SOURCES OF PHOSPHORUS FOR BEEF CATTLE WINTERED ON DRY BLUESTEM PASTURE

by

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INTRODUCTION

It has long been known that minerals play an important role in proper animal nutrition. The importance of trace minerals is of comparatively recent discovery, but the need for such minerals as common salt, phosphorus and calcium has been well established for some time. Except for common salt, farm animals are more apt to suffer from a lack of calcium or phosphorus than any other minerals.

Roughages are rich in calcium and only fair to poor in phosphorus depending upon such factors as type of roughage, fertility of the soil and maturity of the plants. On the other hand, most plant concentrates are fair to good sources of phosphorus and very poor in calcium. Rations fed to swine and fattening ruminants, are composed mostly of concentrates which contain adequate phosphorus, but which are usually deficient in calcium. Rations fed to ruminants, other than fattening rations, consist largely of roughages. Such rations contain adequate calcium, but in many instances are lacking in phosphorus. Most of the commonly fed phosphorus supplements are also rich sources of calcium which is usually not needed in phosphorus deficient rations. In such instances the calcium in these supplements is of no benefit. Therefore, there is a need for an economical, readily available source of phosphorus without the extra calcium.

These experiments were planned to determine whether or not phosphoric acid could be used as a source of phosphorus for ruminants and, if so, to determine the efficiency of utilization of the phosphorus from this source.

REVIEW OF LITERATURE

Amounts of Phosphorus in the Animal Body

Phosphorus is foremost in importance among the mineral elements needed by animals. Most of the phosphorus in the body is located in the skeleton. However, the smaller portion present in the soft tissues is very important (Mitchell, 80). Maynard (77) stated that around 80 per cent of the phosphorus of the body is present in the bones and teeth. Moisture-free, fat-free bone ash is composed of approximately 36 per cent calcium, 17 per cent phosphorus, 0.8 per cent magnesium and traces of several other minerals. Several workers (6, 35, 37, 41, 62, 84, 90, 108) found that the ash content varies under certain conditions where there is a deficiency of phosphorus in the ration or a deficiency caused by some factor which interferes with phosphorus utilization. Hall et al. (51), however, found no difference in the bone phosphorus or ash content of bones from steers receiving a low phosphorus ration containing 7 gms. of phosphorus and steers fed a ration supplying 20 gms.

The remaining 20 per cent phosphorus makes up from 0.15 to 0.2 per cent of the soft tissues of the body. However, in studying mineral nutrition we are mainly interested in the inorganic phosphorus in the blood plasma. In normal animals this level varies from 4 to 9 mg. per 100 ml. of plasma depending upon many factors such as age, species and mineral nutrition of the animal (27, 77). Dukes (30) gave the normal inorganic phosphorus level of serum of cows as 2.3 to 9.6 mg. per 100 cc. For sheep values from 2.5 to 9 mg. per 100 cc. serum are given.

Many experimentors (2, 11, 13, 14, 18, 19, 31, 33, 35, 37, 43, 45, 47, 50, 57, 58, 59, 60, 61, 62, 64, 65, 72, 75, 76, 86, 88, 89, 97, 99, 100, 101, 102, 104, 106, 109) working with cattle, sheep and hogs have reported a close correlation between the level of inorganic phosphorus in the blood and the amount of phosphorus in the ration.

Davis (28) wrote that access to a phosphorus source as recent as 24 to 48 hours before sampling will cause a sudden rise in inorganic plasma phosphorus level. He also stated that violent exercise from 10 to 60 minutes before sampling will cause a rise in the phosphorus level.

Eckles, et al. (33) found that the inorganic phosphorus level of blood increases until calves are about six months of age. The level than gradually decreases until the normal level of mature cattle is reached. They also reported that the inorganic phosphorus level may fluctuate as much as 15 to 25 per cent within a two hour interval.

Long, et al. (72) in 1952 reported that mature cattle on a high plane of nutrition had inorganic phosphorus levels between 4 and 6 mg. per 100 cc. of plasma. Animals under six months of age had levels near 7.4 mg. per cent. Two years later these same cattle had inorganic phosphorus levels of 4.5 mg. per cent. No difference was found in this level between three different breeds of beef cattle. Haag and Jones (50) found that the decline of blood inorganic phosphorus in cattle may continue well into the third or fourth year.

Collip (25) in 1952 found that the hormone produced by the parathyroid glands had an influence on calcium and phosphorus metabolism and therefore affected the amount of these minerals in the blood.

Functions of Phosphorus

Phosphorus has more functions than any other element in the body (Davis, 27). Woods (110) and Davis (27) stated that phosphorus has some fourteen vital functions in the body. It is concerned in normal muscle metabolism, carbohydrate, fat, and protein metabolism. It is also found in many compounds involved in brain and nerve metabolism. It has also been shown that phosphorus plays an important role in regulating acid-base balance and is concerned in certain enzyme activity. It is distributed in every cell in the body and is vitally concerned with their functions. One of the main functions of phosphorus is its role in the formation of bones and teeth. Mitchell (80) stated that phosphorus aids in the storage of energy and its transfer in small packages to localities and reaction centers where it is needed.

California workers (17, 63, 70, 71, 91, 92, 93, 94, 95) demonstrated the dynamic nature of bone and tooth structure as well as of other phosphorus containing tissues by using radioactive phosphorus. Black, et al, (17) in 1953 found that about one per cent of the skeletal phosphorus was "labile" phosphorus. This skeletal "labile" phosphorus pool was about fifteen times as large as the total circulating phosphorus pool in the plasma. Cortical bone contains one third as much phosphorus in the "labile" state as does trabecular bone.

Smith, et al. (91, 93) using radioactive P^{32} found that phosphorus may function as a buffer for volatile fatty acids produced in the rumen of cattle and sheep. P^{32} injected intravenously enters the rumen via the saliva and directly through the rumen wall. It was estimated that as much as 4.8 and 66 gms. of phosphorus, for sheep and cattle respectively, enter the rumen each day. Most of this phosphorus enters by way of the saliva. Clark (23) also found that in ruminants there is a circulation of water soluble phosphorus from the blood, through the saliva, into the rumen. Parthasarathy, et al. (85) reported that rumen liquor may contain as much as 25 to 100 mg. of inorganic phosphorus per 100 ml.

Oklahoma scientists (39, 103) found that phosphorus may be concerned with the conversion of carotene to vitamin A and the storage of vitamin A in the liver of cattle. They noted that plasma carotene levels were consistently higher in phosphorus deficient steers and cows. A decreased vitamin A storage in the liver was indicated. Gallup, et al. (39) ran a similar experiment with lambs, but the results obtained with lambs were in direct controversy with those obtained with cattle. This indicates that there may be a species difference in the vitamin A response of cattle and sheep to phosphorus deficiency.

The Occurrence and Effects of Phosphorus Deficiency

Pronounced evidence of mineral malnutrition appear when cattle are fed phosphorus deficient rations. Symptoms of such deficiency were first reported to occur in cattle grazing phosphorus deficient pastures in South Africa by Theiler, et al. (101) in 1924. In the United States Eckles, et al. (33), in 1926, reported a phosphorus deficiency in cattle in Minnesota.

Areas of phosphorus deficiency in cattle feeds are now known to occur throughout the world, particularly in semiarid regions. They are more commonly associated with soils deficient in this element (1). Beeson (9) presented a map showing the general location of reported mineral deficiency areas in the United States.

