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CALCIUM IN THE NUTRITION OF THE FATTENING CALF

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TABLE OF CONTENTS

CALCIUM IN THE NUTRITION OF THE FATTENING CALF[1]

A. D. WEBER,[2] C. W. MCCAMPBELL, J. S. HUGHES, and W. J. PETERSON

INTRODUCTION

Calves are now fattened outside the Corn Belt on feeds which are often markedly different in calcium content from feeds commonly used in the older cattle-fattening areas. This is particularly true in those sections where legumes are not grown extensively. The substitution of a carbonaceous roughage such as prairie hay for alfalfa hay means changing the calcium content of the roughage portion of the ration from 1.43 to 0.49 percent *(54)*.[3] Even more striking reductions in calcium content may result when certain other low-protein roughages like corn fodder or cottonseed hulls are used instead of a legume hay. It may be noted in this connection that protein-rich roughages usually have a relatively high calcium content while carbonaceous roughages are almost invariably low in this element.

Variations in rainfall also may be responsible for differences in the mineral content of plants used in the ration of the fattening calf. Daniel and Harper *(26)* found that during periods of high rainfall, the calcium content of bluestem and alfalfa decreased and the phosphorus content increased. On the other hand, when the effective rainfall was low, the calcium content of the plant increased and the phosphorus content decreased. While a considerable range in calcium content related to variation in rainfall was noted in both bluestem and alfalfa, the characteristic differences between the two persisted throughout the period studied. Thus, the calcium content of prairie hay ranged from 0.311 to 0.60 percent, and of alfalfa hay from 1.566 to 2.186 percent.

Other investigators *(36, 40)* have observed seasonal variations in the composition of plants. There is a distinct tendency for plants to be higher in nutritive value during the early vegetative stages of growth. Daniel's results *(25)* show that plants extremely low in phosphorus are frequently high in calcium and vice versa. Soils low in minerals are responsible for decreasing the mineral content of plants. An outstanding example of this is the phosphorus-deficient areas in various parts of the world *(30)*. Such areas in the United States are found in Minnesota and Kansas.

1. Contribution No. 141 from the Department of Animal Husbandry and No. 257 from the Department of Chemistry.

2. Based upon a thesis submitted by A. D. Weber to the faculty of Purdue University in partial fulfillment of the requirements for the degree of Doctor of Philosophy, June, 1940. He is indebted to Prof. F. G. King and Dr. C. L. Shrewsbury, of Purdue University, for guidance in his graduate work and for helpful suggestions and criticism in planning this study and in preparation of the thesis. He is also indebted to Prof. D. L. Mackintosh for valuable assistance in grading and slaughtering the animals.

3. Italic figures in parentheses refer to Literature Cited, p. 73.

Another reason for the low-calcium content of some calf-fattening rations is the high proportion of grain to roughage that must be fed for comparatively long periods in order to produce the desired degree of finish. Most grains are very low in calcium. Even prairie hay, which is classified as a low-calcium roughage, contains approximately fifty times as much calcium as shelled corn *(54).* Cottonseed meal, linseed meal and other protein-rich feeds of plant origin which are commonly fed with grain and carbonaceous roughages to fattening calves contribute little to the calcium content of the ration. These feeds are rich in phosphorus, however.

Bohstedt *(21)* has pointed out that if calf-fattening rations consisting of grain, dried carbonaceous roughage, and cottonseed meal were ground up and fed to pigs, there would be an inadequate supply of calcium for this species. It is generally recognized that rations of pigs are more likely to be lacking in calcium than in phosphorus because it is necessary to feed a high proportion of grain to roughage.

The situation is often the reverse of this in the case of cattle rations. Because of the large amounts of roughage included in many cattle rations the calcium intake may be adequate even when low-calcium, carbonaceous roughages like silage and prairie hay are used exclusively. It is evident, therefore, that a calf-fattening ration of grain, low-calcium roughage, and cottonseed meal is an exception to the rule ordinarily applied to cattle rations, since calcium, not phosphorus, is likely to be the important limiting element.

Very little work has been done on the response of fattening calves to different levels of calcium intake. The information available does not, explain the effect of a low-calcium intake on growth, fattening, digestibility of nutrients, mineral balances and composition and strength of bone. The influence of the calcium intake on blood has been studied in dairy cattle and other species, but has not been checked with actual determinations on the blood of the fattening calf. Nor have the calcium requirements either for the growth or fattening of calves been established. This point was emphasized by Mitchell and McClure *(52)* when they stated that, "It is hazardous to venture any precise statement of the concentration of calcium and phosphorus required for maximal growth in calves."

The field of calcium metabolism has not been ignored, however. The role of calcium in the structure and function of the body has been clarified by the results of numerous experiments with laboratory animals. These and other data found in the literature furnish an excellent background for a study of calcium in the nutrition of the fattening calf.

REVIEW OF LITERATURE

GENERAL STATEMENT CONCERNING LITERATURE

With increasing knowledge of mineral metabolism has come a voluminous literature. As a consequence, it is no longer practical to give all of the original citations when reviewing the literature of even a restricted phase of this field. In fact, if it were not for the reviews of various aspects of mineral metabolism that have appeared from time to time, interpretation of the great mass of data would be exceedingly difficult.

Mitchell and McClure *(52)* are responsible for an excellent review of the mineral nutrition of farm animals. Complete information concerning the absorption, excretion and functions of calcium is to be found in Stewart and Percival's review *(79)*. Greenberg *(38)* recently extended Schmidt and Greenberg's review *(70)* of the occurrence, transport and regulation of calcium, magnesium and phosphorus in the animal body. Stohl's monograph *(71),* which appeared in 1939, is another valuable contribution on mineral metabolism. In this review, the material has been selected from data on human beings; and several elements are discussed under each physiological function, instead of grouping all the data concerning each mineral in one place.

While much of the material given in these reviews helps to explain the role of calcium in the nutrition of the fattening calf, only that which seems to have a direct bearing on the results forming the basis of this paper will be considered in the discussion which follows. Additional information either not found in these reviews or appearing since they were published will also be included whenever it is useful in the interpretation of the results just mentioned.

RELATION OF CALCIUM TO BONE

Calcium is closely associated with phosphorus in the animal body. Together these two elements comprise more than 90 percent of the body ash. One of the principal functions of calcium in animal nutrition is related to the skeleton which supports the body and contributes to its form and protection *(12)*. As a matter of fact, about 99 percent of the body calcium is in the bones and teeth.

The belief that bone consists of a simple mixture of tricalcium phosphate, calcium carbonate and magnesium phosphate has given way to the view that a complex salt of the apatite series is its principal component *(49, 53)*. However, little is known concerning the exact composition of this complex salt.

Bogert and Hastings *(20)* working with unaltered bone substances found that the Ca_3PO_4: $CaCO_3$ ratio approximates 2. Neal and coworkers *(60)* reported that the calcium phosphate/calcium carbonate ratio of the bones of dairy cattle decreases with age and with phosphorus deficiency, but recovers when a phosphorus supplement is fed. While the results were inconclusive, these workers also obtained some indications that a calcium deficiency may alter the proportion of phosphate in the skeleton. The ratio of calcium phosphate to calcium carbonate was not affected by a high-calcium ration.

Analyses of the fat-free bodies of mature, normal cattle by Meigs and coworkers *(50)* showed that the calcium-phosphorus ratio both in the whole body and in bone is highly constant. They found that. keeping cows on low-calcium rations for long periods changes this relationship but little.

Morgulis *(53)* studied the elementary percentage composition of the bone ash of a cow and found the following: Ca, 36.50; Mg, 0.74; K, 0.85; P, 16.43; and Co, 4.58. Studies such as these indicate definitely that the elementary composition of bone ash does not vary greatly. Under most conditions the ratio of calcium to phosphorus remains approximately 2. For that reason and also because calcium and phosphorus are the principal elements in bone, the ash content of bone reveals the state of its calcium and phosphorus nutrition quite accurately.

Certain aspects of bone formation help to explain why bone furnishes a supply of calcium which is readily available to the body at any time. While bones grow in length at the junction of the epiphysis and diaphysis, a portion of the extra mineral is deposited in the trabeculae, which are lacelike structures located near the epiphyseal ends of bones. Bauer, Aub, and Albright *(9)* have shown that depletion of the trabeculae occurs easily during growth as well as during negative calcium balance. When a high-calcium diet is continued for a considerable period, there is a rapid accumulation of calcium in the trabeculae.

These workers *(9)* also showed that in the case of adult animals easily mobilizable calcium is deposited in the trabeculae, not in the shafts of the bones. There is a small exchange of inorganic salts in the case of the shafts, but they are not influenced except by unusual body demands.

Bethke, Edgington and Kick *(15)* have demonstrated that the calcium-phosphorus ratio of the ration is a factor in bone formation in the pig. The best result's were obtained when the ratio was between 1 and 2. The pigs became more rachitic when the ratio was greater than 3, and the requirements for vitamin D were increased. It was found that by adjusting the calcium and phosphorus content of the ration, the requirement for vitamin D could be minimized. Similar results were obtained by Bethke, Edgington and Wilder *(16)* in studies of the calcium-phosphorus ratio in bone formation in the rat. It was also observed in these studies that the concentration of calcium and phosphorus in the ration exerted an effect on growth and bone formation.

