal ration, consisting of the concentrate mixture, met the protein requirement.

After the 168-day fattening period, twenty-eight of the thirty-two

Table XIV. Average Daily Intake of Protein, Phosphorus, and Calcium for Steers Fed Rations Differing in Sources of Supplemental Nitrogen During the Fattening Trial of Experiment I.

| Lot No. | NRC Requirements1/ | 1 (MAP) | 2 (DAP) | 3 (UREA) | 4 (SBOM) |
|---|---|---|---|---|---|
| Average daily intake: | | | | | |
| Protein (lbs.) | 2.2 | 2.41 | 2.51 | 2.50 | 2.16 |
| Phosphorus (gms.) | 20.0 | 30.6 | 32.6 | 32.6 | 32.5 |
| Calcium (gms.) | 20.0 | 58.8 | 60.5 | 59.0 | 59.6 |
| Percent of Total Ration: | | | | | |
| Protein (%) | 10.0 | 12.7 | 12.6 | 12.6 | 11.2 |
| Phosphorus (%) | 0.20 | 0.36 | 0.36 | 0.36 | 0.37 |
| Calcium (%) | 0.20 | 0.68 | 0.68 | 0.65 | 0.68 |
| Protein equivalent from non-protein nitrogen (%) | | 1.4 | 2.9 | 2.5 | ---- |

1/ National Research Council requirements for fattening an 800-pound yearling calf.

head of steers yielded carcasses in the choice grade. The carcass grades of the steers in each lot are shown in Table XIII.

The proximate chemical analyses of the feed ingredients used in the experiment are given in Table XV.

Table XV. Proximate Chemical Analyses of the Feeds Used During the Fattening Trial of Experiment I. 1/

| | Moisture | Crude Protein | Ether Extract | Crude Fiber | Ash | Phosphorus | Calcium |
|---|---|---|---|---|---|---|---|
| Ingredient: | | | | | | | |
| Dried molasses beet pulp | 6.5 | 8.4 | 0.4 | 20.7 | 5.8 | 0.09 | 0.75 |
| Steam-rolled barley | 9.2 | 13.5 | 2.3 | 5.7 | 3.1 | 0.34 | 0.45 |
| Grass hay | 6.0 | 7.9 | 1.9 | 31.0 | 9.3 | 0.18 | 1.30 |
| Supplements | | | | | | | |
| MSC 161 (Lot 4, SBOM) | 7.9 | 15.9 | 1.7 | 6.4 | 13.0 | 1.88 | 3.00 |
| MSC 162 (Lot 3, UREA) | 8.2 | 17.1 | 1.4 | 6.6 | 11.3 | 1.67 | 2.70 |
| MSC 163 (Lot 2, DAP) | 8.7 | 17.9 | 2.0 | 7.2 | 11.1 | 1.65 | 3.00 |
| MSC 164 (Lot 1, MAP) | 7.8 | 17.5 | 1.8 | 5.6 | 11.2 | 1.50 | 3.10 |

1/ The feed analyses was conducted by the Montana State College Chemistry Department -- Station.

## SUMMARY

Diammonium phosphate was compared to monammonium phosphate, urea, and soybean oil meal, as a partial source of supplemental nitrogen for steer calves. The experiment consisted of a 112-day wintering trial and a 168-day fattening trial. The thirty-two Hereford steer calves used in this study were grouped into four lots of eight head each. Each lot of steers remained in the same lot and on the same source of nitrogen during both feeding trials.

The experimental sources of nitrogen served as a part of the total nitrogen in eighteen percent protein supplements. The protein supplements were fed at the rate of one pound per head daily throughout both trials.

During the wintering trial, the steers were individually fed in feeding stalls once daily. The basal ration consisted of five pounds of a barley-beet pulp concentrate mixture and five pounds of grass hay. The phosphorus and calcium content of the four rations were balanced and supplied adequate amounts of each element. All of the rations were low in crude protein. The rations contained approximately 9.8 percent protein.

The weight gains made during the wintering period by the steers in Lot 1 (MAP) and Lot 2 (DAP) were slightly greater than the gains made by the steers in Lot 3 (UREA) and Lot 4 (SBOM). The steers receiving part of the supplemental nitrogen from diammonium phosphate made the greatest daily gains (1.14 pounds) during the trial and required less feed per pound of gain. However, the differences obtained in weight gains and feed required per pound of gain among the four lots of steers were not significant.

Blood samples taken and analyzed every 28 days showed that the steers

maintained normal plasma-inorganic phosphorus levels throughout the wintering trial. The plasma-phosphorus levels at the conclusion of the trial were significantly higher ($P<.05$) for the steers in Lot 1 (MAP), than were the levels for the steers in Lot 3 (UREA). Although the differences were not significant, the steers in Lot 2 (DAP) did show slightly higher plasma-phosphorus levels at the end of the trial, than those of steers in Lot 3 (UREA) and Lot 4 (SBOM).

During the fattening trial, the steers were self-fed a high-concentrate basal ration supplemented with one pound per head daily of the supplement, which furnished the additional nitrogen.

All of the steers made satisfactory gains during the fattening trial. The steers in Lot 4 (SBOM) made the greatest daily gain (3.07 pounds) and required less fed per pound of gain. The steers in Lot 1 (MAP), the lowest gaining lot (2.81 pounds per day) required 7.5 percent more feed to produce 100 pounds of gain than the steers in Lot 4 (SBOM). Similar gains were made by the steers in Lot 2 (DAP) and Lot 3 (UREA).

From the results obtained in this experiment, only small differences were noted among the steers fed the sources of nitrogen compared. Diammonium phosphate appeared to be a satisfactory source of nitrogen, when used to furnish part of the supplemental nitrogen for steers.

## EXPERIMENT II -- DIAMMONIUM PHOSPHATE AS A SOURCE OF PHOSPHORUS FOR WINTERING HEIFER CALVES

Experiment II was designed to compare diammonium phosphate with defluorinated phosphate, as a supplemental source of phosphorus for heifer calves receiving a wintering ration.

### PROCEDURE

The experimental animals used in this experiment consisted of thirty-two head of Hereford heifer calves weighing approximately 370 pounds. The experimental animals were from two sources: twenty-four head of heifers were from the Kyd Cattle Company, Three Forks, Montana and eight head came from the Montana Experiment Station, Red Bluff herd, Norris, Montana. The experiment was conducted at the steer barn located on the Montana State College Campus. On arrival at the steer barn, the first week of November, the heifers were divided into four groups and fed native grass had *ad libitum*.

The heifers were allotted to their respective lots on December 15, 1961. The thirty-two head of heifers were randomly selected to receive one of the eight treatments used in this experiment on the basis of individual weights and source. The four heifers assigned to each treatment were randomly assigned to one of the four pens and within each pen the heifers were assigned to one of the eight individual feeding stalls at random.

In order for the heifers to become accustomed to their respective feeding stall prior to the initiation of the experiment they were put into their stalls once daily starting December 20, 1961 and started on the concentrate mixture they were to receive during the experiment.

All of the heifers received the same basal ration, the only difference among treatments being either the added source or level of phosphorus in each of the supplements. Diammonium phosphate and defluorinated phosphate were compared as supplemental sources of phosphorus at three different levels of total phosphorus intake. The three levels selected were 0.18, 0.24, and 0.30 percent phosphorus of the total ration. A phosphorus intake of 0.12 percent of the total ration served as the control ration. Lots 1 and 2 received the control ration and received no inorganic source of additional phosphorus. The heifers in Lots 1 and 2 received a total phosphorus intake of approximately 0.12 percent of the daily ration. In the remaining lots, the heifers received either 0.18, 0.24, or 0.30 percent phosphorus of the total ration. Part of the additional phosphorus at each level of intake was supplied by either diammonium phosphate or defluorinated phosphate. The design of this experiment is shown in Table XVI.

Table XVI. Experimental Design of Experiment II Comparing Two Sources of Supplemental Phosphorus Fed to Heifers at Various Levels.

| Lot No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Percent phosphorus in total ration | 0.12 | 0.12 | 0.18 | 0.18 | 0.24 | 0.24 | 0.30 | 0.30 |
| Supplemental source of phosphorus | | | | | | | | |
| Defluorinated phosphate | 0 | 0 | X | 0 | X | 0 | X | 0 |
| Diammonium phosphate | 0 | 0 | 0 | X | 0 | X | 0 | X |
| No. of animals | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |

The heifers were started on the basal ration consisting of two pounds of dried molasses beet pulp, one pound of steam-rolled corn and five pounds of native grass hay. In addition the heifers received one pound of the twenty percent protein supplement, which served as a carrier for the added phosphorus sources. The composition of the protein supplements is given in Table XVII.

The heifers were fed their experimental ration once daily in the individual feeding stalls. They were put into their feed stalls at approximately eight o'clock every morning and turned out at about one o'clock in the afternoon. Individual daily feed records were obtained and any feed not eaten was weighed back and recorded.

In order to keep the phosphorus content of the basal ration as low as possible, on February 27, 1962, the grass hay which had been fed the first 56 days of the experiment was discontinued and the heifers were fed five pounds of grass hay which contained 0.13 percent phosphorus. Also, at this time, one more pound of dried molasses beet pulp was added to the concentrate mixture, making a total of three pounds of beet pulp fed daily.

On March 27, 1962, the hay feeding was reduced to four pounds per head daily and the concentrate mixture was increased with the addition of another pound of dried molasses beet pulp. At this time, the heifers were consuming daily four pounds of dried molasses beet pulp, one pound of steam-rolled corn, one pound of the twenty percent protein supplement, and four pounds of grass hay. This level of feeding was then maintained for the remaining 56 days of the experiment.