Morrison (82) stated that all roughages are generally rich in calcium but that none of them are rich in phosphorus. DuToit, et al. (32), in a study of the mineral content of pasture plants in South Africa, found a distinct variation in the phosphorus content among different species. The phosphorus lowered as plants matured and dropped until new growth began in the spring. Phosphorus deficient winter pasture contained not more than 0.1

per cent P_2O_5. Pasture growth varies from 0.75 per cent for young grass to 0.03 per cent for the same grass when mature (31). In the United States Black, et al. (18, 19) in Texas, Eckles, et al. (33) in Minnesota, Knox and Watkins (65) in New Mexico, and Stanley (97) in Arizona also found a seasonal variation in the phosphorus content of pasture plants. They noted that the phosphorus content was affected directly by the amount of phosphorus in the soil and by the amount of rainfall received during the growing season. Black, et al. (18, 19) increased the phosphorus content of grasses considerably by adding phosphorus fertilizer to phosphorus deficient pastures.

The National Research Council (Guilbert, et al., 48) recommended that cattle rations contain from 0.15 to 0.28 per cent phosphorus depending upon the age and purpose for which the animal is being fed. Stanley (97) found that grass containing an average of 0.178 per cent phosphorus furnished adequate phosphorus for beef cows in Arizona. Kleiber, et al. (62) found that beef heifers ceased to grow after six months on a ration supplying 0.13 per cent phosphorus. This agrees with results reported by Black, et al. (18, 19) from Texas, where pasture plants supplying an average of 0.13 per cent phosphorus were found inadequate for range cattle.

Archibald and Bennett (4) stated that hays containing less than 0.20 per cent of phosphorus will not supply adequate phosphorus for a growing dairy heifer.

Beeson (10, 13) produced symptoms of aphosphorosis in fattening steers in the feed lot in from 60 to 100 days by feeding rations supplying 0.11 to 0.15 per cent phosphorus. He reports that 0.18 per cent or more of phosphorus or 2 gms. of phosphorus per 100 pounds of live weight is adequate for fattening steers.

However, Maynard, et al. (78) produced a phosphorus deficiency by feeding 1.96 gms. of phosphorus per 100 pounds live weight. Reports vary widely as to phosphorus requirements.

In young animals a phosphorus deficiency results in a condition called rickets. Mitchell and McClure (81) in a review of mineral nutrition found that malnutrition with respect to calcium and phosphorus results in an arrest in bone growth or in a distorted bone growth. This may result from the feeding of rations containing low levels of phosphorus or calcium, or from feeding rations containing forms of calcium and phosphorus that are poorly utilized by the animal. This may also be the result of either an unfavorable Ca:P ratio or the lack of adequate vitamin D.

In the mature animal the condition caused by a deficiency of phosphorus is called aphosphorosis. Theiler, et al. (102) stated that aphosphorosis in cattle is identical with the naturally occurring South African "styfsickte" and "osteomalacia" in Europe and probably the same as "cripples" of Australia. Phosphorus deficiency in cattle in Florida has been called "stiffs" or "sweeny" (8) and "creeps" in Texas (18, 19).

Lowered inorganic blood phosphorus usually somewhere below 4 mg. per cent, is one of the first signs of aphosphorosis in cattle. However, Jameson (60) found that cows grazing deficient forage in Montana had average phosphorus levels of 3.02 mg. per 100 ml. of blood and did not show any external signs of phosphorus deficiency. Theiler, et al. (102) found that inorganic phosphorus may drop to one fourth the normal value before the disease can be diagnosed clinically.

Other symptoms of phosphorus deficiency are decreases in appetite (anorexia), rate of gain, and milk production. Efficiency of feed utilization, particularly of protein, is depressed. These effects are followed by pica, with specific craving for bones (osteophagia). Depraved appetite may lead to excessive salt ingestion, chewing of stones and other objects and the eating of dirt (allotriophagia). Carcass debris and feces, if available, may be consumed (coprophagia). The result may be a secondary disease, loin disease in Texas or lamsiekte in South Africa, caused by a toxin produced by a Clostridium botulinum type organism injested with the carcass debris. Long continued phosphorus deficiency results in bone changes causing lameness, stiffness and possible bone fractures. If serious enough death may ultimately occur (31, 33, 35, 43, 48, 62, 81).

Gordon, et al. (43), Green (46), and Huffman, et al. (59) all agree that a depraved appetite is not a good criterion to use in diagnosing phosphorus deficiency.

Black, et al. (18, 19), Eckles, et al. (33, 35), and Knox, et al. (64, 65) found that cows receiving adequate phosphorus weaned larger calf crops and calves that were heavier at weaning. Ross, et al. (89) reported that cows receiving adequate phosphorus weaned calves weighing about 45 pounds more than control cows.

Eckles, et al. (33) noticed an inhibition of oestrum in cows receiving low phosphorus rations.

Kleiber, et al. (62) found that phosphorus deficiency lowers the total efficiency of energy utilization mainly by lowering the appetite and secondly by lowering the partial efficiency. It had no effect on body temperature, digestibility and metabolizability of the food energy, R. Q. and fasting katabolism.

Working with dairy cattle, Eckles, et al. (34, 35) found that cows receiving low phosphorus rations required about 20 per cent more TDN than cows receiving adequate phosphorus. In one case it took 27.93 pounds of

TDN to produce a pound of gain on a cow receiving a low phosphorus ration in contrast to 6.32 pounds of TDN per pound of gain on a cow receiving adequate phosphorus.

In the feed lot Beeson, et al. (10, 13, 14), Hall, et al. (51), and Matsushima, et al. (75) found that fattening cattle receiving phosphorus deficient rations, composed of such feeds as beet by-products, urea and etc., were also slower and less efficient in putting on pounds of gain. Beeson, et al. (13) found that steer calves suffering from aphosphorosis required 30 per cent more feed to make a pound of gain and gained 37 per cent slower than calves receiving adequate phosphorus.

Hall, et al. (51) noticed that steers that had received adequate phosphorus produced higher yielding carcasses that exhibited better keeping qualities. Roasts from animals which received a high phosphorus ration were favored over roasts from animals fed low phosphorus rations in regard to tenderness, flavor of lean and fat, juiciness, aroma and texture.

Aphosphorosis in sheep appears to be about the same as that which occurs in cattle. However, less work seems to have been reported on sheep. Phosphorus in sheep rations has been studied by several workers (2, 11, 12, 15, 16, 56, 65, 88).

Beeson, et al. (15) reported that low phosphorus diets decreased the number of lambs raised and depressed milk production of the ewes. However, Hodgson, et al. (56) found that ewes on a low phosphorus intake produced as many lambs as those fed adequate phosphorus.

Hodgson, et al. (56) reported that the phosphorus requirement for pregnant ewes is 0.16 per cent or more of the ration. Beeson, et al. (16) found 0.17 or 2.40 gms. per 100 pounds live weight optimum for fattening lambs.

Knox, et al. (65) reported higher wool production from range ewes fed a phosphorus supplement in New Mexico.