Similar studies, particularly as they relate to bone formation have not been conducted with cattle. Studies made by Du Toit Malin and Groenwald *(28)* and by Maynard, Greaves, and Smith *(48)* throw considerable doubt on the practical significance of varying calcium and phosphorus ratios in the nutrition of calves. Recently, however, Otto *(62)* reported that varying the intakes of calcium and phosphorus from the optimum resulted in less efficient retention of both elements by growing calves,

The influence of feed on the bone strength of cattle has been studied by Becker and Neal *(13)*. The breaking strengths of the humerus and femur of native Florida cattle suffering from aphosphorosis were only 360 and 320 pounds, respectively. The values for cattle receiving adequate minerals in their rations were 4,050 and 3,200 pounds. From these results it would seem that breaking strength determinations on the bones are reliable measures of the extent of mineral deficiency.

The parathyroid gland controls the movement of calcium from the trabeculae *(87)*. It is this mechanism which maintains the calcium in the blood at a fairly constant level. It is generally held that depletion of the trabeculae during periods of low-calcium intake or physiological stress is not harmful to the animal provided the calcium reserves are restored before the shafts of the bones become involved.

In a review published in 1937, Huggins *(43)* points out that from a physical standpoint, bone is in a dynamic state. This has been shown by feeding a radioactive isotope of inactive phosphorus to rats. In twenty days, 30 percent of the phosphorus atoms deposited in the skeleton had been removed.

Chossat *(24)* is credited with being the first to recognize poor bone development, on a low-calcium diet. He found that the bones of pigeons fed wheat alone were greatly depleted. The trouble was prevented by feeding calcium carbonate.

ROLE OF CALCIUM IN BODY TISSUES AND FLUIDS

The 1 percent of calcium not found in the skeleton is widely distributed in the body tissues and fluids and is of great physiological importance. It is concerned with osmotic relations and the maintenance of acid-base equilibrium. In conjunction with other elements, calcium operates in almost all the activities of the organs and tissues. Of particular interest is its relationship to sodium, potassium, and magnesium in controlling the irritability of the neuromuscular system *(71)*. Severe rickets caused by low-calcium diets may be accompanied by lowered blood calcium and tetany. Hypoparathyroid tetany is a similar condition, since it is also caused directly by the low calcium content of the blood. Whether nervousness or mild irritability may accompany the continued feeding of low-calcium rations even though the blood calcium remains normal appears not to have been discussed in the literature. It is interesting to note in this connection that Bechtel and coworkers *(11)* reported irritability and tetany as prominent symptoms of rickets caused by feeding a vitamin-D deficient ration to dairy calves.

Another report having a bearing on this question was made recently by Greenberg, Boelter, and Kopf *(39)*. They observed a severe neurological disturbance in growing rats maintained on diets furnishing only from 0.01 to 0.02 percent, of calcium. It is said that the condition is best demonstrated by subjecting the experimental animals to short and mild galvanic shocks from an induction coil. The deficient animals may have a very low blood calcium, from 4.4 to 6.6 mg. per 100 cc. of serum, and the bony skeleton may be almost completely decalcified.

Palmer and Eckles *(64)* made a study of the normal variation in the calcium content of the blood of dairy cattle. There was a high coefficient of correlation of the calcium content of the plasma on successive days, yet significant fluctuations of an undertermined cause were also noted. It is difficult, however, to influence the calcium content of the blood by experimental feeding. DuToit, Malin and Groenwald *(29)* observed no significant changes in the blood calcium of cattle fed low-calcium rations. Heller and Paul *(41)* found that drinking abnormal concentrations of saline solutions always caused some increase in the inorganic content of the blood. Under conditions approaching normal, however, the changes in plasma or cells were very slight.

The inorganic phosphorus in the blood plasma may drop abnormally low when phosphorus-deficient rations are fed. However, the blood calcium of phosphorus-deficient cattle is not lowered significantly *(37, 63, 86).* Shohl and Wolbach *(72)* produced rickets in rats by feeding low-calcium, high-phosphorus diets. The blood calcium was lowered and tetany resulted from these conditions. Bechdel, Landsburg, and Hill *(10)* found that lowered blood calcium accompanied the rachitic condition in calves. The ash content of the bones was also lowered.

Auchinachie and Fraser *(5)* succeeded in lowering the blood calcium of lambs by feeding the animals indoors on a low-calcium ration. These results prove that normal calcium metabolism depends not only upon an adequate supply of calcium, but also upon a factor (vitamin D) necessary for the utilization of the calcium.

The blood of the rachitic calves in Bechdel and coworker's experiments *(10)* was subjected to weekly hemoglobin determinations the results of which revealed an anemic condition. These appear to be the only hemoglobin determinations that have been made on rachitic calves. Brooks and Hughes *(22)* concluded from their studies with dairy cattle that breed, age, and prolonged fasting had no appreciable effect on the hemoglobin content. of the blood. Nor was there any significant individual variation observed from day to day. On the other hand, Dukes, Schwarte, and Brandt *(27)* report statistically significant differences between breeds of chickens in respect to the hemoglobin content of the blood. Furthermore, older hens had more hemoglobin than pullets and the amount in chickens of all ages increased significantly in winter.

FACTORS INFLUENCING CALCIUM RETENTION

Vitamin D has a marked influence on the retention of calcium and phosphorus in the animal body *(14).* Wallis, Palmer, and Gullickson *(88)* report that the average calcium retention by dairy calves may be increased 14-fold and the phosphorus retention 11-fold by vitamin D therapy. They observed no favorable influence on the mineral retention by increasing the mineral content of the ration of vitamin-D deficient calves. Their data indicate that the daily retention of normal calves approximated 6.50 grams of calcium and 3.25 grams of phosphorus. The retention was in approximately a 2:1 ratio regardless of the mineral content of the ration. This interrelationship suggests that a shortage of either one in the ration would limit the retention of the other.

Growth, calcium retention, and calcium utilization were alike, irrespective of the form of carbohydrate contained in experimental diets used by Spiers and Sherman *(77)*.

According to Elmslie and Steenbock *(33),* excessive magnesium salts in rat rations reduced palatability, lowered the food intake and resulted in severe digestive disturbances. But when lesser yet still relatively large amounts of magnesium were fed, no such disturbances were noted. Nor was it possible to demonstrate any effect of magnesium salts on the assimilation of calcium either when the rations were definitely deficient in calcium or when supplemented with adequate amounts of calcium.

The work of Huffman, Robinson, and Winter *(42)* also tends to minimize the danger from the inclusion of magnesium salts in the ration. They found that three to five percent of a magnesium salt in the ration of dairy calves did not affect the health of the animals nor the retention of calcium and phosphorus.

EFFECT OF THE CALCIUM INTAKE ON GROWTH

Experimental data concerning body growth on low-calcium rations are of particular interest because of the economic importance of gains in body weight of farm animals. Sherman and Booher *(69)* fed four levels of calcium intake (0.50 percent, 0.30 percent, 0.21 percent and 0.16 percent) to rats and found no differences in rate of growth or physical appearance. However, chemical analyses showed that the bodies of the rats on the low levels of calcium were calcium-poor. It was concluded that normal growth does not mean normal development. These investigators state that it has been demonstrated that maturity is speeded up by feeding diets of high-calcium content which permit more rapid calcification of the growing body than is possible on diets of lower calcium content. Campbell, Bessey and Sherman *(23)* have also reported good growth on low-calcium diets. They concluded that for rats a calcium intake of 0.1 percent of the dry food sufficed for growth in the first but not in the second generation.

Fairbanks and Mitchell *(35)* concluded that subsistence upon a ration containing as low as 0.18 percent of calcium definitely impairs growth in the rat. Levels of 0.32 percent and 0.49 percent appeared to be adequate. According to these authors, very low levels of calcium in the diet may retard growth aside from the effect on the appetite. They also state that there is a tendency for rapid growth to be associated with slow calcifications of bones.

With rice as the major item in a human diet having a calcium content of only 0.124 percent, Ranganathan and Rau 165) found the biological value of protein to be 44 percent and the digestibility value 64 percent. When 2 percent of calcium carbonate was added to the same diet, corresponding values of 76 and 89 percent, respectively, were obtained.

In extensive studies by Evans *(34)* the addition of calcium carbonate to a calcium-deficient ration had no influence whatsoever on the digestibility of the various nutrients by swine. The deficient ration was said to be satisfactory in every respect except that the sows to which it was fed suffered periodically from loss of appetite.

Theiler, Du Toit and Malan *(84)* fed pigs a ration deficient in calcium, but adequate in other respects. The low-calcium group gained as well as the control group during the first seven months of the experiment, but during the remainder of the test the difference in gain was more pronounced. There were no differences in the calcium and phosphorus of the blood, but the ash of the bones of the group fed the calcium-deficient ration was considerably reduced.

Macroscopic and microscopic examinations of the skeletons of two heifers that received only 5.8 grams of calcium daily for a period of 22 months revealed marked calcium undernutrition, yet there were no clinical symptoms *(83)*. One heifer increased in weight from 470 to 1,240 pounds and the other from 480 to 1,320 pounds. According to Theiler, who was in charge of this experiment, relative immunity of cattle to acalcicosis has been repeatedly confirmed in South Africa.

SYMPTOMS OF APHOSPHOROSIS

On the other hand, pronounced evidences of mineral malnutrition appear when cattle are fed phosphorus-deficient rations. Symptoms of this deficiency have been described in considerable detail by Eckles, Becker and Palmer *(30, 31)* and Theiler and Green *(85)*. These authors also have contributed excellent reviews of the literature.