The heifers were given an overnight shrink prior to the initial and final weighing. Every 28 days, throughout the 140-day wintering period, the heifers were individually weighed and blood samples obtained. Plasma-inorganic phosphorus levels were determined by the colorimetric method of Fiske and Subbarow (1925). Plasma carotene and plasma vitamin A levels

Table XVII. Composition of the Protein Supplements Containing the Various Levels of Phosphorus From the Two Sources Fed During Experiment II.

| Treatment | | | | | | | |
|---|---|---|---|---|---|---|---|
| Level of phosphorus | 0.12% | 0.18% | 0.18% | 0.24% | 0.24% | 0.30% | 0.30% |
| Source | Control | Defl. | DAP | Defl. | DAP | Defl. | DAP |
| MSC Formula No. | 236 | 237 | 240 | 238 | 241 | 239 | 242 |
| Lot No. | 1 & 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Ingredients: | | | | Percent of ration | | | |
| Barley | | | | | | | |
| Light (17% protein) | 92.75 | 90.50 | 92.00 | 86.50 | 70.00 | 83.20 | ----- |
| Heavy (13% protein) | ---- | ---- | ---- | ---- | 20.00 | ---- | 87.50 |
| Molasses | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| Urea | 1.75 | 2.00 | 1.00 | 2.00 | ---- | 2.30 | ---- |
| Diammonium phosphate | ---- | ---- | 1.50 | ---- | 4.50 | ---- | 7.00 |
| Defluorinated phosphate | ---- | 2.00 | ---- | 6.00 | ---- | 9.00 | ---- |
| Salt | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Trace minerals | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Vitamin A & D 1/ | X | X | X | X | X | X | X |
| Total | 100.05 | 100.05 | 100.05 | 100.05 | 100.05 | 100.05 | 100.05 |

1/ Vitamin A added to provide 10,000 I. U. per lb. of feed; Vitamin D added to provide 1,000 I. U. per lb. of feed.

were determined by the method of Kimble (1939).

An analysis of variance was used to test the differences among treatments in amounts of feed consumed and weight gains made by the heifers. The final heifer weights and plasma-inorganic phosphorus levels were adjusted by analysis of covariance, (Steel and Torrie, 1960), for differences existing at the beginning of the experiment. Differences among adjusted treatment means were tested for significance by using the Multiple range test (Duncan, 1955).

# RESULTS AND DISCUSSION

This study was designed to evaluate diammonium phosphate as a supplemental source of phosphorus, when compared to defluorinated phosphate. The pertinent data of this wintering trial concerning average weight gains, feed consumption and feed utilization are given in Table XVIII. Appendix Table VI and VII show individual heifer weight gains and feed consumption records.

Only small differences were noted among the eight treatments in average total gains made by the heifers for the 140-day feeding period. An analysis of covariance revealed that there were no statistical significant differences in the weights of the heifers at the conclusion of the experiment. When the total gains made by the heifers were subjected to an analysis of variance, no significant differences were found among treatments; however, there were statistically significant differences ($P<.05$) in the total weight gains made by the heifers in the four replicated pens. The average total weight gains made by the heifers in experimental pens 1, 2, 3, and 4 were 126, 138, 131, and 148 pounds, respectively. The gains made by the heifers in pen 4 were significantly greater ($P<.05$) than gains made by the heifers in pens 1 and 3.

An underground drain pipe broke in pen 3 during this wintering trial, causing extremely adverse conditions for several weeks. However, it is doubtful if these conditions resulted in the differences between total gains made by the heifers in pens 3 and 4, because the drainage from pen 3 also caused pen 4 to become extremely muddy.

Using weight gains as the criteria for measuring the response of the

Table XVIII. Average Weight Gains, Feed Consumption, and Feed Efficiency of Heifers on Experiment II Fed the Various Levels of Phosphorus from Two Sources. (January 2, 1962 to May 22, 1962 -- 140 Days).

| Lot No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Treatment | | | | | | | | |
| Level of phosphorus | 0.12% | 0.12% | 0.18% | 0.18% | 0.24% | 0.24% | 0.30% | 0.30% |
| Source | Control | Control | Defl. | DAP | Defl. | DAP | Defl. | DAP |
| No. Animals | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Average weight (lbs.) | | | | | | | | |
| Initial | 369 | 379 | 381 | 363 | 368 | 374 | 370 | 375 |
| Final | 498 | 510 | 529 | 501 | 503 | 516 | 506 | 501 |
| Gain | 129 | 131 | 148 | 139 | 135 | 142 | 136 | 126 |
| Average daily gain | 0.92 | 0.94 | 1.05 | 0.99 | 0.96 | 1.02 | 0.97 | 0.90 |
| Average daily feed consumption (lbs.) | | | | | | | | |
| Concentrates 1/ | 3.90 | 3.90 | 3.90 | 3.90 | 3.90 | 3.90 | 3.90 | 3.90 |
| Supplement | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 |
| Hay | 4.50 | 4.41 | 4.47 | 4.38 | 4.38 | 4.46 | 4.42 | 4.46 |
| Total | 9.37 | 9.28 | 9.34 | 9.25 | 9.25 | 9.27 | 9.29 | 9.33 |
| Feed required/cwt. gain | | | | | | | | |
| Concentrates | 428 | 420 | 374 | 397 | 408 | 388 | 400 | 436 |
| Supplement | 106 | 104 | 92 | 98 | 101 | 89 | 100 | 108 |
| Hay | 484 | 471 | 423 | 441 | 454 | 438 | 432 | 484 |
| Total | 1018 | 995 | 889 | 936 | 963 | 915 | 922 | 1028 |
| Feed cost/cwt. gain 2/ | $18.56 | $18.15 | $16.22 | $17.14 | $17.73 | $16.74 | $17.64 | $19.26 |

1/ The concentrate mixture consisted of dried molasses beet pulp and steam-rolled corn.
2/ Feed costs are shown in Appendix Table XI.

heifers to increased levels of phosphorus, the heifers receiving either the 0.18 or 0.24 percent phosphorus rations made slightly greater gains than did the heifers receiving the control ration (0.12 percent phosphorus). The gains made by the heifers receiving the 0.18 and 0.24 percent phosphorus rations were nearly the same, and there appeared to be no particular differences between the gains made by the heifers receiving part of the added phosphorus either from diammonium phosphate or from defluorinated phosphate.

Table XIX shows the average daily gains of the heifers by 28-day periods.

Table XIX. Average Daily Gains of Heifers by 28-day Periods Fed Various Levels of Phosphorus from Two Sources.

| Lot No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Treatment | | | | | | | | |
| Level of phosphorus | 0.12% | 0.12% | 0.18% | 0.18% | 0.24% | 0.24% | 0.30% | 0.30% |
| Source | Control | Control | Defl. | DAP | Defl. | DAP | Defl. | DAP |
| 28-day periods | | | Average daily gain (lbs.) | | | | | |
| 1st (1-2-62) | 0.80 | 0.49 | 0.94 | 0.76 | 0.71 | 0.71 | 0.49 | 0.40 |
| 2nd (2-27-62) | 1.21 | 1.07 | 1.25 | 1.16 | 1.03 | 1.38 | 1.21 | 1.25 |
| 3rd (3-27-62) | 1.12 | 1.34 | 1.16 | 0.94 | 1.12 | 0.85 | 0.98 | 0.89 |
| 4th (4-24-62) | 1.07 | 1.25 | 1.21 | 1.47 | 1.07 | 1.42 | 0.47 | 1.25 |
| 5th (5-22-62) | 0.40 | 0.54 | 0.71 | 0.63 | 0.89 | 0.71 | 0.71 | 0.71 |
| Cumulative average daily gains (140-days) | 0.92 | 0.94 | 1.05 | 0.99 | 0.98 | 1.02 | 0.97 | 0.90 |

The average daily gains made by the heifers on all eight treatments were considerably smaller during the last 28 days of the experiment than the gains of the previous period. The extremely rainy weather and muddy conditions of th experimental pens during the last 28 days of the experiment, may explain to some extent the lesser gains made by the calves during the last period.

The experimental rations used in this experiment were originally calculated to contain either 0.12, 0.18, 0.24, or 0.30 percent phosphorus. However, the rations fed during the experiment did contain slightly higher levels of phosphorus than was expected. The difficulty encountered in obtaining the desired levels of phosphorus in the experimental rations was corrected to some extent by the feeding of a grass hay of lower phosphorus content, (0.13 percent), following the first 56 days of the trial; nevertheless, the rations still contained approximately 0.03 percent more phosphorus than was desired to evaluate critically the supplemental phosphorus sources. Plumlee et al. (1958) pointed out that in order to evaluate critically phosphorus supplements the basal ration to which the supplements are to be added should be as low in phosphorus as possible. The basal ration fed in this experiment contained approximately 0.12 percent phosphorus. Table XX gives the estimated amounts of phosphorus supplied by the experimental ration.

Table XX. The Estimated Amounts of Phosphorus Furnished by the Experimental Rations Differing in Level and Source of Supplemental Phosphorus Fed During Experiment II.

| Lot No. | Treatment | Percent phosphorus | Grams phosphorus | Lbs. Phos. per 100 lbs. body wt. | Grams Phos. 100 lbs. body wt. |
|---|---|---|---|---|---|
| 1 | 0.12% P. | .153 | 6.95 | .0034 | 1.52 |
| 2 | 0.12% P. | .153 | 6.95 | .0034 | 1.51 |
| 3 | 0.18% P. Defl. | .193 | 8.60 | .0040 | 1.81 |
| 4 | 0.18% P. DAP | .200 | 9.08 | .0045 | 2.04 |
| 5 | 0.24% P. Defl. | .253 | 11.35 | .0056 | 2.52 |
| 6 | 0.24% P. DAP | .250 | 11.33 | .0055 | 2.49 |
| 7 | 0.30% P. Defl. | .285 | 12.94 | .0064 | 2.90 |
| 8 | 0.30% P. DAP | .291 | 13.21 | .0065 | 2.95 |

The proximate chemical analysis of the feed ingredients used in the experiment is shown in Appendix Table XII.