Very few articles concerning aphosphorosis in swine were reviewed. However, Aubel, et al. (6) of this station had to resort to a very uncommon ration composed of chiefly pearl hominy, tapioca roots, and blood meal in order to produce a phosphorus deficiency in growing pigs. Results obtained from feeding a low phosphorus ration were: a lowering of inorganic phosphorus in blood, a failure of normal growth and development of bone and muscle, a lowered utilization of feed and storage of energy, a loss of appetite, and a marked increase in thirst with a corresponding excretion of urine.

Chapman, et al. (21) found that the optimum dietary level of phosphorus needed for the 100 pound pig fed antibiotic supplemented rations appears to by 0.6 per cent. The optimum level for the 200 pound growing-finishing pig was 0.5 per cent.

Factors Affecting the Utilization and Availability of Phosphorus

The utilization of minerals in rations is modified by many factors relating to either the ration or to the environment (81). Both Morrison (82) and Maynard (77) stressed the fact that there is an interrelationship between vitamin D, calcium and phosphorus. Several workers (4, 26, 29, 44, 52, 55, 59, 90, 100, 101, 102, 109) have reported on calcium and phosphorus interrelationships or upon the effects of vitamin D on calcium and phosphorus absorption and utilization. Comar, et al. (24) found that an interrelationship exists between molybdenum, cooper and phosphorus metabolism.

Huffman, et al. (59) found that a Ca:P ratio of 5:1 did not interfere with phosphorus utilization in cows. Dowe, et al. (29) fed steer calves rations with an unusually wide ratio of 13.6:1 with no ill effects except a slight lowering of feed efficiency. Phosphorus was fed at National Research Council recommended levels. However, Theiler, et al. (100, 101, 102) and Williams (109), a practicing veterinarian, found that when phosphorus is low a relatively high calcium intake may reduce the absorption of phosphorus and in this way increase the danger of aphosphorosis.

Theiler, et al. (101, 102) stated that when calcium is low a relatively high proportion of phosphorus may increase rather than decrease the utilization of the small proportion of calcium in the ration.

Hansard and Plumlee (52) found that rats fed low calcium rations absorbed about as much phosphorus as when fed rations containing optimum ratios, but most of this phosphorus was re-excreted by way of the urine.

Data indicate that ruminants can withstand rather wide Ca:P ratios if vitamin D is adequate. Morrison (82) stated the ratio for cattle should range anywhere from 6:1 down to 0.6:1.

Many researchers have tried to determine to what extent the phosphorus in plants, present mostly in the seeds, is utilized by animals. It seems that plant phosphorus, phytin, can be utilized by ruminants and hogs. Lofgreen and Kleiber (69) working with sheep; Beeson, et al. (13), Eckles, et al. (35), Jarl (61) and Mathur (74) working with cattle; and Hart, et al. (53), Plumlee, et al. (86) and Rather (87) working with hogs, found that these animals could utilize the phosphorus in plants. However, Jarl (61) found the availability of phosphorus in wheat bran and ground oats significantly less for dairy cows than the phosphorus supplied by disodium phosphate. Elmslie, et al. (37) found phytate phosphorus in grain to be of very poor availability for chicks. Spitzer, et al. (96) found that the rat could utilize calcium phytate almost as effectively as inorganic phosphorus only if adequate vitamin D was supplied.

Comparison of Phosphorus Supplements

There are many different phosphorus supplements available and, also, several different methods of supplying these supplements to livestock. Louw (73) stated that the three main methods of feeding phosphates in South Africa are: the crush method, where each individual animal is dosed with the correct amount of phosphate; the lick method, where animals have free access to a phosphate mix in a mineral box; and the drinking water method where, a quantity of phosphate is dissolved in the animals drinking water.

In this country workers supplying supplemental phosphorus to cattle, especially on pasture, have most often used the lick method mentioned above (8, 14, 18, 19, 57, 65, 72, 89, 103, 106). In most cases salt was mixed with the supplement to increase the palatibility or to regulate phosphorus consumption.

Cattle are supposed to crave phosphorus supplements according to their need and therefore consume enough mix to satisfy their phosphorus needs. However, Gordon, et al. (43) found that sheep and cattle grazing phosphorus deficient pastures failed to remedy their deficiency by eating sufficient quantities of a phosphorus supplement when offered a choice between a calcium supplement and a calcium-phosphorus supplement. Hodgson, et al. (58), also, reported that steers fed a low-phosphorus ration failed to consume sufficient quantities of either steamed bone meal or defluorinated phosphate when fed free choice, either alone or mixed with salt. Knox and Watkins (65) found that mineral mixtures supplying at least 6.5 per cent phosphorus gave best results when fed free choice.

Black, et al. (19) compared supplying phosphorus to cattle by allowing free access to bone meal, supplying it through the use of disodium phosphate in the drinking water, and by fertilizing pastures with triple superphosphate.

In this experiment involving a five year period, the supplying of phosphorus by fertilization of pasture gave the greatest returns per acre, but disodium phosphate resulted in highest return per cow.

Many efforts have been made in order to determine the value of different phosphorus supplements. Ammerman, et al. (2) reported no significant difference between the per cent phosphorus retained by steers when fed two dicalcium phosphates, bone meal, defluorinated rock phosphate, imported rock phosphate or colloidal phosphate as sources of phosphorus. Beeson, et al. (14), however, found that a mix of two parts defluorinated phosphate and one part salt or Cudahy's mineral fed free choice was of less value than steamed bone meal in preventing aphosphorosis. Knox and Watkins (65) found steamed bone meal, di and mono calcium phosphates to be satisfactory for range cattle. Becker, et al. (7) have written a very good review concerning mineral supplements for cattle in Florida.

Gullickson and Olson (49), Jarl (61), and Turner, et al. (105) have compared various phosphorus supplements in dairy cow rations. Jarl (61) found that acid phosphate added as a preservative to silage was equally as well utilized as bone meal, dicalcium or disodium phosphate. Gullickson and Olson (49) reported that defluorinated rock phosphate was equal to steamed bone meal in palatability and availability of phosphorus.

In a very recent experiment, Tillman, et al. (104), in three trials working with both cattle and sheep found that colloidal clay was an unsatisfactory source of phosphorus. Pica, stiffness and coprophagy were noted in animals consuming colloidal clay. Signs of fluorine toxicity, such as exostosis of cannon bone and wearing away of the teeth, were noticed. This colloidal clay contained 0.97 per cent fluorine.

Elmslie (36) fed two dairy cows an average of 1.3 to 1.7 mg. of fluorine per day for $5\frac{1}{2}$ years with no ill effects. Mitchell (79) stated that supplements should contain less than .10 per cent flourine to be safe. However, Becker, et al. (8) reported that supplements containing less than 0.2 per cent fluorine are regarded safe for feeding purposes.

Matsushima, et al. (75, 76) found no difference between the availability of phosphorus when supplied by either coarse or fine textured bone meal in cattle rations.

Ammerman, et al. (2) reported significant differences in the per cent phosphorus retained by lambs fed four different phosphorus supplements.

Gillis, et al. (40, 41), Motzok, et al. (83), and Willcox, et al. (108) have conducted experiments comparing various phosphorus supplements for poultry. They report quite a variation in the availability of phosphorus from different sources.