Anorexia, retarded growth, and extreme emaciation are some of the plainly evident symptoms of aphosphorosis. The emaciation that invariably accompanies this disease would seem to indicate impaired utilization of food. Eckles and Gullickson *(31)* found that lowering the phosphorus content of the ration to that of prairie hay grown in certain sections of Minnesota increased the requirement for digestible nutrients at least 20 percent. Riddell, Hughes, and Fitch *(67)* found that phosphorus deficiency does not depress the digestive functions of lactating dairy cows. Their results show a higher energy metabolism for animals in the phosphorus deficient condition. Gains in weight following the addition of a phosphorus supplement indicated more economical utilization of nutrients. Kleiber, Goss, and Guilbert *(46)* also found that the efficiency of energy utilization was lowered by phosphorus deficiency. They reported that lowering of the appetite was the principal contributing factor, however. Aubel, Hughes, and Lienhardt *(14)* suggested that pigs on low-phosphorus rations store less energy than those receiving higher amounts.

Phosphorus deficiency in cattle has been reported from many countries. Its widespread occurrence reflects the influence of a deficiency of available phosphorus in the soil on the phosphorus content of forage crops.

Plants normally are higher in calcium than in phosphorus and the ratio between these elements is widened in the case of forage crops, hays and pasture grown on phosphorus-deficient soil. Cattle, in the main, subsist on pasture and roughages; therefore, are more likely to suffer deficiencies of phosphorus than of calcium.

It is generally recognized that cattle rations throughout the world are much more likely to be deficient in phosphorus than in calcium, for the reasons that have just been discussed. It is also a well-known fact that since hogs subsist largely on grains which tend to be relatively high in phosphorus and low in calcium, their rations are more likely to be deficient in calcium than in phosphorus. Particularly are hog rations likely to be deficient in calcium when a protein supplement of plant origin is used. Extensive investigations have been conducted with a number of such rations An outstanding example is the work of Shrewsbury and Vestal *(76)*. They found that the addition of a mineral supplement improved a ration of corn and soybeans. When fed to both hogs and rats, not only was growth improved, but the bones of the animals to which the mineral supplement was fed had a higher ash content and a greater breaking strength.

It appears reasonable, therefore, that in the past research workers should have focused their attention quite largely on phosphorus for cattle and calcium for hogs insofar as the mineral needs of these species are concerned. It was pointed out previously, however, that under certain conditions the calcium content of calf fattening rations may be comparable to that of hog rations in which a protein supplement of plant origin is used. In recent years the results of a number of feed lot experiments with basal rations comprised of grain, carbonaceous roughage and a protein supplement of plant origin have served to direct the attention of research workers and others to the importance of calcium in the nutrition of the fattening calf.

LOW-CALCIUM RATIONS FOR FATTENING CALVES

The first work with this type of calf-fattening ration was done by McCampbell and Winchester *(59)*. They found that the addition of two pounds of alfalfa hay per head daily to a ration of shelled corn, cane silage and cottonseed meal increased the gains and finish of calves full fed 207 days. Similar results were obtained later by McCampbell, Anderson and Marston *(56)*. They not only found that the basal ration was improved by the addition of two pounds of alfalfa hay, but also observed that larger gains in weight were obtained when alfalfa was fed after the first 60 days than after the first 120 days of a 195-day feeding period. In these tests the protein content of the rations was equalized by increasing the cottonseed meal when alfalfa was not fed.

McCampbell *(55)* reported that' calcium was responsible for the benefits obtained from adding alfalfa hay to this basal ration. He compared corn, cottonseed meal, silage and ground limestone with corn, cottonseed meal, silage and alfalfa hay in three experiments conducted in different years. One-tenth pound ground limestone and 0.28 pound cottonseed meal were substituted for 1.98 pounds alfalfa hay on the average for the three tests. At the end of 178 days full feeding, there were no significant differences between the two groups of calves in gains or finish.

Other experiments conducted at the Kansas Agricultural Experiment Station by Anderson and Alexander *(1)* and Anderson and Marston *(2, 3),* also led to the conclusion that a calf-fattening ration composed of silage, carbonaceous roughage and cottonseed meal is deficient in calcium. In three tests, prairie hay was substituted for the alfalfa hay in a ration of corn, silage, cottonseed meal, and alfalfa. The cottonseed meal was increased 0.21 pound per head daily where no alfalfa was fed, yet the gains in each test were significantly greater in the alfalfa lot. A third group of calves was fed one-tenth pound ground limestone, 0.21 pound cottonseed meal and 1.62 pounds prairie hay instead of 2 pounds of alfalfa, along with corn, silage and cottonseed meal. Gains of the two lots in this comparison were approximately the same each year and the two groups were equally well finished at the end of the full feeding period which averaged 174 days.

Anderson and Alexander *(1)* also reported that increased gains and finish resulted when ground limestone was added to a ration of corn, prairie hay and cottonseed meal. As a matter of fact, prairie hay plus the calcium supplement produced just as satisfactory results as alfalfa in this test where corn and cottonseed meal were the other ingredients in the ration. Thus the studies made by the Kansas workers showed that irrespective of whether the roughage was silage, prairie hay, or both, better results were obtained where ground limestone was added to the ration. It should be emphasized that the roughage intake was relatively low, since the corn consumption was maintained at a comparatively high level after the calves were on full feed.

That a calf-fattening ration of corn, cottonseed meal and prairie hay is improved by the addition of a calcium supplement was also indicated by the results of subsequent tests reported by Blizzard *(18, 19)*. His results show conclusively, however, that failure to feed a protein supplement with corn and prairie hay limits gains in weight much more than failure to feed a calcium supplement.

Skinner and King *(74)* substituted 1.57 pounds of oats straw and 0.11 pound ground limestone for 2.86 pounds of clover hay. Shelled corn, silage and a protein supplement were the basal feeds used. The calves receiving clover hay ate more corn and made larger gains than those fed oats straw and ground limestone. There was no adequate check by which the effect of the calcium supplement in the ration comprised of corn, silage, oats straw and protein supplement could be measured. However, the over-all effect of this ration was definitely inferior to that of the ration in which clover hay was used instead of oats straw. The difference in the over-all effects of these rations cannot be ascribed to a single factor, since there was more than one variable in the comparison. Manifestly, differences in energy and protein intake as well as in protein quality may have been responsible for the differences in gains. There is also a possibility that the feeds used in the Indiana experiments were higher in calcium than those used in the Kansas trials.

Jones and coworkers *(44)* obtained larger gains in two calf-feeding experiments by adding a calcium supplement to a low-calcium ration of ground hegari heads, cottonseed meal and ground hegari stover. This type of ration was used in eight comparisons in six different experiments conducted with lambs by Jones and Stangel *(46)*. In each comparison the gains were increased significantly by the addition of a calcium supplement, indicating that lambs respond similarly to calves despite the fact that they ordinarily receive less grain in proportion to roughage.

Extensive investigations with dairy cattle by Reed and Huffman *(66),* on the other hand, indicate that sufficient calcium and phosphorus for normal growth, good reproduction and liberal milk production are furnished by a ration of timothy hay, corn silage and grain. They concluded that when plenty of good quality roughage is fed with a protein concentrate like cottonseed meal or linseed meal, supplements to furnish calcium and phosphorus are not needed for growing cattle and milk cows under ordinary farm conditions.

Results with growing beef calves appear to confirm Reed and Huffman's statement. McCampbell and Aicher *(57)* reported in 1929 that the gains were not increased significantly when ground limestone was added to a calf wintering ration of silage and cottonseed meal. Similar results were reported later by Baker *(7, 8)* and Jones and coworkers *(44)*. Thalman and coworkers *(81, 82)* obtained a small increase In gains from the addition of ground limestone to such a ration, but it could be said that normal growth was obtained without the addition of calcium. The excellent growth obtained without adding calcium is doubtless explained by the fact that silage furnishes an adequate supply of this element when fed in relatively large amounts.

The results of two experiments reported by Snapp *(75, 76)* show that under some conditions, two pounds of alfalfa hay may not furnish enough calcium in a calf-fattening ration. Increased gains were noted when bone meal was added to a ration of ear corn silage, cottonseed meal and two pounds of alfalfa hay. Likewise the gains were increased when ground limestone was included in a ration of shelled corn, soybean oil meal, corn silage and two pounds of alfalfa hay. In each of these rations the proportion of grain to roughage was quite high.

Results obtained by Anderson and Alexander *(1)* also show increased gains by feeding ground limestone when two pounds of alfalfa hay are included with shelled corn, cottonseed meal, and cane silage as a ration for fattening calves. They obtained no benefit, however, from adding the calcium supplement where alfalfa hay was the entire roughage portion of the ration. Nor did Blizzard *(17)* observe any benefit. from the addition of ground limestone to a ration of corn, cottonseed meal and alfalfa hay. Liberal amounts of silage plus 2.75 pounds of clover hay were fed with shelled corn and a protein supplement in three trials at the Indiana station by Skinner and King *(74)*. The results were not changed significantly when ground limestone was added to this ration.

Variations in the calcium content of legume hay as well as variations in the amount of hay fed obviously may be important factors in determining the adequacy of a ration with respect to calcium.

McCampbell, Reed and Connell *(58)* made the first comparison of a ration of shelled corn, cottonseed meal, and silage with one comprised of these basal feeds plus ground limestone. The same amount of cottonseed meal was fed to each lot. The steers fed the calcium supplement consumed more corn and silage and made significantly greater gains than those fed the basal ration. They were also fatter at the conclusion of the feeding trial. Similar results were obtained in an experiment conducted a few years later by Baker *(6)*.