Supplementing the basal ration with additional levels of phosphorus seemed to improve feed utilization. The heifers receiving the 0.18 and 0.24 percent phosphorus rations required less feed per pound of gain than did the heifers receiving the control rations (0.12 percent phosphorus). As shown in Table XVI and Appendix Table VII the heifers in Lot 8 were the only heifers which received additional phosphorus (0.30 percent total phosphorus) that did not show an improvement in feed utilization above the control Lots 1 and 2.

Although the feed utilization differences among treatments were not statistically significant in this experiment, the results do tend to agree with work reported by Eckles and Gullickson (1927) and Klieber _et al_. (1936). These workers found that cattle receiving rations inadequate in phosphorus utilize their ration less efficiently than cattle fed adequate phosphorus rations.

The plasma-inorganic phosphorus levels of the heifers receiving supplemental phosphorus revealed further that the control rations fed Lots 1 and 2 were low in phosphorus. Average plasma-inorganic phosphorus levels by 28-day periods are shown in Table XXI. Individual heifer plasma-inorganic phosphorus data are shown in Appendix Table VIII.

The plasma-inorganic phosphorus levels of the heifers receiving the rations containing added phosphorus were significantly higher ($P < .05$) at the conclusion of the experiment than plasma-phosphorus levels of the heifers in Lots 1 and 2. The differences between the plasma-phosphorus levels of the heifers in Lot 1 and the two lots receiving 0.30 percent phosphorus were highly significant ($P < .01$). When the plasma-phosphorus levels of the heifers in Lot 2 were compared with the levels of the two lots receiving 0.30 percent phosphorus, the differences were highly significant ($P < .01$) for the lot of heifers (Lot 8) receiving diammonium but only significant ($P < .01$) for the lot of heifers (Lot 7) receiving defluorinated phosphate.

Table XXI. Average Plasma-inorganic Phosphorus Levels of Heifers Fed Different Levels and Different Sources of Phosphorus by 28-Day Periods.

| Lot No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Treatment | | | | | | | | |
| Level of phosphorus | 0.12% | 0.12% | 0.18% | 0.18% | 0.24% | 0.24% | 0.30% | 0.30% |
| Source | Control | Control | Defl. | DAP | Defl. | DAP | Defl. | DAP |
| 28-day periods | | | Mg. phosphorus per 100 ml. blood | | | | | |
| Initial (1-2-62) | 7.09 | 6.78 | 6.95 | 7.26 | 6.50 | 7.24 | 7.06 | 6.59 |
| 1st (1-30_62) | 8.63 | 8.33 | 9.54 | 8.88 | 9.34 | 9.62 | 9.17 | 9.02 |
| 2nd (2-27-62) | 7.79 | 8.27 | 8.93 | 8.78 | 9.41 | 10.05 | 8.79 | 9.30 |
| 3rd (3-27-62) | 7.13 | 7.19 | 6.24 | 7.03 | 8.46 | 7.71 | 7.85 | 8.66 |
| 4th (4-24-62) | 5.52 | 6.16 | 7.28 | 6.96 | 8.23 | 8.60 | 7.98 | 8.61 |
| 5th (5-22-62) | 5.07 | 5.89 | 6.77 | 6.79 | 7.60 | 7.52 | 7.62 | 8.04 |

The only significant differences in plasma-phosphorus levels among the lots of heifers getting added phosphorus were that the heifers in Lot 8 had significantly ($P < .05$) higher levels than those of heifers in Lots 3 and 4 (0.18 percent phosphorus). The heifers in Lot 5, receiving defluorinated phosphate in a 0.24 percent phosphorus ration, had slightly higher plasma-phosphorus levels than those of heifers receiving the same level of phosphorus but part of the phosphorus coming from diammonium phosphate.

The plasma-vitamin A levels of the heifers were well above the minimum of 16 mcg. of vitamin A per 100 cc. of plasma reported by Davis et al. (1941), until the last part of the experiment. When the blood samples were analyzed for plasma-vitamin A on the 112th day of the experiment, it was found that the levels were considerably lower than they had been the previous 28 days (see Appendix Table X). The heifers had been receiving 10,000 I. U. of vitamin A daily in the one pound of protein supplement. The vitamin A levels in the supplements were increased to 20,000 I. U. per pound during the last 28 days of the experiment. The final plasma-vitamin A analysis showed the levels had increased and were within the normal range.

The plasma-carotene levels were higher throughout the experiment than the minimum level of 25 mcg. of carotene per 100 cc. of plasma reported by Davis et al. (1941).

# SUMMARY

Diammonium phosphate was compared to defluorinated phosphate as a supplemental source of phosphorus for heifers fed a low phosphorus wintering ration. Thirty-two Hereford heifers were used to conduct this 140-day wintering trial.

The two phosphorus compounds were compared at three levels of phosphorus in the ration. The levels used were 0.18, 0.24, and 0.30 percent phosphorus of the ration. A ration containing 0.12 percent phosphorus served as the control ration. All of the heifers received the same basal ration, the only difference among treatments being either the added source or level of phosphorus in each of the twenty percent protein supplements. One pound of the supplement, furnishing the added phosphorus, was fed per head daily. The heifers were individually fed the experimental rations once daily during the feeding trial.

The heifers in Lots 1 and 2 received the control ration, (0.12 percent phosphorus). In the remaining six lots, the heifers were fed rations containing either 0.18, 0.24, or 0.30 percent phosphorus. Part of the added phosphorus at each level was supplied by either diammonium or defluorinated phosphate.

The differences among the eight lots of heifers in weight gains and feed efficiency were not significant. There was a trend for the heifers fed rations with added phosphorus to require less feed per pound of gain and make greater gains than the heifers fed the control ration. However, this trend was only evident for the heifers receiving the 0.18 and 0.24 percent phosphorus rations.

The differences between plasma-inorganic phosphorus levels of heifers fed the control rations and the heifers fed added phosphorus rations were significant ($P < .05$), and highly significant ($P < .01$) for the heifers fed 0.30 percent phosphorus rations. The differences between the plasma phosphorus levels of the heifers fed 0.18 and 0.30 percent phosphorus rations were significant ($P < .05$).

There were no apparent differences between the heifers fed added phosphorus supplied either by diammonium phosphate or defluorinated phosphate, as measured by weight gains, feed efficiency, and plasma-phosphorus levels.

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# APPENDIX

APPENDIX TABLE I. INDIVIDUAL PERFORMANCES OF STEERS WINTERED ON RATIONS DIFFERING IN SOURCES OF SUPPLEMENTAL NITROGEN.

| Steer No. | Initial Weight (12-27-60) | Final Weight (4-18-61) | Total Gain by Periods 1 | 2 | 3 | 4 | Total Gain | Average Daily Gain |
|---|---|---|---|---|---|---|---|---|
| | | | Lot No. 1 (Monoammonium Phosphate) | | | | | |
| 17 | 510 | 630 | 10 | 30 | 50 | 30 | 120 | 1.07 |
| 21 | 425 | 535 | 5 | 25 | 35 | 45 | 110 | 0.98 |
| 12 | 420 | 575 | 25 | 30 | 45 | 55 | 155 | 1.38 |
| 70 | 360 | 470 | 15 | 25 | 35 | 35 | 110 | 0.98 |
| 41 | 475 | 610 | 5 | 40 | 50 | 40 | 135 | 1.21 |
| 27 | 465 | 570 | -5 | 45 | 40 | 25 | 105 | 0.94 |
| 85 | 410 | 530 | 10 | 30 | 30 | 50 | 120 | 1.07 |
| 52 | 445 | 575 | 15 | 30 | 55 | 30 | 130 | 1.16 |
| Total | 3510 | 4495 | 80 | 225 | 340 | 310 | 985 | |
| Avg. | 435.75 | 561.8 | | | | | 123.1 | |
| Avg. Daily Gain | | | 0.36 | 1.14 | 1.42 | 1.49 | | 1.10 |
| | | | Lot No. 2 (Diammonium Phosphate) | | | | | |
| 14 | 480 | 610 | 10 | 30 | 55 | 35 | 130 | 1.16 |
| 16 | 450 | 575 | 5 | 30 | 45 | 45 | 125 | 1.12 |
| 46 | 365 | 490 | 0 | 35 | 45 | 45 | 125 | 1.12 |
| 35 | 460 | 595 | 20 | 40 | 55 | 20 | 135 | 1.12 |
| 54 | 425 | 530 | 10 | 20 | 50 | 25 | 105 | 0.94 |
| 18 | 510 | 645 | 15 | 50 | 40 | 30 | 135 | 1.21 |
| 57 | 455 | 575 | 5 | 45 | 40 | 30 | 120 | 1.07 |
| 80 | 345 | 485 | 25 | 20 | 60 | 35 | 140 | 1.25 |
| Total | 3490 | 4505 | 90 | 270 | 390 | 265 | 1015 | |
| Avg. | 436.25 | 563.1 | | | | | 127 | |
| Avg. Daily Gain | | | 0.40 | 1.21 | 1.63 | 1.27 | | 1.14 |
| | | | Lot No. 3 (Urea and Defluorinated Phosphate) | | | | | |
| 20 | 480 | 605 | 15 | 35 | 45 | 30 | 125 | 1.12 |
| 9 | 535 | 635 | 0 | 50 | 25 | 25 | 100 | 0.89 |
| 8 | 490 | 590 | -10 | 35 | 30 | 45 | 100 | 0.89 |
| 77 | 365 | 495 | 5 | 45 | 50 | 50 | 130 | 1.16 |
| 11 | 440 | 570 | 10 | 50 | 40 | 30 | 130 | 1.16 |
| 34 | 485 | 585 | -10 | -50 | 135 | 25 | 100 | 0.89 |
| 32 | 475 | 540 | -25 | 25 | 35 | 30 | 65 | 0.58 |
| 56 | 370 | 485 | 0 | 15 | 45 | 55 | 115 | 1.03 |
| Total | 3640 | 4505 | -15 | 305 | 395 | 280 | 865 | |
| Avg. | 455 | 563.1 | | | | | 108 | |
| Avg. Daily Gain | | | -0.05 | 1.36 | 1.23 | 1.35 | | 0.97 |