Comparisons of various phosphorus sources for swine have been studied by several workers (22, 37, 42, 86). Chapman, et al. (22), Elmslie, et al. (37) and Plumlee, et al. (86) all found that soft phosphate supplied by colloidal clay was significantly inferior to other sources of phosphorus in promoting growth. It did, however, in all cases maintain the inorganic serum phosphorus levels as well as did other phosphorus sources. Gobble, et al. (42), in contrast, found that the phosphorus of both dicalcium phosphate and soft phosphate was utilized and that the biological availability of both sources was approximately the same.

Blosser, et al. (20) made a chemical composition comparison of twenty-two samples of bone meal. They found quite a variation in the amounts of calcium, phosphorus and other constituents of different samples. This emphasizes the importance of buying supplements on a composition guarantee.

METHODS AND DATA

Experiment 1

Experimental Procedure. The purpose of this experiment, consisting of a wintering phase, a grazing phase, and a bone study, was to determine whether or not phosphoric acid could be used as a source of phosphorus for beef cattle.

Forty head of choice quality Hereford heifers, averaging about 515 pounds at the start of the experiment, were used. They were randomly divided into four lots of ten head each on the basis of weight and type. Each animal was fire branded with a different number and all the animals in each lot were branded lightly on the shoulder with a lot number.

All 40 heifers were grazed in the same pasture throughout the wintering and grazing phases in order to rule out any affect that might have been caused by differences in the condition of different pastures.

The phosphoric acid used in this experiment was 75 per cent technical grade acid that contained 23.6 per cent phosphorus.

Wintering Phase. This phase of the experiment began on November 17, 1954 and continued for 162 days until April 28, 1955. During this period all animals were grazed together on dry bluestem grass. Prairie hay was fed as a supplemental roughage when snow covered the grass. This averaged 1.67 pounds of hay per head daily for the entire wintering phase. Water and salt were available at all times.

Each day all the heifers were brought into the pens and divided into four lots to receive their respective supplemental feed. A basal supplement consisting of 1.5 pounds of soybean oil meal and 0.2 pound of blackstrap molasses was fed per head each day. In addition to the basal supplement each heifer in lot 2 received 8 gms. of phosphorus daily from steamed bone meal, and those in lots 3 and 4 received 8 and 4 gms. respectively of phosphorus daily supplied from phosphoric acid. Lot 1 served as the control lot and received no additional phosphorus.

The phosphorus supplements were mixed with the basal supplement in an upright spiral type feed mixer. Phosphoric acid is a strong mineral acid and certain precautions had to be taken in mixing and handling it. In this case the acid was added to the molasses in a large tub and mixed throughly. A small amount of soybean oil meal was then mixed with this until a crumbly consistency was obtained. This mixture was then added, along with the remaining soybean oil meal, to the feed mixer. This procedure seemed to reduce the corrosive action of the acid.

The supplements were fed in open troughs. Plates 1 and 11 demonstrate this method of feeding.

All animals were individually weighed every 28 days in order that weight records might be obtained on each individual and on each lot.

Phosphorus utilization was measured by taking blood samples from the jugular vein of each animal to determine the serum inorganic phosphorus level. Four collections were made during the wintering phase. Due to the large number of animals it was necessary to bleed one-half of the heifers in each lot on one day and bleed the remaining five the following day. This procedure was followed throughout the wintering phase except for the first collection. In the first collection all the heifers in lots 1 and 2 were bled one day and those in lots 3 and 4 were bled the following day. This was changed as it was realized that any mistake made in handling the samples on a given day would show up in only two lots or one-half of the animals.

Grazing Phase. All animals remained on pasture for spring and early summer grazing. No supplement was fed during this phase that lasted for 68 days, from April 28, 1955 to July 5, 1955.

Weights were taken every 28 days and blood samples were obtained from each heifer only once during this period.

Salt and water were available at all times.

Bone Study. After the end of the summer grazing period the heifers were brought into the feedlot where all lots were self fed the same fattening ration. Records on this fattening phase will not be presented, since six heifers died from over-eating during the early part of this period.

Since these heifers had received different amounts of phosphorus from different sources during the wintering phase, it was felt that some difference might still be detected by a bone study. Therefore, when they were slaughtered, on October 25, 1955, in Armour's Kansas City plant, the left cannon or metacarpal bone was obtained from each animal. These bones were dried and cleaned thoroughly.

Measurements obtained from the intact bone were the overall length and the smallest diameter, measured from medial to lateral sides using a sliding caliper. Each bone was then sawed into on a band saw at this point. The volar, dorsal, lateral and medial walls of this cut were measured with a sliding caliper. These four measurements were used to determine the average wall thickness for each bone.

Two bone samples were obtained from each bone for ash determinations. One sample consisted of a quarter inch section sawed from the distal end of the bones. This section extended about equal distance on either side of the epiphyseal cartilage. The other sample was composed of two quarter-inch rings sawed from the shaft of the bones. One of these rings was obtained just proximal to the cut made at the smallest diameter of each bone. The other ring was sawed one inch from the smallest diameter of the bones toward the distal end.

Results and Discussion. Wintering and grazing phases. A summary table of the weight results for the wintering phase is found in Table 1. These results show that the average total gain and average daily gain did not differ significantly between lots. The average daily gains were .41, .42, .48, and .53 pound for lots 1, 2, 3 and 4 respectively. The heifers in lots 2, 3 and 4, that received additional phosphorus, made only slightly more gain than did the control heifers in lot 1 that received no additional phosphorus.

Several workers (10, 13, 14, 51, 75) have reported that cattle receiving low phosphorus rations make slower, less efficient gains than those receiving adequate phosphorus. Therefore, the control heifers in this instance were getting enough phosphorus to make normal gains. The exact amount of phosphorus supplied by the basal ration was not known. It was known, however, that the soybean oil meal used in this experiment supplied 0.56 per cent phosphorus. Morrison (82) lists blackstrap molasses as containing 0.08 per cent phosphorus. Using the figure of 0.09 per cent phosphorus given by Morrison for weathered, mature, western pasture grass and taking into consideration reports on the phosphorus content of mature pasture grass given by Black et al. (18, 19), DuToit et al. (32), Eckles et al. (33), Knox et al. (65) and Stanley (97), it was concluded that the dry, mature pasture used in this experiment probably contained about 0.1 per cent phosphorus. Using these figures and assuming that the heifers consumed around 10 to 12 pounds of grass per head per day,

Table 1. Weight data summary for wintering phase
November 17, 1954 - April 28, 1955 - 162 days

Lot no.	1	2	3	4
Added phosphorus	None	8 grams from bone meal	8 grams from H_3PO_4	4 grams from H_3PO_4
No. heifers per lot	10	10	10	10
Av. initial wt., lbs.	515.5	517.0	515.5	516.5
Av. final wt., lbs.	582	585	595	602
Av. gain, lbs.	66.5	68	78	85.5
Av. daily gain, lbs.	.41	.42	.48	.53

it was figured that the control heifers would probably be receiving somewhere around 8.5 to 9.0 gms. of phosphorus per head each day. The National Research Council (Guilbert, et al., 48) recommends 12 gms. of phosphorus per head per day for wintering 500 to 600 pound calves. The heifers in lots 2 and 3 were probably getting around 17 gms. of phosphorus per head each day and those in lot 4 that received 4 gms. of additional phosphorus were probably receiving around 12 gms. each day.

The gains made by all four lots during the wintering phase were lower than expected. This was probably due to the high condition of the heifers at the beginning of the test and also may be partially due to the large amount of snow received during the winter.