INORGANIC VERSUS ORGANIC SOURCES OF CALCIUM

Osborne and Mendel *(61)* were among the first to report that it is unnecessary to provide calcium and phosphorus in natural foods for the growing animal. They pointed out that the need for these elements can be fully supplied from inorganic sources. Steenbock and coworkers *(78)* found no difference in the availability of calcium lactate, carbonate, phosphate, silicate or sulfate when these were fed in liberal amounts to young rate. Anderson and Marston *(3)* reported that ground limestone was superior to both 16 percent acid phosphate and bone meal when added to a calf-fattening ration of shelled corn, cane silage, prairie hay and cottonseed meal. However, each of these minerals increased the gains above those in the lot fed the basal ration with no mineral supplement. Because of the widespread use of ground limestone as a calcium supplement, results obtained by Reed and Huffman *(66)* where excessive amounts of limestone rock were fed are of particular interest. They fed a basal ration of timothy hay, corn silage and grain to dairy cattle. The inclusion of as much as 3 percent of limestone rock in the grain mixture had no harmful effects on the health and teeth of animals up to 42 months of age.

After reviewing the results reported in the foregoing literature, it was decided to extend the investigations of calcium in the nutrition of the fattening calf by making further studies of the effects of ground limestone when added to a basal ration of corn, silage and cottonseed meal.

EXPERIMENTAL PROCEDURE

The object of this study was to obtain detailed information concerning the effects of a low-calcium ration on the fattening calf. The study was uncomplicated by the amount of phosphorus in the ration, and the feeds used contained all known essentials of an adequate ration for calves. The calcium content was the only known variable in the rations studied.

To accomplish this objective, the paired feeding method described by Mitchell and Beadles *(51)* was used in Experiments 1 and 2. Both members of each pair of steers received the same amounts of digestible nutrients, vitamins and minerals, with the exception of calcium. One member of each pair received in addition to the basal ration one-tenth pound of ground limestone daily, which raised the calcium intake from a relatively low to a high level. The differences in the response of the steer calves to these two levels of calcium intake were measured in terms of body and bone growth, utilization of feed, blood composition and carcass quality. Digestion trials and mineral balance studies were included in Experiment 2. The third experiment was a group-feeding trial conducted to check the results obtained in the paired feeding experiments and also to determine the effect of the two levels of calcium intake on the amount of feed and water consumed.

Experiments 1 and 2 consisted of six pairs of steers each. Two lots of ten steers each were fed in Experiment 3.

CALVES USED IN THE EXPERIMENTS

Range-bred steer calves approximately six months old were used in each experiment. They were high-grade Herefords from the same ranch, but nothing was known regarding the relationship of the various individuals used. They were obtained at weaning time, and all were thrifty and appeared to have been adequately nourished prior to the beginning of the experiments.

After arriving at the college farm, the steers in each experiment were given a preliminary feeding period of from four to six weeks before being started on the experimental rations. The ration used during the preliminary period was the same for all of the steers and consisted of a full feed of silage and about one pound of cottonseed meal per head daily. During this time, the steers were vaccinated for blackleg and carefully observed for sickness and lack of thrift. Those individuals that, were to be used in the paired-feeding experiments were halter broken and handled individually almost every day during the preliminary period so that they would be accustomed to the treatment they were to receive.

The steers selected for the experiments were quite uniform in weight, type and fleshing. Particular care was taken to see that both members of each pair mere closely matched, not only in these respects but also as to disposition and potential feeding qualities.

2—6399

MANAGEMENT AND CARE OF THE CALVES

The steers used in the paired-feeding experiments were housed in a well-lighted, well-ventilated beef cattle nutrition barn (fig. 1, Appendix) especially constructed for this type of experiment. While in this barn, they were confined in stanchions, three pairs of steers facing the south side and three pairs facing the north side of the barn. The mangers were so constructed that no feed could be wasted and it was impossible for the steers to reach back of the stanchions to eat the straw with which they were bedded.

An outside paved lot adjoining the barn was used as an exercise pen. The pavement extended beyond the fence far enough to make it impossible for the steers to obtain access to soil. The steers in Experiment 1 were started on feed before the nutrition barn was completed and as a consequence were muzzled when allowed to exercise in a dirt lot. After these steers were moved to the nutrition barn, there was a tendency for both groups to nibble at feces when turned out in the paved exercise lot, hence it was deemed advisable to muzzle them while they were outside the barn. The steers in Experiment 2 were not inclined to nibble at feces and for that reason were not muzzled. However, the paved exercise lot was kept clean in order to discourage them from acquiring the habit.

Except during extremely bad weather, the steers were allowed to spend approximately five hours outdoors during the middle of each day. Thus they were exposed to a considerable amount of ultraviolet rays since they had access to the direct rays of the sun. Water was available while the steers were in the exercise lot. During warm weather, they were turned out at night.

The steers did not leave the nutrition barn at any time during the experiment. Scales were located in the barn, and a special restraining chute was taken into the barn each time the steers were bled. The usual procedure was to bleed the steers about 6:30 a. m. before they had been fed.

In the paired-feeding experiments, the steers were fed individually at 7:30 a.m. and 4:30 p. m. The feed constituents were weighed separately on a solution balance, but later were mixed and fed together.

At regular intervals, several weeks' requirements of the calcium supplement was weighed out in daily portions and placed in cellophane bags. The calcium supplement was fed only in the evening.

The feeds were increased from time to time, but both members of each pair were always fed the same amount. Obviously, the amount fed each pair was determined by the steer having the poorer appetite. Special care was taken to avoid having any refused feed. This resulted in a lower feed intake than would have been the case had this factor been ignored. On the other hand, the value of this procedure is evidenced by the fact that in every instance the amount of feed not consumed was so small that it could be ignored entirely. Most of the pairs left no feed whatsoever.

The steers in all three experiments were weighed individually at

28-day intervals. An additional check on the growth of the steers in Experiment 2 was obtained by taking several body measurements at the beginning and close of the experiment. The initial and final weights of each steer were taken on three successive days and the average of the three weights mas used as the initial and final weight, respectively. Where body measurements were taken, a single measurement at the beginning of the experiment was used as the initial measurement and the one at the end was used as the final measurement.

In Experiments 1 and 2, analyses of the blood for calcium, inorganic phosphorus and hemoglobin were made near the beginning of the experiments and each 28 days thereafter. Similar analyses were made at the beginning and close of Experiment 3, where the steers were group-fed.

In order to study the effect of the calcium intake on the development of the bones, carcasses and body organs, four of the six pairs were slaughtered in the College abbatoir at the close of Experiment 1, while all six pairs used in Experiment 2 were slaughtered at the close of the feeding period. A special study of the carcasses of all the steers used in Experiment 3 was made in the coolers of a packing plant at Kansas City. However, it was not possible to study the bones and body organs of the steers that were group-fed.

Dressing percentages were calculated and the weights of heart, liver, and spleen taken in Experiments 1 and 2. The humerus, femur, 5th and 13th ribs of each steer slaughtered from these experiments were used to determine the effect of the rations upon the skeletal structure. Bone studies included analyzing for ash, calcium and phosphorus, taking weights and determining specific gravities and breaking strengths. An electrically driven Riehle testing machine was used to determine the breaking strength of the bones (fig. 4, Appendix).

Pictures were taken at the beginning and close of the experiments to illustrate the uniformity of the individuals in the various pairs at the start, and to show the differences, if any, in growth and development that occurred during the experiments. Other pictures were taken to illustrate interesting features of experimental procedure.

DIGESTION TRIALS AND MINERAL BALANCES

Three pairs of steers were used in the digestion trials and balance studies at the conclusion of the regular feeding period in Experiment 2. Two weeks before these trials began, slight adjustments were made in the amount of feed fed to the steers selected for the studies. No changes were made from that time until the trials were completed.

The special apparatus used in collecting the feces and urine is shown in figures 2 and 3 (Appendix). Collections were made at 2 p. m. the first day and the feces and urine were weighed and sampled beginning at 2 p. m. each day thereafter throughout the 10-day period. Aliquots of the feces were dried in an electric oven each day and a composite sample for analysis taken following the last collection. Aliquots of the urine were taken and preserved for chemical analysis. All weights of feeds, feces, and urine were checked by two persons to insure accuracy. Feeds to be used during the trial were collected before the trial began, and except for silage, sampled for chemical analyses. Silage samples were taken daily and dried. These dried samples were composited later and analyzed. Wherever practical, the daily feed allowances for the entire balance trial were weighed, placed in sacks or suitable containers and labeled, so that they would be available as needed and also to eliminate the possibility of error in weighing.

A rigid schedule was observed throughout these trials and an attendant was on hand at all times. Particular emphasis was placed upon cleanliness of the stalls and all materials used in connection with the collection of urine and feces. The steers were brushed daily in order to make them more comfortable and contented during the time they were subjected to the unusual conditions.

Feeds Used in the Experiments

The basal ration was comprised of No. 2 ground shelled corn, mostly mixed in color, cottonseed meal, 43 percent protein grade; and Atlas sorgo silage. Experiments 2 and 3 were conducted in the same year and silage made in 1938 from reasonably well-matured Atlas sorgo was used in both experiments. The silage used in Experiment 1 was made in 1936 from Atlas sorgo that failed to mature because of unusually dry weather. The limestone used in all three experiments was ground to a powdery condition. It contained over 98 percent calcium carbonate. A table giving the composition of the feeds used in a particular experiment is included with the other tables and material for that experiment.

Chemical Analyses

Analyses of feeds, bones, blood, feces and urine were made in the chemical laboratories of Kansas State College under the supervision of Dr. W. J. Peterson and Dr. A. T. Perkins. A. O. A. C. methods were used in the analyses of feeds, feces and urine. The methods used in blood analyses were as follows: Phosphorus, modified Fiske and Subborow *(47);* calcium, Chi Che Wang method *(92);* hemoglobin, the method described by Shenk, Hall and King *(68)*.