APPENDIX TABLE I. (CONTINUED).

| Steer No. | Initial Weight (12-27-60) | Final Weight (4-18-61) | Total Gain by Periods 1 | 2 | 3 | 4 | Total Gain | Average Daily Gain |
|---|---|---|---|---|---|---|---|---|
| | Lot No. 4 (Soybean Oil Meal and Defluorinated Phosphate) | | | | | | | |
| 58 | 420 | 510 | 0 | 30 | 30 | 30 | 90 | 0.80 |
| 65 | 455 | 575 | 15 | 30 | 45 | 30 | 120 | 1.07 |
| 22 | 510 | 625 | -5 | 40 | 35 | 45 | 115 | 1.03 |
| 75 | 460 | 570 | -10 | 50 | 35 | 35 | 110 | 0.98 |
| 72 | 400 | 490 | -15 | 25 | 35 | 45 | 90 | 0.80 |
| 68 | 380 | 520 | 0 | 45 | 50 | 45 | 140 | 1.25 |
| 61 | 475 | 610 | 15 | 45 | 35 | 40 | 135 | 1.21 |
| 31 | 500 | 580 | -15 | 35 | 40 | 20 | 80 | 0.71 |
| Total | 3600 | 4480 | -15 | 300 | 305 | 290 | 880 | |
| Avg. | 450.0 | 560.0 | | | | | 110 | |
| Avg. Daily Gain | | | -0.50 | 1.34 | 1.27 | 1.39 | | 0.98 |

APPENDIX TABLE II. INDIVIDUAL STEER FEED RECORDS FOR STEERS WINTERED ON RATIONS DIFFERING IN SOURCES OF SUPPLEMENTAL NITROGEN.

| Steer No. | Gain (lbs.) | Concentrates1/ | Supplement | Hay1/ | Total1/ | Feed/cwt. |
|---|---|---|---|---|---|---|
| | | | Lot No. 1 (Monoammonium Phosphate) | | | |
| 17 | 120 | 414 | 105 | 657 | 1176 | 946.6 |
| 21 | 110 | 414 | 102 | 607 | 1123 | 1020.9 |
| 12 | 155 | 414 | 105 | 658 | 1177 | 759.3 |
| 70 | 110 | 382 | 63 | 623.5 | 1068.5 | 971.3 |
| 41 | 135 | 414 | 105 | 631 | 1150 | 811.2 |
| 27 | 105 | 414 | 103 | 645.5 | 1162.5 | 1107.1 |
| 85 | 120 | 414 | 99 | 660.5 | 1173.5 | 977.9 |
| 52 | 130 | 414 | 105 | 601 | 1120 | 861.5 |
| Total | 985 | 3280 | 787 | 5083.5 | 9150.5 | |
| Average | 123.1 | 410.0 | 98.4 | 635.4 | 1138.8 | 928.9 |
| | | | Lot No. 2 (Diammonium Phosphate) | | | |
| 14 | 130 | 414 | 105 | 635.5 | 1154.5 | 888.0 |
| 16 | 125 | 402.5 | 76 | 625 | 1103.5 | 882.8 |
| 46 | 125 | 392.5 | 101 | 615 | 1108 | 820.7 |
| 35 | 135 | 411 | 104 | 656.5 | 1171.5 | 867.7 |
| 54 | 105 | 414 | 105 | 629.5 | 1148.5 | 1093.8 |
| 18 | 135 | 414 | 105 | 667.5 | 1186.5 | 878.8 |
| 57 | 120 | 414 | 105 | 635.0 | 1154 | 961.6 |
| 80 | 140 | 411 | 104 | 605.5 | 1120.5 | 800.3 |
| Total | 1015 | 3272 | 805 | 5069.5 | 9147.0 | |
| Average | 126.8 | 409 | 100.6 | 633.6 | 1143.3 | 901.1 |
| | | | Lot No. 3 (Urea) | | | |
| 20 | 125 | 414 | 105 | 651 | 1170 | 936.0 |
| 9 | 100 | 411 | 105 | 658 | 1174 | 1174.0 |
| 8 | 100 | 414 | 105 | 647.5 | 1166.5 | 1166.5 |
| 77 | 130 | 414 | 105 | 602.5 | 1121.5 | 862.6 |
| 11 | 130 | 410 | 104 | 647 | 1161 | 893.0 |
| 37 | 100 | 414 | 105 | 661.5 | 1180.5 | 1180.5 |
| 32 | 65 | 332 | 78 | 649.5 | 1059 | 1629.0 |
| 56 | 115 | 229 | 74 | 619.5 | 992.5 | 798.3 |
| Total | 865 | 3108 | 781 | 5136.5 | 8954.4 | |
| Average | 108 | 388 | 97.6 | 642 | 1118.8 | 1035.2 |

APPENDIX TABLE II. (CONTINUED).

| Steer No. | Gain (lbs.) | Concentrates[1/] | Supplement | Hay[1/] | Total[1/] | Feed/cwt. |
|---|---|---|---|---|---|---|
| | | | Lot No. 4 (Soybean Oil Meal) | | | |
| 58 | 90 | 401.5 | 104 | 607.5 | 1113 | 1236.7 |
| 65 | 120 | 410 | 104 | 626.5 | 1140.5 | 950.4 |
| 22 | 115 | 414 | 105 | 621.5 | 1140.5 | 991.7 |
| 75 | 110 | 414 | 105 | 596 | 1115 | 1013.6 |
| 72 | 90 | 358 | 92.5 | 609.5 | 1060 | 1177.8 |
| 68 | 140 | 406 | 103 | 600 | 1109 | 792.1 |
| 61 | 135 | 414 | 104 | 624 | 1142 | 845.9 |
| 31 | 80 | 388.5 | 99 | 652 | 1139.5 | 1424.4 |
| Total | 880 | 3206.0 | 816.5 | 4937.0 | 8959.5 | |
| Average | 110 | 400.8 | 102.1 | 617.1 | 1119.9 | 1018.1 |

1/ Feed not consumed was weighed back to the nearest one-half pound.

APPENDIX TABLE III. PLASMA-INORGANIC PHOSPHORUS LEVELS OF STEERS WINTERED ON RATIONS DIFFERING IN SOURCES OF SUPPLEMENTAL NITROGEN.

| Steer No. | Mg. Phosphorus per 100 ml. blood | | | | |
|---|---|---|---|---|---|
| | 12-27-60 | 1-24-61 | 2-21-61 | 3-23-61 | 4-18-61 |
| | Lot No. 1 (Monoammonium Phosphate) | | | | |
| 17 | 7.9 | 8.9 | 9.8 | 7.9 | 8.8 |
| 21 | 7.4 | 6.8 | 8.2 | 7.8 | 7.9 |
| 12 | 7.0 | 7.5 | 8.9 | 8.1 | 9.0 |
| 70 | 6.4 | 7.5 | 7.2 | 6.8 | 6.7 |
| 41 | 10.2 | 8.9 | 10.8 | 8.8 | 8.4 |
| 27 | 7.8 | 6.9 | 8.3 | 7.0 | 6.9 |
| 85 | 7.5 | 7.7 | 8.3 | 8.4 | 8.1 |
| 52 | 7.9 | 8.7 | 7.0 | 6.2 | 7.4 |
| Average | 7.8 | 7.8 | 8.6 | 7.6 | 7.9 |
| | Lot No. 2 (Diammonium Phosphate) | | | | |
| 14 | 7.1 | 7.8 | 8.3 | 8.2 | 8.4 |
| 16 | 6.2 | 7.9 | 8.5 | 7.2 | 6.9 |
| 46 | 6.7 | 8.5 | 9.4 | 6.8 | 7.6 |
| 35 | 6.9 | 9.1 | 10.0 | 7.3 | 8.7 |
| 54 | 6.4 | 6.9 | 7.3 | 8.6 | 7.9 |
| 18 | 7.0 | 8.7 | 9.4 | 8.3 | 7.2 |
| 57 | 7.2 | 7.5 | 8.7 | 8.3 | 7.6 |
| 80 | 6.8 | 8.9 | 10.8 | 7.1 | 6.5 |
| Average | 6.8 | 8.2 | 9.0 | 7.7 | 7.6 |
| | Lot No. 3 (Urea) | | | | |
| 20 | 7.1 | 8.9 | 8.4 | 8.6 | 7.0 |
| 9 | 6.6 | 7.8 | 9.1 | 7.6 | 7.8 |
| 8 | 7.6 | 8.2 | 8.2 | 7.1 | 6.5 |
| 77 | 7.1 | 6.0 | 7.0 | 7.9 | 6.8 |
| 11 | 7.9 | 7.1 | 8.3 | 6.8 | 5.9 |
| 37 | 8.4 | 7.9 | 9.4 | 8.2 | 7.1 |
| 32 | 7.6 | 8.1 | 8.3 | 7.7 | 7.8 |
| 56 | 7.3 | 7.5 | 7.8 | 7.9 | 5.7 |
| Average | 7.5 | 7.7 | 8.3 | 7.7 | 6.8 |
| | Lot No. 4 (Soybean Oil Meal) | | | | |
| 58 | 7.8 | 7.4 | 7.6 | 8.2 | 8.0 |
| 65 | 7.3 | 9.4 | 9.4 | 8.4 | 6.8 |
| 22 | 5.4 | 8.1 | 7.5 | 7.5 | 7.1 |
| 75 | 5.6 | 6.8 | 7.6 | 7.0 | 6.6 |
| 72 | 7.8 | 8.9 | 8.4 | 8.2 | 6.7 |
| 68 | 6.6 | 6.6 | 8.2 | 8.2 | 6.5 |
| 61 | 6.7 | 8.9 | 7.6 | 7.8 | 7.0 |
| 31 | 6.1 | 7.7 | 7.9 | 7.9 | 7.2 |
| Average | 6.7 | 8.0 | 8.0 | 7.9 | 7.0 |