A weight data summary for the 68 day grazing phase is given in Table 2. All lots gained practically the same during this phase. Average daily gains were 2.13, 2.30, 2.15 and 2.20 pounds for lots 1, 2, 3 and 4, respectively. No supplemental feed was fed to any of the heifers during this phase.

Table 3 gives a summary of the weight results for the combined 230 day wintering and grazing phases. Individual weight results for the wintering

Table 2. Weight data summary for grazing phase
April 28, 1955 - July 5, 1955 - 68 days

Lot no.	1	2	3	4
No. heifers per lot	10	9*	9**	10
Av. initial wt., lbs.	582	588.9	595	602
Av. final wt., lbs.	726.5	745.1	740.9	751.5
Av. gain, lbs.	144.5	156.2	146.0	149.5
Av. daily gain, lbs.	2.13	2.30	2.15	2.20

Table 3. Combined weight data summary for wintering and grazing phases
230 days

Lot no.	1	2	3	4
No. heifers per lot	10	9*	9**	10
Initial wt., lbs.	515.5	517.0	515.5	516.5
Final wt., lbs.	726.5	745.1	740.9	751.5
Av. gain, lbs.	211.0	226.8	224.4	235.0
Av. daily gain, lbs.	.92	.99	.97	1.02

* One heifer was removed from experiment on June 6, 1955 because of pregnancy.

** One heifer died June 25, 1955 of undetermined cause.

and grazing phases and a combination of these phases are presented in Table 7 in the Appendix.

A summary of the inorganic serum phosphorus data is found in Table 4. Data on individual heifers are presented in Table 8 in the Appendix.

Some mistake was evidently made in running the inorganic phosphorus determinations or in handling the samples during the first collections made on November 16th and 17th. There is quite a difference in the serum phosphorus level found in lots 1 and 2, bled on November 16, and that found in lots 3 and 4, bled on November 17. This difference should not have been present as the heifers had just been divided into their respective lots on November 16. For this reason the method outlined in the experimental procedure was followed in obtaining samples at the other collection periods.

Lots 2 and 3 that received the basal ration plus 8 gms. of additional phosphorus from steamed bone meal and phosphoric acid, respectively, and lot 4 that received 4 gms. of additional phosphorus during the wintering phase maintained normal serum inorganic phosphorus levels throughout both the wintering and grazing phases. The serum inorganic phosphorus levels in the control lot dropped during February and March. During this period the average inorganic phosphorus levels in the control lot were from 2.5 to 3 mg. per cent below the levels maintained in the other three lots. However, no external signs of aphosphorosis were noticed at any time in this lot.

As the grass began to grow in the spring the inorganic phosphorus level in the control lot began to rise. On June 22, 1955 this level was equal to the serum inorganic phosphorus level found in the other three lots. This trend shows that the additional phosphorus supplied to lots 2, 3 and 4 by steamed bone meal and phosphoric acid was being utilized since many experimentors (2, 11, 13, 14, 18, 19, 31, 33, 35, 37, 43, 45, 47, 50, 57, 58, 59, 60, 61, 62, 64, 65, 72, 75, 76, 86, 88, 89, 97, 99, 100, 101, 102, 104, 106, 109) working with cattle, sheep and hogs have reported a close correlation between the level of inorganic phosphorus in the blood and the amount of phosphorus in the ration.

In this test the 4 gms. of additional phosphorus fed to lot 4 was equally as effective as the 8 gms. supplied to lots 2 and 3 in maintaining

Table 4. Average milligrams per cent of inorganic serum phosphorus

Lot no.	1	2	3	4
	Wintering Phase			
November 16 & 17	8.93	8.53	10.51	10.36
February 16 & 17	6.12	8.61	8.79	8.42
March 22 & 23	6.83	9.55	10.08	9.44
April 27 & 28	7.76	7.91	8.03	7.94
	Grazing Phase			
June 22	7.63	7.51	7.91	8.13

normal serum inorganic phosphorus levels. However, this was probably due to the fact that lots 2 and 3 were probably receiving an excess of phosphorus. On the other hand this might indicate that the phosphorus from phosphoric acid was being utilized more efficiently.

It was noted that the supplements containing phosphoric acid were very palatable as compared to the basal ration or the basal ration plus steamed bone meal.

No harmful effects caused by feeding phosphoric acid were noticed at any time during this experiment. Each heifer in lot 3 was receiving 21.6 ml. of phosphoric acid per day. Those in lot 2 were receiving only 10.8 ml. per head per day.

Quite a lot of work concerning the effects of feeding acid diets to animals is reported in the literature. Steenbock, et al. (98), in 1914, fed 200 to 300 cc. of normal HCl to calves with no harmful effects on growth or reproduction. A rise in urinary ammonia was reported. Lamb and Evvard (66, 67) studied the effects of feeding sulfuric, lactic, and acetic acids to swine, rats and rabbits. In 1932 they reported feeding swine for three

EXPLANATION OF PLATE 1

Picutred in this plate are lots 1 and 2 eating their respective supplements. These picutres were taken on March 9, 1955, which was near the end of the wintering phase.

Fig. 1 shows the heifers in lot 1 eating the basal ration of 1.5 lbs. of soybean oil meal and 0.2 lbs. of blackstrap molasses.

Fig. 2 shows the heifers in lot 2 eating the basal ration plus 8 gms. phosphorus supplied by steamed bone meal.

PLATE 1

Fig. 1

Fig. 2

EXPLANATION OF PLATE 11

Pictured in this plate are lots 3 and 4 eating their respective supplements. These picutres were taken on March 9, 1955, which was near the end of the wintering phase.

Fig. 1 shows the heifers in lot 3 eating the basal ration plus 8 gms. of phosphorus supplied by phosphoric acid.

Fig. 2 shows the heifers in lot 4 eating the basal ration plus 4 gms. phosphorus supplied by phosphoric acid.

PLATE 11

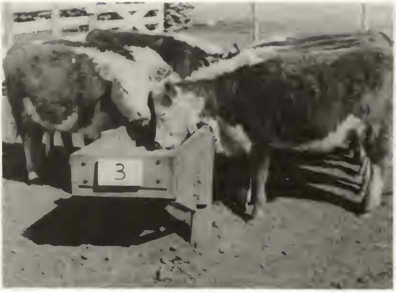

Fig. 1

Fig. 2

generations over a period of $3\frac{1}{2}$ years a ration containing 200 to 300 cc. of normal sulfuric acid solution each day. No deleterious effects on growth, well being, or reproduction were observed. They found that rabbits could not tolerate more than 5 cc. of normal sulfuric acid per day. Hayden, et al. (54) and Lepard, et al. (68) studied the effects of feeding phosphoric acid treated silage to dairy cows. They reported that the ammonia in the urine of cows fed phosphoric acid silage alone was increased and the pH and bicarbonates were decreased. Lepard, et al. (68) found that feeding the treated silage, 20 pounds of 68 per cent phosphoric acid per ton of green feed, as the only feed to lactating cows caused a decrease in appetite and milk production and consequently a loss in weight. The addition of either hay or limestone relieved these conditions.

Bone Study. Results of this study are presented in Table 5.