RESULTS OBTAINED IN EXPERIMENT 1

This experiment was started January 10, 1937, and closed September 16, 1937. Six pairs of steer calves were fed a basal ration of ground shelled corn, Atlas sorgo silage and cottonseed meal. Both members of each pair received the same amounts of the basal feeds. Each pair was regarded as a unit and no attempt was made to keep the feed consumption of the various pairs the same. In addition to the basal ration, one member of each pair received one-tenth pound of finely ground limestone as an additional source of calcium. The analyses of the feeds used in this experiment are given in table 1.

TABLE 1. *Analyses of the feeds used in the study of the calcium intake in the nutrition of calves*

Experiment 1.

(Paired feeding)

FEED CONSTITUENT.	Water.	Crude protein.	Ether extract.	Crude fiber.	N-free extract.	Ash.	Calcium.	Phosphorus.
	Percent.	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*
Atlas sorgo silage	72.90	4.81	0.56	7.40	11.96	2.37	0.177	0.039
Cottonseed meal	6.78	42.06	5.75	12.59	26.94	5.88	0.212	1.090
Ground shelled corn	9.52	10.00	2.90	2.27	73.98	1.33	0.030	0.200
Ground limestone	....	....	....	....	....	....	98.820	0.016
Water	....	....	....	....	....	....	0.008	....

Body Weights and Gains

The body weights and gains of the steers are given in table 2. In four of the six pairs, the steers on the high-calcium intake made larger gains than their mates and in two pairs those on the low-calcium intake increased in body weight at a slightly more rapid rate. The significance of differences obtained in paired-feeding experiments such as this may be analyzed by the use of "Student's" method *(80)*. The average differences between the gains of the six pair mates is 0.15 pound and the standard deviation of the differences is 0.24 pound. "Student's" Z value is obtained by dividing the mean difference by the standard deviation and in this case is 0.60. With N = 6 (six pairs) and a Z value of 0.6 the odds are only 7 to 1 that the mean difference in gains was not due to chance. While the difference in gains is not statistically significant, it will be noted from Graph 1 that after the first 28 days, the average gain of the high-calcium steers was consistently larger than that of the low-calcium steers. It is also interesting that similar differences were noted both by McCampbell and coworkers *(59)* and by Baker *(6)*.

TABLE 2. *The effect of the calcium intake in the nutrition of calves*

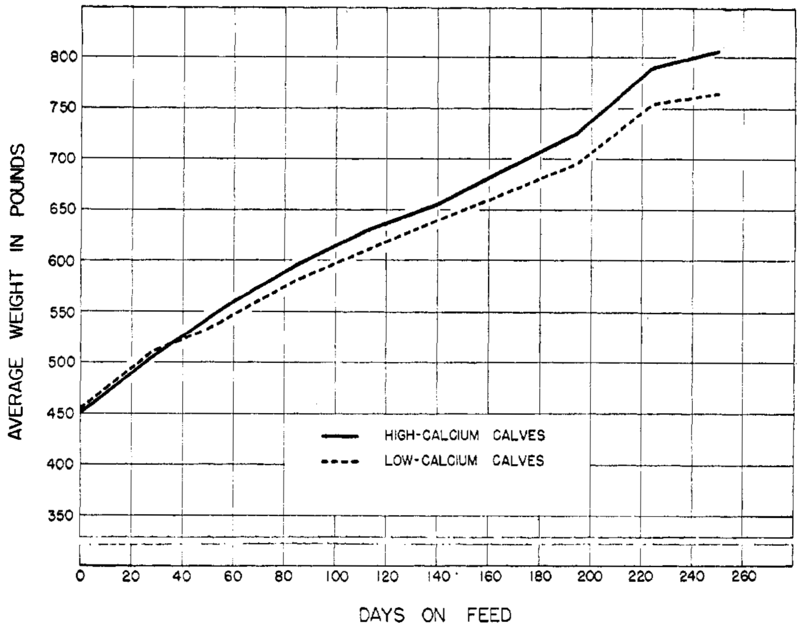
Body weights and gains of steers fed in Experiment 1.

Pair No.	Calcium intake.	Body weight		Total gain.	Daily gain.
		Initial.	Final.		
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
1	Low	448.33	793.00	344.67	1.38
	High	451.67	780.00	328.33	1.32
2	Low	470.00	841.50	371.50	1.49
	High	480.00	899.50	419.50	1.68
3	Low	468.33	805.00	336.67	1.35
	High	448.33	820.00	371.67	1.49
4	Low	436.67	655.00	218.33	0.88
	High	438.33	817.00	378.67	1.52
5	Low	438.33	737.00	298.67	1.20
	High	443.33	727.00	283.67	1.14
6	Low	455.00	761.00	306.00	1.23
	High	448.33	775.50	327.17	1.31
Av.	Low	452.78	765.42	312.64	1.26
Av.	High	451.67	803.50	345.67	1.41

Consumption and Utilization of Feed

With the exception of the low-calcium steer in Pair No. 4, all the steers grew satisfactorily. However, none made as large gains as are expected when calves are full-fed in groups under more nearly normal conditions. It is well-known among experienced cattlemen that competition at the feed bunk tends to increase feed consumption, while individual feeding usually lowers the amount eaten. That tendency was clearly demonstrated in this experiment, as the data in table 3 show. Further restriction of feed consumption resulted by reason of the fact that it was deemed advisable to prevent, if possible, the refusal of feed in any amount whatsoever. There was nothing to indicate, however, that the calcium intake had any effect on the appetite of these steers.

There was some indication, however, that the low-calcium steers exhibited greater thirst, particularly during hot weather. It was not possible to obtain accurate records on water consumption



GRAPH 1.—The effect of calcium intake on the body growth of calves. (Experiment 1.)

throughout the entire experiment, hence conclusions on this point are not justified.

Both steers in each pair ate the same amount of corn, silage and cottonseed meal. As a consequence, the efficiency with which these feeds were utilized was related directly to the amount of gain. Manifestly, the steer that made a larger gain than his mate also utilized each feed constituent more efficiently. The average difference in feed required for 100 pounds of gain amounted to 77 pounds of corn, 90 pounds of silage and 15 pounds of cottonseed meal, the lesser amounts being required by the steers on the high intake of calcium (table 3). Since this group required 7.2 pounds of ground limestone for 100 pounds gain, it might be concluded that this small amount of calcium supplement saved the other feeds in amounts represented by the differences just noted in the requirements for 100 pounds of gain. Yet such a conclusion is not justified on the basis of the re-

TABLE 3. *The effect of the calcium intake in the nutrition of calves*

Daily feed consumed and feed required for 100 pounds gain in Experiment 1.

Pair No.	Calcium intake.	Feed consumed daily.				Feed required for 100 pounds gain.			
		Corn.	Silage.	Cottonseed meal.	Ground limestone.	Corn.	Silage.	Cottonseed meal.	Ground limestone.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
1	Low	7.85	7.56	1.36	....	567.06	546.39	98.06	....
	High	7.85	7.56	1.36	0.10	595.28	573.58	102.95	7.58
2	Low	8.84	9.66	1.49	....	592.26	647.17	99.93	....
	High	8.84	9.66	1.49	0.10	524.49	573.12	88.50	5.94
3	Low	7.86	7.43	1.38	....	581.36	549.57	101.81	....
	High	7.86	7.43	1.38	0.10	525.80	498.09	92.22	6.69
4	Low	8.22	8.96	1.47	....	937.57	1022.42	167.75	....
	High	8.22	8.96	1.47	0.10	540.58	589.50	96.72	6.58
5	Low	8.00	8.30	1.46	....	666.71	692.15	121.62	....
	High	8.00	8.30	1.46	0.10	701.96	728.75	128.05	8.78
6	Low	8.71	9.09	1.49	....	708.74	739.95	121.32	....
	High	8.71	9.09	1.49	0.10	662.58	692.07	113.47	7.59
Av.	Low	8.25	8.50	1.43	....	675.62	699.61	118.42	....
	High	8.25	8.50	1.43	0.10	591.78	609.19	103.65	7.19

TABLE 4. *Calcium and phosphorus in the rations fed in Experiment 1 compared with the estimated requirements of growing beef steers*

	Average body weight.	Dry matter daily.	Feed calcium daily.	Calcium in dry ration.	Feed phosphorus daily.	Phosphorus in dry ration.
	Pounds.	*Grams.*	*Grams.*	*Percent.*	*Grams.*	*Percent.*
Low-calcium group	609	5040	11.0	0.22	16.1	0.32
High-calcium group	627	5085	28.6	0.56	16.1	0.32
Estimated requirements	615	4907	12.5	0.25	12.3	0.25

NOTE: Computations of the estimated requirements are based on the data given in table 8, page 130, Bulletin 99 of the National Research Council by Mitchell and McClure. The water consumption was estimated as 47 pounds per steer daily for each lot. This estimate was based on accurate records obtained in three ten-day periods during the experiment.

sults obtained in only one experiment, particularly when the variations among the different pairs are as great as those noted in this experiment.

Calcium Intake Compared With Estimated Requirements

In table 4, the calcium and phosphorus in the rations fed in Experiment 1 are compared with the estimated requirements of growing beef steers. The estimates are the writers' interpolations of the figures compiled by Mitchell and McClure *(52)*. These authors have worked out tables for the calcium and phosphorus requirements of both fattening and growing beef steers. The estimated requirements decrease with increasing age and weight in both cases, but are considerably higher at a given weight for fattening steers. It may also be pointed out that the dry matter requirement is also considerably higher for the fattening than for the growth of beef steers.

While the steers in Experiment 1 were fed fattening rations, the dry matter consumed was only about 75 percent of the requirement recommended by the Morrison standards for fattening steers of this weight *(54)*. The dry matter intake corresponded much more closely to the requirements recommended for growing steers. It is for this reason that the calcium and phosphorus in the rations are compared in table 4 with the estimated requirements of growing beef steers rather than with those for fattening steers.