APPENDIX TABLE IV. PLASMA-CAROTENE AND VITAMIN A BLOOD LEVELS OF STEERS WINTERED ON RATIONS DIFFERING IN SOURCES OF SUPPLEMENT NITROGEN.

| Steer No. | Mcg. Carotene per 100 ml. blood 12-27-60 | 1-24-61 | 2-21-61 | Mcg. Vitamin A per 100 ml. blood 12-27-60 | 1-24-61 | 2-21-61 |
|---|---|---|---|---|---|---|
| | | | Lot No. 1 (Monoammonium Phosphate) | | | |
| 17 | 107 | 95 | 104 | 19 | 34 | 53 |
| 21 | 102 | 112 | 117 | 33 | 40 | 24 |
| 12 | 76 | 118 | 192 | 25 | 42 | 20 |
| 70 | 152 | 189 | 198 | 53 | 68 | 16 |
| 41 | 136 | 174 | 147 | 50 | 62 | 25 |
| 27 | 113 | 102 | 154 | 46 | 36 | 29 |
| 85 | 158 | 123 | 249 | 34 | 44 | 36 |
| 52 | 108 | 159 | 219 | 36 | 57 | 47 |
| Average | 119 | 134 | 172 | 37 | 48 | 48 |
| | | | Lot No. 2 (diammonium Phosphate) | | | |
| 14 | 183 | 128 | 193 | 18 | 46 | 31 |
| 16 | 158 | 196 | 243 | 23 | 70 | 33 |
| 46 | 154 | 152 | 148 | 17 | 55 | 38 |
| 35 | 110 | 154 | 195 | 40 | 55 | 27 |
| 54 | 145 | 113 | 147 | 46 | 40 | 23 |
| 18 | 117 | 181 | 204 | 28 | 65 | 20 |
| 57 | 103 | 112 | 95 | 21 | 44 | 38 |
| 80 | 120 | 112 | 117 | 35 | 40 | 41 |
| Average | 136 | 145 | 168 | 29 | 52 | 31 |
| | | | Lot No. 3 (Urea) | | | |
| 20 | 119 | 137 | 201 | 14 | 49 | 33 |
| 9 | 171 | 174 | 147 | 27 | 62 | 26 |
| 8 | 108 | 139 | 162 | 19 | 50 | 22 |
| 77 | 113 | 104 | 123 | 18 | 37 | 31 |
| 11 | 108 | 171 | 92 | 34 | 61 | 31 |
| 37 | 110 | 183 | 165 | 36 | 65 | 20 |
| 32 | 137 | 159 | 146 | 34 | 57 | 23 |
| 56 | 115 | 238 | 144 | 42 | 85 | 32 |
| Average | 123 | 163 | 147 | 28 | 58 | 27 |
| | | | Lot No. 4 (Soybean Oil Meal) | | | |
| 58 | 138 | 219 | 234 | 19 | 79 | 34 |
| 65 | 156 | 198 | 180 | 56 | 66 | 34 |
| 22 | 159 | 178 | 100 | 50 | 64 | 32 |
| 75 | 76 | 117 | 113 | 15 | 42 | 30 |
| 72 | 97 | 208 | 206 | 48 | 74 | 27 |
| 68 | 132 | 159 | 177 | 34 | 57 | 22 |
| 61 | 117 | 198 | 148 | 25 | 71 | 22 |
| 31 | 137 | 147 | 175 | 55 | 53 | 32 |
| Average | 127 | 178 | 167 | 38 | 63 | 29 |

APPENDIX TABLE V. INDIVIDUAL WEIGHT GAINS OF STEERS FATTENED ON RATIONS DIFFERING IN SOURCES OF SUPPLEMENTAL NITROGEN.

| Steer No. | Initial Weight (4-18-60) | Final Weight (10-3-61) | Total Gain by Periods 1 | 2 | 3 | 4 | 5 | 6 | Total Gain | Average Daily Gain |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Lot No. 1 (Monoammonium Phosphate) | | | | | | | |
| 17 | 630 | 1130 | 70 | 100 | 120 | 100 | 75 | 35 | 500 | 2.98 |
| 21 | 535 | 945 | 15 | 105 | 55 | 95 | 90 | 50 | 410 | 2.44 |
| 12 | 575 | 1120 | 65 | 135 | 115 | 110 | 70 | 50 | 535 | 3.24 |
| 70 | 470 | 960 | 50 | 85 | 110 | 95 | 85 | 65 | 490 | 2.92 |
| 41 | 610 | 1130 | 40 | 135 | 120 | 85 | 90 | 50 | 520 | 3.10 |
| 27 | 570 | 1000 | 70 | 95 | 60 | 100 | 75 | 30 | 430 | 2.56 |
| 85 | 530 | 975 | 90 | 70 | 80 | 90 | 60 | 55 | 445 | 2.65 |
| 52 | 575 | 1015 | 75 | 95 | 100 | 60 | 75 | 35 | 440 | 2.62 |
| Avg. Wt. | 562 | 1034 | 621 | 724 | 819 | 911 | 988 | 1034 | | |
| Avg. Gain (lbs.) | | | 59 | 103 | 95 | 92 | 78 | 46 | 473 | |
| Avg. Daily Gain | | | 2.21 | 3.66 | 3.39 | 3.28 | 2.77 | 1.65 | | 2.81 |
| | | | Lot No. 2 (Diammonium Phosphate) | | | | | | | |
| 14 | 610 | 1120 | 60 | 100 | 110 | 95 | 100 | 45 | 510 | 3.04 |
| 16 | 575 | 1020 | 45 | 105 | 100 | 105 | 45 | 45 | 445 | 2.65 |
| 46 | 490 | 985 | 60 | 115 | 75 | 110 | 80 | 55 | 495 | 2.95 |
| 35 | 595 | 1160 | 75 | 120 | 120 | 110 | 100 | 40 | 565 | 3.36 |
| 54 | 530 | 955 | 70 | 105 | 85 | 75 | 70 | 20 | 425 | 2.53 |
| 18 | 645 | 1175 | 115 | 110 | 125 | 110 | 85 | -15 | 530 | 3.16 |
| 57 | 575 | 1065 | 75 | 110 | 110 | 85 | 95 | 15 | 490 | 2.92 |
| 80 | 485 | 995 | 65 | 85 | 120 | 130 | 65 | 45 | 510 | 3.04 |
| Avg. Wt. | 563 | 1059 | 634 | 740 | 846 | 948 | 1028 | 1059 | | |
| Avg. Gain (lbs.) | | | 71 | 106 | 106 | 103 | 80 | 31 | 496 | |
| Avg. Daily Gain | | | 2.52 | 3.79 | 3.78 | 3.66 | 2.86 | 1.12 | | 2.95 |
| | | | Lot No. 3 (Urea and Defluorinated Phosphate) | | | | | | | |
| 20 | 605 | 1060 | 75 | 105 | 80 | 105 | 55 | 35 | 455 | 2.71 |
| 9 | 635 | 1160 | 90 | 115 | 110 | 90 | 100 | 120 | 525 | 3.13 |
| 8 | 590 | 1045 | 80 | 80 | 80 | 75 | 105 | 35 | 455 | 2.71 |
| 77 | 495 | 980 | 80 | 75 | 135 | 95 | 75 | 25 | 485 | 2.89 |
| 11 | 570 | 1115 | 100 | 100 | 95 | 100 | 90 | 60 | 545 | 3.24 |
| 37 | 585 | 1100 | 20 | 75 | 90 | 85 | 110 | 35 | 515 | 3.07 |
| 32 | 540 | 1020 | 110 | 75 | 115 | 85 | 40 | 55 | 480 | 2.86 |
| 56 | 485 | 1020 | 35 | 140 | 105 | 115 | 95 | 45 | 535 | 3.18 |
| Avg. Wt. | 563 | 1063 | 649 | 745 | 846 | 940 | 1024 | 1063 | | |
| Avg. Gain (lbs.) | | | 86 | 96 | 101 | 94 | 84 | 39 | 499 | |
| Avg. Daily Gain | | | 2.98 | 3.42 | 3.62 | 3.35 | 2.99 | 1.38 | | 2.97 |

APPENDIX TABLE V. (CONTINUED).

| Steer No. | Initial Weight (4-18-60) | Final Weight (10-3-61) | Total Gain by Periods 1 | 2 | 3 | 4 | 5 | 6 | Total Gain | Average Daily Gain |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Lot No. 4 (Soybean Oil Meal and Defluorinated Phosphate) | | | | | | | |
| 58 | 510 | 1045 | 100 | 95 | 100 | 100 | 95 | 45 | 535 | 3.18 |
| 65 | 575 | 1145 | 105 | 110 | 140 | 90 | 70 | 55 | 570 | 3.39 |
| 22 | 625 | 1085 | 65 | 110 | 110 | -30 | 130 | 75 | 460 | 2.74 |
| 75 | 570 | 1015 | 85 | 100 | 95 | 55 | 65 | 45 | 445 | 2.65 |
| 72 | 490 | 1005 | 65 | 75 | 120 | 100 | 80 | 75 | 515 | 3.07 |
| 68 | 520 | 1060 | 105 | 115 | 105 | 85 | 60 | 70 | 540 | 3.21 |
| 61 | 610 | 1160 | 60 | 90 | 120 | 110 | 100 | 70 | 550 | 3.27 |
| 31 | 580 | 1090 | 85 | 70 | 105 | 105 | 80 | 65 | 510 | 3.04 |
| Avg. Wt. | 560 | 1076 | 644 | 739 | 851 | 928 | 1013 | 1076 | | |
| Avg. Gain (lbs.) | | | 84 | 96 | 112 | 77 | 85 | 63 | 516 | |
| Avg. Daily Gain | | | 2.98 | 3.42 | 4.00 | 2.75 | 3.04 | 2.23 | | 3.07 |