There were practically no differences in the bone weight, length, smallest diameter, wall thickness, or ash content between lots. This was probably due to the fact that all 4 lots had been receiving the same ration for about six months prior to slaughter when the bones were obtained for analysis. If any bone changes were caused when the different phosphorus supplements were being fed during the wintering phase, they were corrected by the time of slaughter.

It will be noted in Table 5 that the distal end of the bones had lower ash content than the shank portion. This was due to the fact that the section obtained from the distal end for ash determination contained the epiphyseal cartilage. This increased the organic content and lowered the ash content of this sample.

Table 5. Bone data

Bone no.	Weight gms.	Length cm.	Smallest diameter mm.	Wall thickness mm.	% Ash distal end	% Ash shank
			Lot 1. Basal ration			
3	306	20.4	4.15	.70	61.20	70.34
14	248	19.6	3.54	.73	61.61	70.52
19	243	18.2	3.72	.69	63.22	69.47
31	250	18.8	3.72	.77	60.14	71.26
49	271	19.6	3.90	.72	61.89	69.33
51	283	19.8	4.06	.75	60.47	70.80
71	272	19.9	3.76	.71	59.88	69.59
82	264	19.9	3.64	.72	61.58	69.96
R14	246	19.5	3.73	.64	61.61	69.65
R17	257	19.8	3.88	.64	59.01	70.55
Average	264	19.6	3.81	.71	61.06	70.15
			Lot 2.* Basal ration plus 8 gms. P. from steamed bone meal during wintering phase			
4	234	17.9	3.8	.72	61.75	71.00
8	253	19.3	3.51	.78	60.56	69.74
24	255	18.7	3.75	.71	63.49	69.44
43	303	20.0	3.83	.76	59.95	70.66
50	253	19.6	3.72	.76	60.22	70.02
57	288	20.5	3.66	.69	61.78	70.41
66	299	20.4	3.8	.79	61.22	71.50
70	240	19.8	3.54	.67	61.46	70.49
84	281	20.1	3.8	.78	62.57	71.97
Average	267.33	19.58	3.71	.74	61.44	70.58
			Lot 3.** Basal ration plus 8 gms. P. from H_3PO_4 during wintering phase			
9	260	19.6	3.67	.73	61.58	69.80
46	263	18.6	3.57	.76	60.22	71.60
61	269	19.2	3.65	.68	60.64	70.41
67	255	19.9	3.58	.77	62.33	71.43
R21	267	20	3.7	.73	61.53	69.61
Average	262.8	19.46	3.63	.73	61.26	70.57

Table 5. (Concluded)

Bone no.	Weight gms.	Length cm.	Smallest diameter mm.	Wall thickness mm.	% Ash distal end	% Ash shank
	Lot 4.*** Basal ration plus 4 gms. P. from H_3PO_4 during wintering phase					
16	281	19.5	3.76	.78	60.86	70.45
53	288	19.7	3.78	.75	60.81	68.35
55	278	19.4	3.8	.76	60.19	70.61
68	248	19.0	3.6	.70	62.46	69.94
69	246	18.8	3.8	.68	60.71	69.09
74	250	19.4	3.73	.68	62.88	68.87
88	249	18.2	3.68	.78	61.81	69.46
R6	248	19.5	3.55	.76	60.31	68.78
Average	261	19.19	3.71	.74	61.25	69.44

* Heifer number 91 was removed from experiment on 6-10-55 because of pregnancy.

** Heifer number 34 died on 6-25-55 from unknown cause and heifers 12, 15, 25 and 85 died on 7-28-55 from overeating.

*** Heifer number 77 died on 7-28-55 from overeating and heifer number 10 died on 9-8-55 from bloat.

Experiment 11

Experimental Procedure. The results of Experiment 1 showed that phosphoric acid was just as efficient as steamed bone meal in maintaining serum inorganic phosphorus levels and in maintaining a normal rate of gain. The purpose of this experiment was to obtain more accurate information on the utilization of phosphorus from phosphoric acid by ruminants.

Eight yearling wether lambs that weighed about 100 pounds each were used in a phosphorus balance study to compare a low phosphorus control ration and a test ration supplying additional phosphorus from phosphoric acid. All lambs were placed in metabolism crates, as shown in Fig. 5. They were fed a control ration of 500 gms. shredded sorghum stover, 300 gms. of cracked yellow corn and 70 gms. of soybean oil meal per head per day. All the lambs received one-half of this ration in the morning and the remaining half at night.

Feces and urine collections were made after allowing a seven day adjustment period. A 24 hour feces sample was obtained from each lamb in the afternoons. This sample was weighed, recorded, and a 5 per cent aliquot was placed in a numbered porcelain pan. This pan was placed in a drying oven between collections. The temperature in the oven was kept around 65° C. Another aliquot was added each afternoon until the 6-day collection period was completed. After the final collection the oven was turned up to about 95° C. until the feces were completely dry. The dry feces were weighed, placed in a sealed jar and taken to the chemistry laboratory for analysis.

Urine was collected separately from the feces. Each afternoon the day's urine was measured and recorded. A 5 per cent sample was pipetted and placed in a sealed jar. A few drops of toluene were placed in each jar at the time

EXPLANATION OF PLATE 111

This plate shows the type of lamb metabolism crate used in the phosphorus balance study.

PLATE 111

of the first collection to prevent bacterial action.

Immediately after the end of the first 6-day collection period 4.24 gms. or 2.7 ml. of phosphoric acid were added to the control ration each day. The acid was mixed with each mornings feed. This acid contained 23.6 per cent phosphorus and supplied 1 gm. of phosphorus per lamb per day.

A 4-day adjustment period was allowed before feces and urine samples were collected. The same procedure was followed in collecting and handling feces and urine as outlined in the preceding collection period.

Representative samples of corn, soybean oil meal, and sorghum stover were obtained for phosphorus determinations.

Results and Discussion. A summary of the results of this experiment is presented in Table 6. The complete data on each individual lamb are found in Table 9 in the Appendix.

Phosphorus determinations on the feeds used in this experiment showed that soybean oil meal contained 0.56 per cent, corn contained 0.34 per cent, stover used in the control ration contained 0.11 per cent, and that used in the test ration contained 0.10 per cent phosphorus. It was then figured that the control ration supplied 1.96 gms. of phosphorus per lamb per day. This was well below the 2.6 gms. recommended by Morrison (82) for a 100 pound yearling lamb. The test ration, control ration plus one gm. of phosphorus supplied by phosphoric acid, supplied 2.91 gms. of phosphorus per lamb per day.

Lambs fed the control ration retained an average of 16.38 per cent or 0.32 gms. of phosphorus per lamb per day. Those fed the test ration retained 15.87 per cent or 0.46 gms. of phosphorus per head per day. Therefore, when the amount of phosphorus fed per lamb each day was incfeased by about one-half

Table 6. Summary of phosphorus balance study with eight lambs

Av. grams P consumed per lamb per day	Percent P voided in feces	Percent P voided in urine	Percent P retained by lamb	Av. grams P retained per lamb per day
		Control		
1.96	82.16	1.46	16.38	.32
	Control plus 1 gm. P from phosphoric acid			
2.91	77.55	6.58	15.87	.46

as much as supplied by the control ration, the amount of phosphorus retained per lamb was also increased by about one-half as much. This showed that the phosphorus supplied by phosphoric acid was being utilized.