When the comparison is made on this basis, the calcium intake of the low-calcium group was only slightly less than the estimated requirement, while that of the high-calcium group was more than twice as great. The rations of both groups contained the same amount of phosphorus, approximately 30 percent more than the estimated requirement. Therefore, insofar as these estimated requirements represent the actual requirements for calcium and phosphorus this comparison suggests that the difference, if any, in the growth of the two groups would probably be insignificant.

Effect of Rations on Carcasses and Internal Organs

Four of the six pairs of steers were slaughtered in the station abbatoir at the conclusion of the 249-day feeding period. The slaughter and carcass grades described in table 5 and listed in table 6 do not reveal any consistent differences between the steers on the two levels of calcium intake. The low-calcium steers held a slight advantage in slaughter grades on the average, but the rating was just the reverse in the case of carcass grades, indicating that the differences were not significant. Photographs of the carcasses (figs. 5, 6, Appendix) also reveal marked similarities in shape and finish.

TABLE 5. *Description of feeder cattle, slaughter cattle and carcass grades used in these experiments*

Feeder cattle grades.	Slaughter cattle grades.	Carcass grades.
2,4,6 = fancy	2,4,6 = prime	2,4,6 = prime
8,10,12 = choice	8,10,12 = choice	8,10,12 = choice
14,16,18 = good	14,16,18 = good	14,16,18 = good
20,22,24 = medium	20,22,24 = medium	20,22,24 = medium
26,28,30 = common	26,28,30 = common	26,28,30 = common
32,34,36 = inferior	32,34,36 = cutter	32,34,36 = cutter
	38,40,42 = low cutter	38,40,42 = low cutter

NOTE: Grading Charts Nos. 100, 101 and 102 developed jointly by the Bureaus of Agricultural Economics and Animal Industry in the United States Department of Agriculture, were used.

TABLE 6. *The effect of the calcium intake in the nutrition of calves*

Slaughter and carcass grades, Experiment 1.

Pair No.	Calcium intake.	Slaughter grade.	Carcass grade.
1	Low	15	20
	High	18	21
3	Low	18	17
	High	17	20
5	Low	17	25
	High	20	18
6	Low	18	18
	High	17	15
Av.	Low	17	20
	High	18	19

NOTE: A description of the grades is given in table 5.

Dressing percentages were calculated as a part of the slaughter studies. Feed was withheld 24 hours before slaughtering, while water was available during this period. An inspection of the data given in table 7 shows minor variations in dressing percentage with no significant differences between the two groups.

It was planned to take weights of the heart, liver, spleen and hide and to compare these with the dressed body weight. The numerical data based on these weights are shown in table 7. The differences were probably not significant, but it is interesting to note that in each of the four comparisons, the liver of the steer on the high-calcium intake represented a higher percentage of the dressed body weight than did the liver of the steer on the low-calcium intake.

TABLE 7. *The effect of the calcium intake in the nutrition of calves*

Dressing percentage and weights of heart, liver, spleen, and hide compared to the dressed body weight.

Experiment 1.

Pair No.	Calcium intake.	Dressing percentage.	Percentage of dressed body weight.			
			Heart.	Liver.	Spleen.	Hide.
1	Low	59.07	0.69	1.60	0.34	11.15
	High	60.18	0.74	1.68	0.45	8.45
3	Low	63.64	0.62	1.41	0.46	8.52
	High	61.19	0.70	1.51	0.38	8.67
5	Low	62.71	0.72	1.58	0.29	8.10
	High	62.65	0.68	1.69	0.33	8.35
6	Low	63.12	0.66	1.66	....	8.65
	High	60.61	0.59	2.09	0.52	8.86
Av.	Low	62.13	0.67	1.56	0.36	9.11
	High	61.16	0.66	1.77	0.42	8.58

Blood Analyses

Blood analyses were included in this study in order to record the variations in the calcium, phosphorus and hemoglobin contents of the blood of fattening calves. It was not expected that a low-calcium level in the ration would lower the calcium level of the blood significantly. It was pointed out in the review of the literature that significant changes in this respect are extremely difficult to produce, since an important function of the parathyroid glands is to mobilize the calcium in the bone trabeculae so that the level of blood calcium will be maintained. It was also pointed out that the phosphorus content of the blood may be changed greatly by an inadequate supply of phosphorus in the ration. These studies afford further comparisons of the relationship between calcium and phosphorus when the ratio of these elements in the ration is markedly different. The hemoglobin studies were undertaken to determine whether the state of calcium nutrition affects the hemoglobin content of the blood.

The calcium content of the blood serum varied little as the feeding period progressed, and the values were normal for the individuals in both groups. The average level was approximately 12 milligrams per 100 c.c. of serum, with the individual determinations ranging between 11 and 14 milligrams. An inspection of these data shows that the variations were common to all steers in both groups (table 8). In other words, there appeared to be no inherent differences in these steers insofar as the calcium content of their blood was concerned. Nor was there any indication that the higher level of calcium intake caused the blood calcium to increase even slightly above that of the steers whose rations contained appreciably less calcium. For some unknown reason, the calcium content of the blood serum of both groups was distinctly less when determined for the seventh period than it was for any other period.

TABLE 8. *The effect of the calcium intake in the nutrition of calves*

Calcium content of the blood serum of steers

Experiment 1.

(Results expressed in milligrams per 100 c.c. of serum.)

Pair No.	Calcium level.	Period.										Average.
		Initial.	1.	2.	3.	4.	5.	6.	7.	8.	9.	
1	Low...............	14.04	12.16	12.04	10.70	12.69	12.50	13.36	10.63	11.30	10.77	12.02
	High...............	13.02	11.66	11.80	11.96	12.34	12.72	11.10	10.63	11.19	11.29	11.77
2	Low...............	13.14	12.35	11.99	12.60	12.86	12.66	12.63	10.91	11.94	13.07	12.42
	High...............	13.58	11.91	12.04	12.29	12.44	12.22	11.22	10.82	11.94	12.47	12.09
3	Low...............	12.76	12.10	12.42	13.04	12.28	13.13	13.40	10.91	13.30	15.13	12.85
	High...............	12.70	11.34	11.86	12.29	11.82	11.67	12.67	9.97	12.40	13.40	12.01
4	Low...............	13.02	11.97	11.86	10.97	12.02	*........	12.22	11.59	11.58	13.98	10.92
	High...............	12.35	11.47	11.09	12.40	13.32	12.32	13.22	10.72	11.78	10.67	11.93
5	Low...............	12.76	12.16	11.60	12.90	12.52	11.21	13.60	11.11	12.48	13.40	12.37
	High...............	13.08	11.97	11.91	12.50	12.88	13.33	11.30	11.40	11.45	12.95	12.28
6	Low...............	12.89	11.78	12.88	12.12	11.89	12.68	13.32	10.34	11.32	10.47	11.97
	High...............	11.36	11.72	13.00	12.04	12.23	11.92	11.62	11.35	9.48	†........	11.64
Av.	Low...............	13.10	12.09	12.13	12.06	12.38	12.44	13.09	10.92	11.99	12.80	12.09
	High...............	12.68	11.68	11.95	12.25	12.51	12.36	11.86	10.82	11.37	12.16	11.96

* Analysis not made.
† Serum clotted.

TABLE 9. *The effect of the calcium intake in the nutrition of calves*

Phosphorus content of the blood serum of steers.

Experiment 1.

(*Results expressed in milligrams per 100 c.c. of serum.*)

Pair No.	Calcium level.	Period.										Average.
		Initial.	1.	2.	3.	4.	5.	6.	7.	8.	9.	
1	Low	11.16	10.19	10.40	10.66	9.79	10.21	10.03	10.13	10.30	8.08	10.10
	High	11.89	9.58	9.11	9.75	10.02	9.80	9.92	9.16	9.98	7.87	9.71
2	Low	9.28	9.20	9.29	9.64	9.93	8.07	11.16	8.73	8.49	7.53	9.13
	High	10.87	9.92	9.37	10.52	9.05	9.34	12.56	10.43	10.72	9.63	10.24
3	Low	11.32	9.96	7.89	8.95	10.35	8.98	9.13	9.19	9.78	6.92	9.25
	High	11.41	10.60	9.52	9.52	11.15	9.63	9.60	10.72	10.91	8.72	10.18
4	Low	9.45	8.60	8.92	9.13	9.02	*........	8.33	6.88	8.91	7.50	8.53
	High	10.87	8.92	8.65	9.35	9.38	9.75	9.88	8.73	10.36	7.58	9.35
5	Low	9.22	10.46	9.59	10.78	10.22	11.33	9.88	9.93	10.67	7.74	9.98
	High	9.27	8.92	8.19	7.93	8.73	7.98	10.62	8.08	8.91	6.21	8.48
6	Low	8.79	9.18	8.86	9.65	10.12	9.65	10.00	8.66	9.55	7.87	9.23
	High	10.87	10.11	9.11	9.78	10.75	8.92	11.70	9.48	8.65	†........	9.93
Av.	Low	9.87	9.60	9.16	9.80	9.91	9.65	9.76	8.92	9.62	7.61	9.40
	High	10.86	9.68	8.99	9.48	9.85	9.24	10.71	9.43	9.92	8.00	9.64

* Analysis not made.
† Serum clotted.

The phosphorus content of the blood serum is given in table 9. The data show some variations among the steers but, like the values for calcium, the values for phosphorus were normal and no significant differences between the two groups were noted at any time.

A preliminary study was made of the hemoglobin content of the blood of these steers, and the data are shown in table 10. There

TABLE 10. *The effect of the calcium intake in the nutrition of calves*

Hemoglobin content of the blood of steers.