APPENDIX TABLE VI. INDIVIDUAL WEIGHT GAINS OF HEIFERS WINTERED ON RATIONS DIFFERING IN SOURCES AND LEVELS OF SUPPLEMENTAL PHOSPHORUS.

| Heifer No. | Initial Weight (1-2-62) | Final Weight (5-22-62) | Total Gain | Average Daily Gain |
|---|---|---|---|---|
| | Lot No. 1 (0.12% Phosphorus) | | | |
| 1798 | 400 | 510 | 110 | 0.79 |
| 153 | 375 | 500 | 125 | 0.89 |
| 1851 | 365 | 505 | 140 | 1.00 |
| 178 | 335 | 475 | 140 | 1.00 |
| Average | 369 | 497 | 129 | 0.92 |
| | Lot No. 2 (0.12% Phosphorus) | | | |
| 1795 | 405 | 535 | 130 | 0.93 |
| 215 | 325 | 465 | 140 | 1.00 |
| 1785 | 400 | 510 | 110 | 0.79 |
| 158 | 385 | 530 | 155 | 1.11 |
| Average | 379 | 510 | 131 | 0.94 |
| | Lot No. 3 (0.18% Phosphorus-Defluorinated Phosphate) | | | |
| 1790 | 430 | 575 | 145 | 1.04 |
| 142 | 380 | 535 | 155 | 1.11 |
| 216 | 365 | 500 | 135 | 0.96 |
| 1792 | 350 | 505 | 155 | 1.11 |
| Average | 381 | 529 | 148 | 1.05 |
| | Lot No. 4 (0.18% Phosphorus-Diammonium Phosphate) | | | |
| 1809 | 320 | 440 | 120 | 0.86 |
| 1800 | 420 | 535 | 115 | 0.82 |
| 151 | 355 | 525 | 170 | 1.21 |
| 1799 | 355 | 505 | 150 | 1.07 |
| Average | 363 | 501 | 139 | 0.99 |
| | Lot No. 5 (0.24% Phosphorus-Defluorinated Phosphate) | | | |
| 1860 | 440 | 560 | 120 | 0.86 |
| 130 | 380 | 530 | 150 | 1.07 |
| 1794 | 345 | 470 | 125 | 0.89 |
| 206 | 305 | 450 | 145 | 1.04 |
| Average | 368 | 503 | 135 | 0.96 |

APPENDIX TABLE VI. (CONTINUED).

| Heifer No. | Initial Weight (1-2-62) | Final Weight (5-22-62) | Total Gain | Average Daily Gain |
|---|---|---|---|---|
| | Lot No. 6 (0.24% Phosphorus-Diammonium Phosphate) | | | |
| 124 | 405 | 535 | 130 | 0.93 |
| 1856 | 365 | 505 | 140 | 1.00 |
| 1858 | 395 | 530 | 136 | 0.96 |
| 1791 | 330 | 495 | 165 | 1.18 |
| Average | 374 | 516 | 142 | 1.02 |
| | Lot No. 7 (0.30% Phosphorus-Defluorinated Phosphate) | | | |
| 241 | 315 | 450 | 135 | 0.96 |
| 148 | 395 | 530 | 135 | 0.96 |
| 1797 | 410 | 540 | 130 | 0.93 |
| 1854 | 360 | 505 | 145 | 1.04 |
| Average | 370 | 506 | 136 | 0.97 |
| | Lot No. 8 (0.30% Phosphorus-Diammonium Phosphate) | | | |
| 146 | 400 | 520 | 120 | 0.86 |
| 189 | 385 | 530 | 145 | 1.04 |
| 1796 | 410 | 520 | 110 | 0.79 |
| 1793 | 305 | 435 | 130 | 0.93 |
| Average | 375 | 501 | 126 | 0.90 |

APPENDIX TABLE VII. INDIVIDUAL FEED RECORDS OF HEIFERS WINTERED ON RATIONS DIFFERING IN SOURCES AND LEVELS OF SUPPLEMENTAL PHOSPHORUS.

| Heifer No. | Total Gain (lbs.) | Feed Consumption | | | Total | Feed/cwt. Gain |
|---|---|---|---|---|---|---|
| | | Concentrates | Supplement | Hay | | |
| | | Lot No. 1 (0.12% Phosphorus) | | | | |
| 1798 | 110 | 551 | 136 | 633 | 1320 | 1200 |
| 153 | 125 | 551 | 136 | 623 | 1310 | 1048 |
| 1851 | 140 | 551 | 136 | 628 | 1315 | 939 |
| 178 | 140 | 551 | 136 | 608 | 1295 | 925 |
| Total | 515 | 2204 | 544 | 2492 | 5440 | |
| Average | 129 | 551 | 136 | 623 | 1360 | 1018 |
| | | Lot No. 2 (0.12% Phosphorus) | | | | |
| 1795 | 130 | 551 | 136 | 637 | 1325 | 1019 |
| 215 | 140 | 551 | 136 | 610 | 1298 | 927 |
| 1785 | 110 | 551 | 136 | 615 | 1303 | 1185 |
| 158 | 155 | 551 | 136 | 609 | 1280 | 826 |
| Total | 525 | 2204 | 544 | 2471 | 5206 | |
| Average | 131 | 551 | 136 | 618 | 1302 | 995 |
| | | Lot No. 3 (0.18% Phosphorus-Defluorinated Phosphate) | | | | |
| 1790 | 145 | 551 | 136 | 635 | 1322 | 912 |
| 142 | 155 | 551 | 136 | 615 | 1302 | 840 |
| 216 | 135 | 551 | 136 | 620 | 1307 | 968 |
| 1792 | 155 | 551 | 136 | 626 | 1213 | 847 |
| Total | 590 | 2204 | 544 | 2496 | 5244 | |
| Average | 148 | 551 | 136 | 624 | 1311 | 899 |
| | | Lot No. 4 (0.18% Phosphorus-Diammonium Phosphate) | | | | |
| 1809 | 120 | 551 | 136 | 614 | 1301 | 1084 |
| 1800 | 115 | 551 | 136 | 621 | 1308 | 1137 |
| 151 | 170 | 551 | 136 | 591 | 1278 | 752 |
| 1799 | 150 | 551 | 136 | 620 | 1297 | 865 |
| Total | 555 | 2204 | 544 | 2446 | 5184 | |
| Average | 139 | 551 | 136 | 612 | 1296 | 936 |

APPENDIX TABLE VII. (CONTINUED).

| Heifer No. | Total Gain (lbs.) | Feed Consumption Concentrates | Supplement | Hay | Total | Feed/cwt. Gain |
|---|---|---|---|---|---|---|
| | | Lot No. 5 (0.24% Phosphorus-Defluorinated Phosphate) | | | | |
| 1860 | 120 | 551 | 136 | 643 | 1328 | 1107 |
| 130 | 150 | 551 | 136 | 626 | 1311 | 874 |
| 1794 | 125 | 551 | 136 | 585 | 1270 | 1016 |
| 206 | 145 | 551 | 136 | 597 | 1283 | 885 |
| Total | 540 | 2204 | 544 | 2451 | 5192 | |
| Average | 135 | 551 | 136 | 613 | 1298 | 963 |
| | | Lot No. 6 (0.24% Phosphorus-Diammonium Phosphate) | | | | |
| 124 | 130 | 551 | 136 | 641 | 1328 | 1022 |
| 1856 | 140 | 551 | 136 | 614 | 1301 | 929 |
| 1858 | 135 | 551 | 100 | 620 | 1271 | 942 |
| 1791 | 165 | 551 | 136 | 620 | 1307 | 792 |
| Total | 570 | 2204 | 508 | 2495 | 5207 | |
| Average | 142 | 551 | 127 | 624 | 1302 | 915 |
| | | Lot No. 7 (0.30% Phosphorus-Defluorinated Phosphate) | | | | |
| 241 | 135 | 551 | 136 | 599 | 1285 | 952 |
| 148 | 135 | 551 | 136 | 615 | 1301 | 964 |
| 1797 | 130 | 551 | 136 | 637 | 1323 | 1018 |
| 1854 | 145 | 551 | 136 | 625 | 1113 | 768 |
| Total | 545 | 2204 | 544 | 2476 | 5022 | |
| Average | 136 | 551 | 136 | 619 | 1255 | 922 |
| | | Lot No. 8 (0.30% Phosphorus-Diammonium Phosphate) | | | | |
| 146 | 120 | 551 | 136 | 630 | 1317 | 1098 |
| 189 | 145 | 551 | 136 | 624 | 1311 | 904 |
| 1796 | 110 | 551 | 136 | 629 | 1316 | 1196 |
| 1793 | 130 | 551 | 132 | 612 | 1245 | 958 |
| Total | 505 | 2204 | 540 | 2495 | 5189 | |
| Average | 126 | 551 | 135 | 624 | 1347 | 1028 |

APPENDIX TABLE VIII. PLASMA-INORGANIC PHOSPHORUS LEVELS OF HEIFERS WINTERED ON RATIONS DIFFERING IN SOURCES AND LEVELS OF SUPPLEMENTAL PHOSPHORUS.