It was interesting to note that most of the excreted phosphorus was voided in the feces while only a very small amount was voided through the urine. Ammerman, et al. (3) and Forbes, et al. (38) working with beef steers and Reinarch, et al. (88) with lambs found that only a very small amount of phosphorus was excreted through the urine.

The lambs receiving the test ration excreted quite a bit more phosphorus through the urine than the lambs fed the low phosphorus control ration. This larger amount was due primarily to the one lamb that voided, through the urine, 42.27 per cent of the total phosphorus consumed.

All lambs ate the test ration readily without any apparent harmful effects.

SUMMARY

The tests reported herein were conducted to determine whether or not phosphoric acid could be used as a source of phosphorus for beef cattle.

There were no differences between 8 gms. of phosphorus supplied from steamed bone meal and 8 or 4 gms. of phosphorus supplied from phosphoric acid in their ability to maintain normal rates of gain or normal phosphorus levels in the blood of heifer calves wintered on dry bluestem pasture plus the basal ration of 1.5 pounds of soybean oil meal and 0.2 pounds of blackstrap molasses. The heifers in the control lot failed to maintain the high serum inorganic phosphorus levels present in the lots receiving additional phosphorus during the 162 day wintering period. However, no external signs of aphosphorosis developed in this lot.

Average rates of gain and serum inorganic phosphorus levels were practically the same for all four lots during the grazing phase. No supplements were fed during this period.

These heifers were grazed during the spring and summer and fattened in the feedlot. They were slaughtered six months after the different phosphorus supplements had been discontinued. A bone study failed to show any differences between lots.

A phosphorus balance study with eight lambs proved that the phosphorus supplied by phosphoric acid was being utilized efficiently.

OBSERVATIONS

The results of this study warrant the following observations:

1. Phosphorus supplied by phosphoric acid is efficiently utilized.

2. The serum inorganic phosphorus level is correlated with the amount of phosphorus in the ration.

3. Phosphoric acid produced no noticeable harmful effects when fed to beef cattle over a 162 day period.

4. Phosphoric acid containing supplements were very palatable.

5. In this test, phosphoric acid was equal to steamed bone meal in maintaining inorganic serum phosphorus levels and apparently is a satisfactory source of phosphorus for ruminants.

6. Beef calves wintered on dry bluestem pasture plus a high phosphorus protein supplement such as soybean oil meal or cottonseed oil meal will receive adequate phosphorus to make normal gains.

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APPENDIX

Table 7. Weight data for individual heifers

Heifer number	Wintering phase – 162 days 10-16-54 to 4-28-55 Initial weight	Total gain	Av. Daily gain	Grazing phase – 68 days 4-28-55 to 7-5-55 Initial weight	Total gain	Av. Daily gain	Combined wintering and grazing phases – 230 days Final weight	Total gain	Av. Daily gain
			Lot 1. Basal ration during wintering phase						
3	510	90	.56	600	155	2.28	755	245	1.07
14	480	55	.34	535	160	2.35	695	215	.93
19	520	75	.46	595	140	2.06	735	215	.93
31	525	55	.34	580	95	1.40	675	150	.65
49	510	55	.34	565	160	2.35	725	215	.93
51	565	70	.43	635	200	2.94	835	270	1.17
71	500	80	.49	580	145	2.13	725	225	.98
82	520	45	.28	565	135	1.99	700	180	.78
R14	525	65	.40	590	130	1.91	720	195	.85
R17	500	75	.46	575	125	1.84	700	200	.87
Average	515.5	66.5	.41	582	144.5	2.13	726.5	211	.92
			Lot 2. Basal ration plus 8 gms. P. from steamed bone meal during wintering phase						
4	480	85	.52	565	138	2.03	703	223	.97
8	510	40	.25	550	175	2.57	725	215	.93
28	515	65	.40	580	160	2.35	740	225	.98
43	525	65	.40	590	185	2.72	775	250	1.09
50	520	75	.46	595	185	2.72	780	260	1.13
57	500	110	.68	610	130	1.91	740	240	1.04
66	535	95	.59	630	143	2.10	773	238	1.03
70	560	25	.15	585	140	2.06	725	165	.72
84	520	75	.46	595	150	2.21	745	225	.98
91*	505	45	.28	550					
Average	517.0	68	.42	585	156.2	2.30	745.1	226.8	.99

Table 7. (Concluded)

	Wintering phase – 162 days 10-16-54 to 4-28-55			Grazing phase – 68 days 4-28-55 to 7-5-55			Combined wintering and grazing phases – 230 days		
Heifer number	Initial weight	Total gain	Av. Daily gain	Initial weight	Total gain	Av. Daily gain	Final weight	Total gain	Av. Daily gain
	Lot 3. Basal ration plus 8 gms. P. from H_3PO_4 during wintering phase								
9	515	100	.62	615	138	2.03	753	238	1.03
12	520	140	.86	660	145	2.13	805	285	1.24
15	525	120	.74	645	103	1.51	748	223	.97
25	520	50	.31	570	150	2.21	720	200	.87
34**	505	75	.46	580					
46	495	35	.22	530	138	2.03	668	173	.75
61	485	80	.49	565	130	1.91	695	210	.91
57	510	65	.40	575	145	2.13	720	210	.91
85	545	65	.40	610	185	2.72	795	250	1.09
R21	535	50	.31	585	180	2.65	765	230	1.00
Average	515.5	78	.48	593.5	146	2.15	740.9	224.4	.97
	Lot 4. Basal ration plus 4 gms. P. from H_3PO_4 during wintering phase								
10	515	95	.59	610	160	2.35	770	255	1.11
16	545	75	.46	620	175	2.57	795	250	1.09
53	525	125	.77	650	145	2.13	795	270	1.17
55	515	95	.59	610	175	2.57	785	270	1.17
68	495	95	.59	590	145	2.13	735	240	1.04
69	510	75	.46	585	170	2.50	755	245	1.07
74	540	85	.52	625	135	1.99	760	220	.96
77	520	70	.43	590	140	2.06	730	210	.91
88	495	70	.43	565	130	1.91	695	200	.87
R6	505	70	.43	575	120	1.76	695	190	.83
Average	516.5	85.5	.53	602	149.5	2.20	751.5	235	1.02

* Heifer number 91 was removed from experiment on 6-10-55 because of pregnancy.