Experiment 1.

(*Results expressed in grams per 100 c.c. of blood.*)

Pair No.	Calcium level.	Period. 6.	7.	8.	Average.
1	Low	13.36	11.30	13.81	12.82
	High	11.10	11.19	12.47	11.59
2	Low	12.63	11.94	13.07	12.55
	High	11.22	11.94	12.47	11.88
3	Low	13.40	13.30	15.13	13.94
	High	12.67	12.40	13.40	12.82
4	Low	12.22	11.58	13.98	12.59
	High	13.22	11.78	14.20	13.07
5	Low	13.60	12.48	13.40	13.16
	High	11.30	11.45	12.95	11.90
6	Low	13.32	11.32	13.40	12.68
	High	11.62	9.48	8.74	9.95
Av.	Low	13.09	11.99	13.80	12.96
	High	11.84	11.37	12.37	11.86

NOTE: Since this was merely a preliminary study of the hemoglobin content of the blood, analyses were made only for periods, 6, 7, and 8. A more complete study was made in Experiment 2.

seemed to be some indication of higher hemoglobin value for the steers on the low-calcium intake. All three determinations showed higher values for the low-calcium steer in five of the six pairs, while in one pair the opposite situation prevailed with respect to all three determinations. Manifestly, no conclusions are warranted from these fragmentary data, but they do suggest that further studies might be of interest.

An interesting observation was made concerning an apparent difference in the irritability of the two groups of steers. After about the first 60 days, those on the low-level of calcium intake were less tractable than those on the high level, and the differences seemed to become greater as the feeding period progressed. Experienced cattlemen and nutrition workers who inspected these steers usually commented upon the differences in irritability. No attempt was made to obtain a numerical measurement of these differences and their exact meaning and significance are not known.

Effect of Rations Upon the Bones

When the four pairs of steers were slaughtered at the close of the experiment, four bones were removed from each carcass for a determination of the effect of the ration upon the physical measurements and chemical composition of the skeleton. The bones used were two leg bones, the humerus and femur, and two rib bones. The bones were heavier, on the average, from the high-calcium steers (table 11). Sixteen comparisons were made and in fourteen of them the heavier bones came from the steers receiving the calcium supplement.

An inspection of the data also shows the specific gravity of the bones to be considerably less in the calves on the low-calcium level

TABLE 11. *The effects of the calcium intake in the nutrition of calves*

Weight, specific gravity and breaking strength of the leg and rib bones. Experiment 1.

Pair No.	Calcium intake.	Bones.	Weight.	Specific gravity.	Breaking strength.
			Grams.		*Pounds.*
1	Low	Humerus	1022	1.175	2335
		Femur	1328	1.199	3170
		5th rib	125	1.214	310
		13th rib	53	1.233	100
	High	Humerus	1108	1.230	2495
		Femur	1402	1.176	2990
		5th rib	130	1.262	380
		13th rib	77	1.351	110
3	Low	Humerus	1015	1.186	2580
		Femur	1320	1.167	2545
		5th rib	103	1.132	320
		13th rib	56	1.245	180
	High	Humerus	1097	1.248	2375
		Femur	1454	1.287	3330
		5th rib	139	1.376	460
		13th rib	78	1.369	240
5	Low	Humerus	1012	1.186	2285
		Femur	1490	1.231	2800
		5th rib	108	1.187	220
		13th rib	51	1.133	170
	High	Humerus	973	1.243	2975
		Femur	1211	1.228	2060
		5th rib	110	1.310	350
		13th rib	70	1.400	190
6	Low	Humerus	1015	1.149	2245
		Femur	1292	1.154	1955
		5th rib	99	1.179	250
		13th rib	82	1.243	210
	High	Humerus	1112	1.203	2700
		Femur	1458	1.187	2830
		5th rib	136	1.271	490
		13th rib	76	1.357	330
Av.	Low	Humerus	1016.0	1.177	2361.3
		Femur	1357.5	1.188	2617.5
		5th rib	108.8	1.178	275.0
		13th rib	60.5	1.214	165.0
	High	Humerus	1072.5	1.231	2636.3
		Femur	1381.3	1.218	2802.5
		5th rib	128.8	1.305	420.0
		13th rib	75.3	1.369	217.5

than in the calves on the higher level. Higher values were recorded in fourteen of the sixteen comparisons.

Marked differences in the strength of the bones were also noted. Considerably more pressure was required to break the bones of the steers on the high-calcium level in thirteen of the sixteen comparisons.

On the basis of the data on the weight, specific gravity and breaking strength of the bones, it appears that the steers on the high-level of calcium intake were in a better state of calcium nutrition than those on the low level.

The data obtained in the chemical analysis of the bones (table 12) support the evidence of the physical measurements. The bones of all four steers of the high-calcium group contained more ash, calcium

TABLE 12. *The effect of the calcium intake in the nutrition of calves*

Ash, Calcium, and Phosphorus in the dry fat-free bones.

Experiment 1.

Pair No.	Calcium intake.	Ash.	Calcium.	Phosphorus
		Percent.	*Percent.*	*Percent.*
1	Low	52.05	19.08	9.53
	High	53.44	19.60	9.80
3	Low	52.53	19.44	9.72
	High	55.73	20.46	10.03
5	Low	52.42	19.60	9.61
	High	54.27	20 30	9.83
6	Low	52.29	18.54	9.88
	High	54.22	20.12	9.94
Av.	Low	52.33	19.17	9.69
	High	54.42	20.12	9.90

and phosphorus than the bones of the four steers with which they were paired. The average difference in ash content is 2.09 percent, and the standard deviation of the differences is 0.68 percent. Thus the Z value of "Student" is 3. With Z=3 and N=4, the odds are well over 300 to 1 that the mean difference is not due to chance. It appears, therefore, that better bone development in growing calves results when the dry ration contains 28.6 grams (0.56 percent) of calcium than when it contains only 11.0 grams (0.22 percent). The difference in body growth, expressed in terms of gain in live weight, also appears more significant when interpreted in the light of the data obtained in the physical and chemical analysis of the bones. Considering all the data collected in this experiment, it would seem that the lower level of calcium intake was not sufficient for maximum growth with limited fattening.

3—6399

RESULTS OBTAINED IN EXPERIMENT 2

Experiment 2 was started November 21,1938, and closed May 29, 1939. Twelve calves were. fed in pairs in accordance with the general plan outlined previously. This experiment was undertaken to check the results obtained in Experiment 1 and to extend the studies to other fundamental aspects of the problem. The most important additions were the digestion trials and mineral balances.

Grade Hereford steer calves ranging in weight from 342 to 401 pounds were selected for this experiment. Their average weight was approximately 375 pounds when the experiment started. Their initial weight, therefore, was about 75 pounds less than that of the steers used in Experiment 1. They also appeared to be somewhat younger, but since rangebred steers were used in both experiments definite information concerning ages is not available. The lighter weights and younger appearance of the calves used in this experiment indicate that their requirement for calcium was probably higher than it was for the calves used in Experiment 1, especially during the early stages of the feeding period. Pictures of the calves at the beginning and close of the experiment are shown in figures 7, 8, and 9 (Appendix).

The feeds used in Experiment 2 were produced under more nearly normal weather conditions than those used in the previous experiment. An examination of the data given in tables 1 and 13 shows that both the Atlas sorgo silage and the ground shelled corn used in Experiment 2 contained an appreciably smaller amount of calcium than those used in Experiment 1. This confirms the belief that drought conditions tend to increase the calcium content of the plants. In any event, the calcium contents of ground shelled corn and the Atlas sorgo silage were 50 and 45 percent more, respectively, in the first than in the second experiment. The lower calcium content of the feeds coupled with a probable higher calcium requirement because the steers were younger and of lighter weight, suggests that the low-calcium ration would have a more noticeable effect than it did in Experiment 1.

TABLE 13. *Analyses of the feeds used in the study of the effect of the calcium intake in the nutrition of calves*

Experiment 2.

(Paired feeding)

FEED CONSTITUENT.	Water.	Crude protein.	Ether extract.	Crude fiber.	N-free extract.	Ash.	Calcium.	Phosphorus.
	Percent.	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*
Atlas sorgo silage	73.45	2.35	0.66	6.84	14.81	1.89	0.122	0.050
Cottonseed meal	7.44	44.94	6.77	10.41	23.59	6.85	0.200	1.290
Ground shelled corn	12.21	11.88	4.15	2.15	68.06	1.55	0.020	0.325
Ground limestone	....	....	....	....	....	....	38.650	0.008
Water	....	....	....	....	....	....	0.0024	....

Body Weights and Gains

A summary of the body weights and gains is given in table 14. It will be noted that with the exception of Pair No. 2, the difference in the initial weights of the steers in each pair was less than five pounds. The difference was only 27 pounds in Pair No. 2; and in type, natural fleshing and quality the two steers in this pair were reasonably well matched.

While the total gains were not as large as are expected when calves are full fed together from a common bunk, all the calves in this experiment grew satisfactorily and showed evidence of having put on considerable fat. The average total gain was 32 pounds more for the steers on the high-calcium ration. In each pair, the steer that received ground limestone made a larger gain than his mate.