| | Mg. Phosphorus per 100 ml. blood | | | | | |
|---|---|---|---|---|---|---|
| Heifer No. | 1-2-62 | 1-30-62 | 2-27-62 | 3-27-62 | 4-24-62 | 5-22-62 |
| | Lot No. 1 (0.12% Phosphorus) | | | | | |
| 1798 | 6.2 | 8.4 | 7.6 | 8.0 | 5.9 | 4.7 |
| 153 | 6.2 | 8.3 | 6.5 | 6.8 | 5.2 | 4.7 |
| 1851 | 8.6 | 8.6 | 9.7 | 6.2 | 6.2 | 5.7 |
| 178 | 7.4 | 9.2 | 7.3 | 7.5 | 4.9 | 5.2 |
| Average | 7.1 | 8.6 | 7.8 | 7.1 | 5.5 | 5.1 |
| | Lot No. 2 (0.12% Phosphorus) | | | | | |
| 1795 | 6.4 | 8.5 | 9.6 | 7.8 | 6.0 | 4.7 |
| 215 | 7.1 | 9.5 | 8.9 | 7.2 | 6.7 | 5.7 |
| 1785 | 6.2 | 7.1 | 7.0 | 7.1 | 5.9 | 6.7 |
| 158 | 7.4 | 8.2 | 7.5 | 6.7 | 6.1 | 6.5 |
| Average | 6.8 | 8.3 | 8.3 | 7.2 | 6.2 | 5.9 |
| | Lot No. 3 (0.18% Phosphorus-Defluorinated Phosphate) | | | | | |
| 1790 | 6.6 | 10.2 | 9.4 | 5.8 | 7.3 | 5.8 |
| 142 | 7.9 | 9.6 | 10.0 | 6.2 | 7.3 | 6.0 |
| 216 | 7.1 | 9.6 | 8.9 | 6.1 | 7.5 | 8.2 |
| 1792 | 6.2 | 8.8 | 7.4 | 6.9 | 7.0 | 7.2 |
| Average | 7.0 | 9.5 | 8.9 | 6.2 | 7.3 | 6.8 |
| | Lot No. 4 (0.18% Phosphorus-Diammonium Phosphate) | | | | | |
| 1809 | 6.3 | 9.6 | 9.7 | 7.1 | 7.1 | 6.2 |
| 1800 | 7.0 | 9.0 | 9.5 | 8.3 | 8.0 | 7.1 |
| 151 | 7.5 | 9.4 | 9.1 | 5.7 | 6.4 | 6.7 |
| 1799 | 8.3 | 7.5 | 6.8 | 7.0 | 6.3 | 7.1 |
| Average | 7.3 | 8.9 | 8.8 | 7.0 | 7.0 | 6.8 |
| | Lot No. 5 (0.24% Phosphorus-Defluorinated Phosphate) | | | | | |
| 1860 | 4.7 | 10.2 | 11.2 | 8.2 | 9.1 | 7.3 |
| 130 | 6.0 | 9.6 | 9.9 | 10.1 | 8.3 | 8.2 |
| 1794 | 7.5 | 8.7 | 8.0 | 7.5 | 7.9 | 7.0 |
| 206 | 7.8 | 8.9 | 8.6 | 8.1 | 7.6 | 7.8 |
| Average | 6.5 | 9.3 | 9.4 | 8.5 | 8.2 | 7.6 |

APPENDIX TABLE VIII. (CONTINUED).

| Heifer No. | Mg. Phosphorus per 100 ml. blood | | | | | |
|---|---|---|---|---|---|---|
| | 1-2-62 | 1-30-62 | 2-27-62 | 3-27-62 | 4-24-62 | 5-22-62 |
| Lot No. 6 (0.24% Phosphorus-Diammonium Phosphate) | | | | | | |
| 124 | 7.3 | 9.3 | 8.9 | 7.4 | 7.8 | 8.2 |
| 1856 | 7.7 | 9.5 | 11.0 | 8.5 | 9.4 | 7.6 |
| 1858 | 6.2 | 10.2 | 10.3 | 7.1 | 8.0 | 6.9 |
| 1791 | 7.8 | 9.6 | 10.0 | 7.8 | 9.2 | 7.3 |
| Average | 7.2 | 9.6 | 10.1 | 7.7 | 8.6 | 7.5 |
| Lot No. 7 (0.30% Phosphorus-Defluorinated Phosphate) | | | | | | |
| 241 | 8.7 | 9.2 | 9.2 | 8.9 | 8.2 | 7.8 |
| 148 | 6.2 | 8.3 | 8.2 | 7.8 | 7.5 | 7.1 |
| 1797 | 5.5 | 8.6 | 9.6 | 6.7 | 7.1 | 6.4 |
| 1854 | 7.9 | 10.5 | 8.2 | 7.9 | 9.1 | 9.2 |
| Average | 7.1 | 9.2 | 8.8 | 7.9 | 8.0 | 7.6 |
| Lot No. 8 (0.30% Phosphorus-Diammonium Phosphate) | | | | | | |
| 146 | 6.5 | 8.6 | 8.7 | 8.9 | 8.0 | 8.6 |
| 189 | 6.1 | 9.2 | 10.0 | 9.4 | 8.9 | 7.8 |
| 1796 | 6.2 | 9.5 | 8.6 | 7.9 | 8.2 | 7.0 |
| 1793 | 7.7 | 8.8 | 9.9 | 8.4 | 9.3 | 8.7 |
| Average | 6.6 | 9.0 | 9.3 | 8.7 | 8.6 | 8.0 |

APPENDIX TABLE IX. PLASMA-CAROTENE LEVELS OF HEIFERS WINTERED ON RATIONS DIFFERING IN SOURCES AND LEVELS OF SUPPLEMENTAL PHOSPHORUS.

| Heifer No. | Mcg. Carotene per 100 ml. blood | | | | | |
|---|---|---|---|---|---|---|
| | 1-2-62 | 1-30-62 | 2-27-62 | 3-27-62 | 4-24-62 | 5-22-62 |
| | | Lot No. 1 (0.12% Phosphorus) | | | | |
| 1798 | 296 | 238 | 275 | 74 | 33 | 47 |
| 153 | 150 | 128 | 100 | 44 | 23 | 53 |
| 1851 | 204 | 201 | 144 | 32 | 22 | 37 |
| 178 | 198 | 186 | 198 | 37 | 28 | 43 |
| Average | 212 | 188 | 179 | 47 | 26 | 45 |
| | | Lot No. 2 (0.12% Phosphorus) | | | | |
| 1795 | 178 | 127 | 140 | 32 | 25 | 25 |
| 215 | 150 | 144 | 131 | 31 | 25 | 42 |
| 1785 | 195 | 193 | 177 | 68 | 33 | 44 |
| 158 | 114 | 127 | 132 | 32 | 37 | 39 |
| Average | 159 | 148 | 145 | 41 | 30 | 37 |
| | Lot No. 3 (0.18% Phosphorus-Defluorinated Phosphate) | | | | | |
| 1790 | 184 | 154 | 143 | 32 | 24 | 27 |
| 142 | 214 | 137 | 137 | 50 | 32 | 30 |
| 216 | 144 | 169 | 169 | 53 | 19 | 26 |
| 1792 | 154 | 102 | 165 | 25 | 28 | 38 |
| Average | 174 | 141 | 154 | 40 | 26 | 30 |
| | Lot No. 4 (0.18% Phosphorus-Diammonium Phosphate) | | | | | |
| 1809 | 178 | 150 | 155 | 40 | 22 | 28 |
| 1800 | 198 | 147 | 89 | 40 | 29 | 28 |
| 151 | 221 | 164 | 224 | 61 | 25 | 22 |
| 1799 | 209 | 281 | 250 | 71 | 34 | 25 |
| Average | 201 | 185 | 180 | 53 | 27 | 26 |
| | Lot No. 5 (0.24% Phosphorus-Defluorinated Phosphate) | | | | | |
| 1860 | 217 | 162 | 189 | 50 | 38 | 29 |
| 130 | 175 | 101 | 124 | 38 | 14 | 21 |
| 1794 | 113 | 101 | 129 | 34 | 24 | 38 |
| 206 | 114 | 117 | 145 | 30 | 33 | 33 |
| Average | 155 | 120 | 147 | 38 | 27 | 30 |

APPENDIX TABLE IX. (CONTINUED).

| Heifer No. | Mcg. Carotene per 100 ml. blood | | | | | |
|---|---|---|---|---|---|---|
| | 1-2-62 | 1-30-62 | 2-27-62 | 3-27-62 | 4-24-62 | 5-22-62 |
| | Lot No. 6 (0.24% Phosphorus-Diammonium Phosphate) | | | | | |
| 124 | 228 | 214 | 152 | 52 | 30 | 30 |
| 1856 | 147 | 104 | 122 | 50 | 25 | 33 |
| 1858 | 177 | 159 | 177 | 52 | 26 | 37 |
| 1791 | 183 | 150 | 192 | 36 | 50 | 50 |
| Average | 183 | 157 | 161 | 48 | 33 | 38 |
| | Lot No. 7 (0.30% Phosphorus-Defluorinated Phosphate) | | | | | |
| 241 | 186 | 148 | 156 | 34 | 25 | 35 |
| 148 | 201 | 124 | 131 | 48 | 36 | 27 |
| 1797 | 148 | 145 | 172 | 43 | 24 | 19 |
| 1854 | 175 | 112 | 196 | 50 | 22 | 20 |
| Average | 177 | 132 | 164 | 44 | 27 | 25 |
| | Lot No. 8 (0.30% Phosphorus-Diammonium Phosphate) | | | | | |
| 146 | 154 | 104 | 81 | 52 | 26 | 30 |
| 189 | 109 | 120 | 119 | 35 | 20 | 23 |
| 1796 | 177 | 127 | 108 | 35 | 23 | 29 |
| 1793 | 82 | 104 | 128 | 43 | 22 | 17 |
| Average | 130 | 114 | 109 | 42 | 23 | 25 |

APPENDIX TABLE X. PLASMA-VIATMIN A LEVELS OF HEIFERS WINTERED ON RATIONS DIFFERING IN SOURCES AND LEVELS OF SUPPLEMENTAL PHOSPHORUS.