** Heifer number 34 died on 6-25-55 from unknown cause.

Table 8. Milligrams per cent of inorganic serum phosphorus
Wintering and grazing phases

Heifer number	Nov. 16 & 17	Feb. 16 & 17	March 22 & 23	April 27 & 28	June 22
		Lot 1. Basal ration during wintering phase			
3	7.32	6.25	6.48	7.25	7.65
14	7.88	5.53	6.42	7.60	8.40
19	11.31	6.86	8.43	8.94	7.70
31	8.75	5.58	7.10	6.00	6.40
49	9.43	6.52	6.97	9.26	7.55
51	9.96	5.91	6.86	8.94	9.15
71	10.30	6.02	5.95	6.70	6.85
82	8.45	7.03	6.94	7.50	7.80
R14	8.17	5.85	6.21	7.50	7.55
R17	7.71	5.63	6.94	7.90	7.20
Average	8.93	6.12	6.83	7.76	7.63
		Lot 2. Basal ration plus 8 gms. P from steamed bonemeal during wintering phase			
4	10.32	7.53	9.07	8.29	7.75
8	8.25	7.42	10.54	8.09	7.70
24	8.38	10.22	10.85	7.76	6.75
43	8.95	9.76	10.09	9.18	7.05
50	7.64	7.42	9.50	7.90	7.45
57	7.77	8.47	7.90	7.15	6.10
66	8.60	8.20	9.03	7.85	8.15
70	7.75	9.93	9.82	7.20	8.40
84	8.62	8.54	11.49	9.25	8.25
91*	8.98	8.65	7.20	6.48	
Average	8.53	8.61	9.55	7.91	7.51

Table 8. (Concluded)
Wintering and grazing phases

Heifer number	Nov. 16 & 17	Feb. 16 & 17	March 22 & 23	April 27 & 28	June 22
		Lot 3. Basal ration plus 8 gms. P. from H_3PO_4 during wintering phase			
9	9.56	8.81	10.52	8.35	7.45
12	9.24	9.31	10.19	9.20	8.45
15	10.82	7.70	8.38	8.40	7.80
25	10.82	8.15	8.66	7.30	7.30
34	11.35	9.60	10.15	7.55	7.95
46	10.92	7.81	10.32	7.02	8.10
61	11.26	8.36	10.43	8.66	7.75
67	10.58	9.81	11.32	7.25	7.80
85	10.08	9.47	10.70	10.59	8.25
R21	10.42	8.92	10.10	5.95	8.20
Average	10.51	8.79	10.08	8.03	7.91
		Lot 4. Basal ration plus 4 gms. P. from H_3PO_4 during wintering phase			
10	9.71	9.81	10.63	8.80	8.60
16	10.51	9.20	10.23	9.42	8.35
53	9.95	7.70	8.41	7.90	8.70
55	10.19	8.58	9.60	8.45	7.10
68	10.79	9.04	10.54	8.70	8.60
69	11.12	8.70	9.84	8.20	9.40
74	9.10	8.03	9.19	6.70	6.65
77	12.29	6.91	8.80	7.45	8.40
88	8.25	8.30	8.05	6.10	8.65
R6	11.72	7.96	9.07	7.66	6.85
Average	10.36	8.42	9.44	7.94	8.13

* Heifer number 91 was removed from experiment on 6-10-55 because of pregnancy.

Table 9. Phosphorus balance study with eight lambs

Lamb no.	Total gms. P consumed	Gms. dried feces	Tot. gms. P. in feces	% P. voided in feces	Tot. ml. urine	Tot. gms. P. in urine	% P. voided in urine	Tot. P. voided in feces & urine	% P. retained per lamb	Tot. gms. P. retained per lamb
					Control ration					
1	11.77	992.43	10.46	88.87	1,390	.0534	.45	10.5134	10.68	1.2566
2	11.77	820.00	7.95	67.54	9,470	.5616	4.77	8.5116	27.68	3.2584
3	11.77	810.74	8.57	72.81	12,815	.1345	1.14	8.7045	26.05	3.0655
4	11.77	941.75	9.40	79.86	13.550	.1301	1.11	9.5301	19.03	2.2399
5	11.77	994.15	10.30	87.51	3,300	.0749	.64	10.3749	11.85	1.3951
6	11.77	913.48	10.72	91.08	6,720	.0995	.85	10.8195	8.08	.9505
7	11.77	995.30	9.70	82.41	21,400	.2054	1.75	9.9054	15.84	1.8646
8	11.77	882.41	10.26	87.17	16,780	.1175	1.00	10.3775	11.83	1.3925
Total	94.16	7350.26	77.36		85,425	1.3769		78.7369		
Av.	11.77	918.78	9.67	82.16	10,678	.172	1.46	9.8421	16.38	1.9279
D.Av.	1.96		1.61			.028		1.64		.32
			Control plus 1 gm. phosphorus from phosphoric acid							
1A	17.47	842.97	15.25	87.29	1,130	.0616	.35	15.3116	12.35	2.1584
2A	17.47	716.85	8.36	47.85	11,465	7.3846	42.27	15.7446	9.88	1.7254
3A	17.47	800.74	13.13	75.16	10,300	.3420	1.96	13.4720	22.88	3.9980
4A	17.47	898.26	16.06	91.93	10,450	.1526	.87	16.2126	7.20	1.2574
5A	17.47	725.53	12.30	70.41	3,450	.5144	2.94	12.8144	26.65	4.6556
6A	17.47	742.54	15.18	86.89	10,410	.4768	2.73	15.6568	10.38	1.8132
7A	17.47	889.02	14.34	82.08	17,470	.1764	1.01	14.5164	16.91	2.9536
8A	17.47	784.25	13.76	78.76	12,380	.0941	.54	13.8541	20.70	3.6159
Total	139.76	6400.16	108.38		77,055	9.2025		117.5825		
Av.	17.47	800.02	13.55	77.55	9,632	1.1503	6.58	14.6978	15.87	2.7722
D.Av.	2.91		2.26			.19		2.45		.46

SOURCES OF PHOSPHORUS FOR BEEF CATTLE WINTERED ON DRY BLUESTEM PASTURE

by

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B.S., Texas Technological College, 1954

AN ABSTRACT OF A MASTER'S THESIS

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Rations fed to ruminants, other than fatt ning rations, consist largely of roughages. Such rations usually contain adequate calcium, but in many instances are lacking in phosphorus. Most of the commonly fed phosphorus supplements are also rich sources of calcium which is usually not needed in phosphorus deficient rations. Therefore, there is a need for an economical, readily available source of phosphorus without the extra calcium. The purpose of this study was to determine whether or not phosphoric acid could be used as a source of phosphorus for ruminants with particular attention given to beef cattle.

Experiment 1 consisted of a wintering phase, a grazing phase and a bone study. Forty head of Hereford heifer calves were used in this experiment. These heifers were grazed on bluestem pasture during both the wintering and grazing phases. During the 162 day wintering phase, all 40 heifers were fed a basal protein supplement consisting of 1.5 pounds of soybean oil meal and 0.2 pound of blackstrap molasses. Thirty of the heifers received additional phosphorus supplied by either steamed bone meal or phosphoric acid. No supplement or additional phosphorus was fed during the summer grazing phase.

There were no differences between 8 grams of phosphorus supplied from steamed bone meal and 8 or 4 grams of phosphorus supplied from phosphoric acid in their ability to maintain normal rates of gain or normal serum inorganic phosphorus levels in the heifers during the wintering phase. The heifers in the control lot failed to maintain the high serum inorganic phosphorus levels present in the lots receiving additional phosphorus during this period. However, no external signs of aphosphorosis developed in these heifers.

Average rates of gain and serum inorganic phosphorus levels were practically the same for all heifers during the grazing phase.

After the summer grazing phase these heifers were fattened in the feedlot. They were slaughtered approximately six months after phosphorus supplementation had been discountinued. A bone study at this time failed to show any differences between lots.

A second experiment consisting of a phosphorus balance study with lambs proved that the phosphorus supplied by phosphoric acid was being utilized efficiently.

Phosphoric acid containing supplements were very palatable and were readily consumed by the cattle in this test over a 162 day period without any noticeable harmful effects.

Phosphoric acid is apparently a satisfactory source of phosphorus for ruminants and was equal to steamed bone meal in this test.