| Heifer No. | Mcg. Vitamin A per 100 ml. blood 1-2-62 | 1-30-62 | 2-27-62 | 3-27-62 | 4-24-62 | 5-22-62 |
|---|---|---|---|---|---|---|
| | | Lot No. 1 (0.12% Phosphorus) | | | | |
| 1798 | 51 | 47 | 22 | 35 | 25 | 29 |
| 153 | 44 | 23 | 26 | 33 | 14 | 22 |
| 1851 | 29 | 42 | 16 | 26 | 17 | 24 |
| 178 | 27 | 40 | 33 | 49 | 19 | 29 |
| Average | 38 | 38 | 24 | 36 | 19 | 26 |
| | | Lot No. 2 (0.12% Phosphorus) | | | | |
| 1795 | 34 | 22 | 14 | 56 | 22 | 21 |
| 215 | 79 | 34 | 22 | 21 | 15 | 34 |
| 1785 | 41 | 24 | 25 | 33 | 19 | 18 |
| 158 | 35 | 37 | 18 | 26 | 22 | 25 |
| Average | 47 | 29 | 20 | 39 | 19 | 25 |
| | Lot No. 3 (0.18% Phosphorus-Defluorinated Phosphate) | | | | | |
| 1790 | 45 | 32 | 16 | 43 | 8 | 26 |
| 142 | 44 | 38 | 26 | 37 | 17 | 23 |
| 216 | 19 | 48 | 16 | 50 | 25 | 30 |
| 1792 | 25 | 24 | 31 | 31 | 20 | 25 |
| Average | 33 | 36 | 22 | 40 | 17 | 26 |
| | Lot No. 4 (0.18% Phosphorus-Diammonium Phosphate) | | | | | |
| 1809 | 46 | 45 | 32 | 41 | 27 | 28 |
| 1800 | 34 | 43 | 38 | 32 | 29 | 28 |
| 151 | 31 | 25 | 23 | 39 | 20 | 22 |
| 1799 | 48 | 62 | 25 | 41 | 20 | 25 |
| Average | 40 | 44 | 30 | 38 | 24 | 26 |
| | Lot No. 5 (0.24% Phosphorus-Defluorinated Phosphate) | | | | | |
| 1860 | 42 | 24 | 32 | 50 | 22 | 19 |
| 130 | 51 | 33 | 23 | 43 | 19 | 30 |
| 1794 | 53 | 26 | 21 | 34 | 18 | 35 |
| 206 | 39 | 25 | 36 | 37 | 17 | 24 |
| Average | 46 | 27 | 28 | 41 | 19 | 27 |

APPENDIX TABLE X. (CONTINUED).

| Heifer No. | 1-2-62 | 1-30-62 | 2-27-62 | 3-27-62 | 4-24-62 | 5-22-62 |
|---|---|---|---|---|---|---|
| | Mcg. Vitamin A per 100 ml. blood | | | | | |
| **Lot No. 6 (0.24% Phosphorus-Diammonium Phosphate)** | | | | | | |
| 124 | 38 | 26 | 16 | 52 | 12 | 19 |
| 1856 | 23 | 25 | 12 | 40 | 24 | 18 |
| 1858 | 54 | 33 | 24 | 36 | 28 | 29 |
| 1791 | 38 | 39 | 23 | 48 | 26 | 24 |
| Average | 38 | 30 | 19 | 44 | 22 | 23 |
| **Lot No. 7 (0.30% Phosphorus-Defluorinated Phosphate)** | | | | | | |
| 241 | 44 | 36 | 36 | 49 | 19 | 35 |
| 148 | 82 | 37 | 28 | 34 | 20 | 27 |
| 1797 | 33 | 29 | 21 | 30 | 15 | 19 |
| 1854 | 36 | 28 | 15 | 44 | 19 | 20 |
| Average | 48 | 32 | 25 | 39 | 18 | 25 |
| **Lot No. 8 (0.30% Phosphorus-Diammonium Phosphate)** | | | | | | |
| 146 | 38 | 38 | 16 | 52 | 26 | 30 |
| 189 | 25 | 20 | 24 | 35 | 20 | 23 |
| 1796 | 32 | 33 | 30 | 35 | 23 | 29 |
| 1793 | 18 | 46 | 20 | 43 | 22 | 17 |
| Average | 28 | 34 | 23 | 42 | 23 | 25 |

APPENDIX TABLE XI. COST OF FEED INGREDIENTS.

| Ingredient | Cost per ton |
|---|---|
| **Experiment I** | |
| Steam Rolled Barley with Molasses | $47.00 |
| Dried Molasses Beet Pulp | 43.00 |
| Grass Hay | 23.00 |
| Supplements used in Wintering Trial | |
| Supplement No. 157 (SBOM) | 75.02 |
| Supplement No. 158 (Urea) | 72.06 |
| Supplement No. 159 (DAP) | 73.35 |
| Supplement No. 160 (MAP) | 67.80 |
| Supplement used in Fattening Trial | |
| Supplement No. 161 (SBOM) | 72.80 |
| Supplement No. 162 (Urea) | 68.00 |
| Supplement No. 163 (DAP) | 68.25 |
| Supplement No. 164 (MAP) | 61.25 |
| **Experiment II** | |
| Steam Rolled Corn | 45.00 |
| Dried Molasses Beet Pulp | 43.00 |
| Grass Hay | 23.00 |
| Supplement No. 236 (0.12% Phosphorus) | 69.27 |
| Supplement No. 237 (0.18% Phosphorus-Defluorinated) | 70.16 |
| Supplement No. 238 (0.24% Phosphorus-Defluorinated Phosphate) | 71.44 |
| Supplement No. 239 (0.30% Phosphorus-Defluorinated Phosphate) | 72.58 |
| Supplement No. 240 (0.18% Phosphorus-Diammonium Phosphate) | 70.60 |
| Supplement No. 241 (0.24% Phosphorus-Diammonium Phosphate) | 73.38 |
| Supplement No. 242 (0.30% Phosphorus-Diammonium Phosphate) | 76.10 |

APPENDIX TABLE XII. PROXIMATE CHEMICAL ANALYSES OF THE FEED FED TO THE HEIFERS WINTERED ON RATIONS DIFFERING IN SOURCES AND LEVELS OF SUPPLEMENTAL PHOSPHORUS.

| | Moisture | Crude Protein | Ether Extract | Ash | Crude Fiber | Phosphorus | Calcium |
|---|---|---|---|---|---|---|---|
| | | | | Percent | | | |
| Dried molasses beet pulp | | | | | | | |
| Chemistry MSC 1/ | 4.4 | 9.3 | 0.3 | 5.4 | 16.7 | 0.08 | 0.83 |
| Monsanto 2/ | --- | 9.4 | --- | --- | ---- | 0.09 | 0.50 |
| Steam-rolled corn | | | | | | | |
| Chemistry MSC | 8.6 | 9.1 | 4.4 | 6.5 | 2.2 | 0.30 | 0.29 |
| Monsanto | --- | 9.7 | --- | --- | --- | 0.27 | 0.07 |
| Grass hay | | | | | | | |
| Chemistry MSC | 4.4 | 8.8 | 1.5 | 5.8 | 29.5 | 0.14 | 0.65 |
| Monsanto | --- | 9.4 | --- | --- | ---- | 0.13 | 0.24 |
| Supplement No. 236 (0.12% phosphorus) | | | | | | | |
| Chemistry MSC | 4.0 | 22.4 | 2.2 | 3.5 | 4.8 | 0.37 | 0.03 |
| Monsanto | --- | 22.4 | --- | --- | --- | 0.38 | 0.14 |
| Supplement No. 237 (0.18% phosphorus-defl.) | | | | | | | |
| Chemistry MSC | 5.6 | 23.6 | 2.2 | 6.0 | 4.8 | 0.74 | 0.96 |
| Monsanto | --- | 24.1 | --- | --- | --- | 0.74 | 0.82 |
| Supplement No. 238 (0.24% phosphorus-defl.) | | | | | | | |
| Chemistry MSC | 5.6 | 22.7 | 2.1 | 9.9 | 4.5 | 1.38 | 2.50 |
| Monsanto | --- | 22.7 | --- | --- | --- | 1.35 | 2.01 |
| Supplement No. 239 (0.30% phosphorus-defl.) | | | | | | | |
| Chemistry MSC | 5.3 | 23.1 | 2.0 | 12.9 | 4.9 | 1.88 | 3.56 |
| Monsanto | --- | 23.2 | --- | ---- | --- | 1.86 | 2.93 |
| Supplement No. 240 (0.18% phosphorus-DAP) | | | | | | | |
| Chemistry MSC | 5.8 | 22.3 | 2.2 | 5.0 | 4.9 | 0.93 | 0.46 |
| Monsanto | --- | 23.8 | --- | --- | --- | 0.93 | 0.50 |
| Supplement No. 241 (0.24% phosphorus-DAP) | | | | | | | |
| Chemistry MSC | 6.1 | 22.1 | 2.2 | 6.9 | 5.4 | 1.63 | 0.46 |
| Monsanto | --- | 23.0 | --- | --- | --- | 1.44 | 0.29 |

APPENDIX TABLE XII. (CONTINUED).

| | Moist-ure | Crude Protein | Ether Extract | Ash | Crude Fiber | Phos-phorus | Calcium |
|---|---|---|---|---|---|---|---|
| | | | | Percent | | | |
| Supplement No. 242 (0.30% phosphorus-DAP) | | | | | | | |
| Chemistry MSC | 6.3 | 22.3 | 1.7 | 7.8 | 4.2 | 2.80 | 0.42 |
| Monsanto | --- | 23.8 | --- | --- | --- | 1.54 | 0.19 |

1/ Feed analyses conducted by the Chemistry Department, Montana State College--Station.

2/ Feed analyses conducted by the Monsanto Chemical Company, St. Louis, Missouri.

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