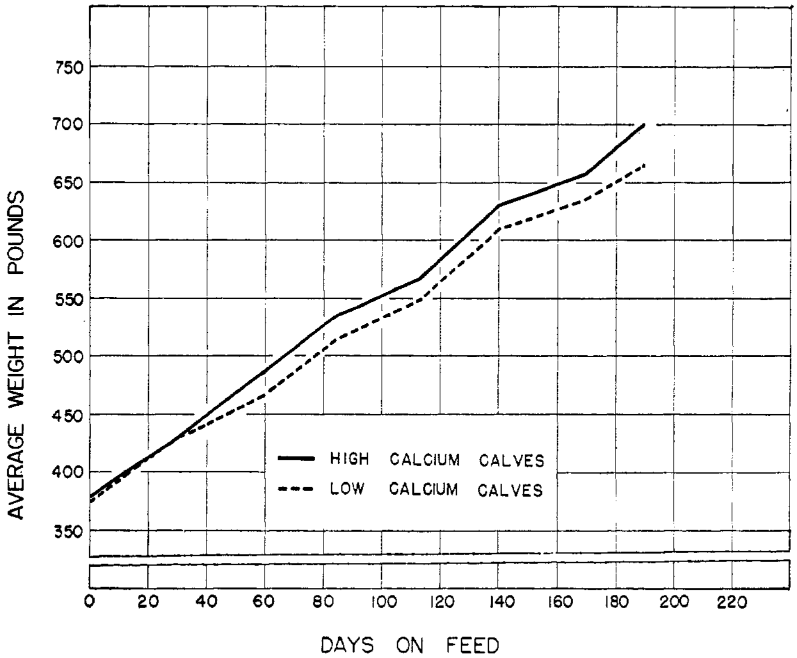
TABLE 14. *The effect of the calcium intake in the nutrition of calves*

Body weights and gains of steers fed in Experiment 2.

Pair No.	Calcium intake.	Body weight.		Total gain.	Daily gain.
		Initial.	Final.		
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
1	Low	342.33	625.00	282.67	1.49
	High	346.33	648.50	302.17	1.59
2	Low	374.00	632.50	258.50	1.36
	High	401.00	715.00	314.00	1.65
3	Low	388.33	693.50	305.17	1.61
	High	386.67	705.00	318.33	1.68
4	Low	389.33	662.50	273.17	1.44
	High	392.00	695.00	303.00	1.59
5	Low	378.33	675.50	297.17	1.56
	High	373.67	727.50	353.83	1.86
6	Low	372.67	691.00	318.33	1.68
	High	368.67	704.00	335.33	1.76
Av.	Low	374.17	663.33	289.17	1.52
	High	378.06	699.17	321.11	1.69

The difference in average daily gain amounted to 0.17 pound. The standard deviation of the average differences was only 0.086 pound, due to the uniformity in the performance of the steers in each group. Odds of 320 to 1 are indicated when "Student's" method is used for analyzing the significance of these differences. It appears reasonably certain, therefore, that the calcium supplement was responsible for the more rapid gains of the steers to which it was fed.

The effect of the calcium intake on the body growth of the calves at different stages of the feeding period is shown in Graph 2. The steers in the two groups gained practically the same during the first 28-day period. During each period thereafter the high-calcium group maintained a distinct advantage in total gain. These growth curves are additional evidence of the uniform performance of the steers as well as of the beneficial effect of the calcium supplement.



GRAPH 2.—The effect of calcium intake on the body growth of calves. (Experiment 2.)

TABLE 15. *The effect of the calcium intake in the nutrition of calves*

Daily feed consumed and feed required for 100 pounds gain in Experiment 2.

Pair No.	Cacium intake.	Feed consumed daily.				Feed required for 100 pounds gain.			
		Corn.	Silage.	Cottonseed meal.	Ground limestone.	Corn.	Silage.	Cottonseed meal.	Ground limestone.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
1	Low	5.89	8.65	1.45	0.00	396.04	581.24	97.20	0.00
	High	5.89	8.65	1.45	0.10	370.49	543.73	90.93	6.29
2	Low	6.40	8.94	1.45	0.00	470.60	657.06	106.29	0.00
	High	6.40	8.94	1.45	0.10	387.42	540.92	87.50	6.05
3	Low	6.40	8.94	1.44	0.00	398.30	556.58	89.95	0.00
	High	6.40	8.94	1.44	0.10	381.84	533.57	86.23	5.97
4	Low	6.55	8.94	1.45	0.00	455.49	621.77	100.58	0.00
	High	6.55	8.94	1.45	0.10	410.64	560.56	90.68	6.27
5	Low	7.23	8.94	1.27	0.00	462.19	571.56	81.18	0.00
	High	7.23	8.94	1.27	0.10	388.18	480.03	68.18	5.37
6	Low	7.04	8.94	1.45	0.00	420.16	533.57	86.31	0.00
	High	7.04	8.94	1.45	0.10	398.86	506.52	81.93	5.67
Av.	Low	6.59	8.89	1.42	0.00	433.80	586.96	93.59	0.00
	High	6.59	8.89	1.42	0.10	389.57	527.56	84.24	5.94

Consumption and Utilization of Feed

An inspection of table 15 shows that both members of each pair received the same amounts of corn, silage, and cottonseed meal. One member of each pair received one-tenth pound ground limestone in addition to the basal feeds.

The amount of corn consumed, 6.6 pounds per head daily on the average, was rather small. If the usual practices followed in group-feeding had been used, the average daily corn consumption would have been at least two pounds more per head daily, assuming that the amounts of the other feeds ingested remained approximately the same. As was pointed out previously, individual feeding definitely lowers feed consumption, particularly in the case of range-bred cattle. Another reason why feed consumption was less than might be expected was the tendency to restrict, somewhat the amount of feed offered in order to avoid the necessity of attempting to account for refused feed. That objective was attained in this experiment as well as in Experiment 1.

The amount of feed offered to a pair of steers was determined by the steer having the poorer appetite. The appetites of individual steers were watched closely and marked variations were noted in the time taken to clean up the feed offered. There was no evidence that the calcium intake had any influence on the appetite.

An examination of the data in table 15 shows that the calves on both levels of calcium intake must be regarded as having made efficient use of the feeds consumed. The low-calcium group used six pounds of ground limestone in producing 100 pounds of gain. On the average, they required 44 pounds less corn, 59 pounds less silage, and 10 pounds less cottonseed meal than the steers on the low-calcium intake to produce 100 pounds of gain. The results may be interpreted as indicating that the use of six pounds of ground limestone with this low-calcium basal ration was responsible for saving corn, silage and cottonseed meal in the amounts listed above.

It appears, therefore, that calcium intake influences the efficiency of food utilization. However, the results considered thus far do not reveal how this is accomplished. The efficiency in terms of feed required for 100 pounds gain was directly proportional to the gains in weight, since the feed consumption of both members of a pair was maintained at the same level. It is also apparent that the statistical significance of the advantage in efficiency of feed utilization is comparable to the advantage in gains held by the high-calcium group.

Calcium Intake Compared With Estimated Requirements

The average daily dry matter intake was considerably lower than the estimated requirement for fattening steers of this weight. It conformed much more closely with the estimated requirement for growing beef steers. Consequently, the comparisons of the calcium and phosphorus contents of the rations fed in this experiment were made with the estimated requirement for growth. (Table 16.)

TABLE 16. *Calcium and phosphorus in the rations fed in Experiment 2 compared with the estimated requirements of growing beef steers.*

	Average body weight.	Dry matter daily.	Feed calcium daily.	Calcium in dry ration.	Feed phosphorus daily.	Phosphorus in dry ration.
	Pounds.	*Grams.*	*Grams.*	*Percent.*	*Grams.*	*Percent.*
Low-calcium group	518	4291	7.2	0.17	20.0	0.47
High-calcium group	539	4336	24.8	0.57	20.0	0.46
Estimated requirements	525	4492	13.1	0.29	12.4	0.28

NOTE: Computations of the estimated requirements are based on the data given in table 8, page 130, Bulletin 99 of the National Research Council by Mitchell & McClure. The water consumption was estimated as 39 pounds per steer daily for each lot. This estimate was based on accurate records obtained in three ten-day periods during the experiment.

As indicated in table 16, the average daily ration of the low-calcium group contained only 7.2 grams of calcium. This was only slightly more than one-half the estimated requirement for calves of this weight, in percent of dry ration as well as in grams. One-tenth pound ground limestone contained 17.6 grams of calcium which, when added to the basal ration, brought the daily calcium intake to 24.8 grams, or 11.7 grams more than the estimated requirement of 13.1 grams.

The data given in table 16 bring out some interesting facts concerning the ratio of calcium to phosphorus in the rations used in this experiment. For the basal ration fed to the low-calcium group, the calcium-phosphorus ratio was only 0.34:1.00. The addition of one-tenth pound ground limestone to the basal ration changed the calcium-phosphorus ratio to 1.24:1.00. The latter ratio compared favorably with that of the estimated requirement, 1.05:1.00, although it should be pointed out in this connection that the amounts of calcium and phosphorus supplied to the high-calcium group were considerably greater than the estimated requirements.

Effect of Rations Upon Carcasses

Feeder, slaughter and carcass grades are given in table 17. The feeder grades indicate that the steers in all pairs were reasonably well matched with the individuals on the low-calcium intake having a slight advantage in feeder quality. This advantage was lost during the feeding period, so that by the time the steers were to be slaughtered, those receiving the calcium supplement were given a higher rating by the three members of the Animal Husbandry

TABLE 17. *The effect of the calcium intake in the nutrition of calves*

Feeder, slaughter and carcass grades, Experiment 2.

Pair No.	Calcium intake.	Feeder grade	Slaughter grade.	Carcass grade.
1	Low	11	19	23
	High	11	19	21
2	Low	13	15	17
	High	10	16	16
3	Low	10	17	16
	High	15	14	15
4	Low	13	20	20
	High	15	17	25
5	Low	16	24	21
	High	15	14	18
6	Low	15	19	15
	High	15	14	15
Av.	Low	13	19	19
	High	14	16	18

NOTE: A description of the grades is given in Table 5.

staff who did the grading. The appearance of these steers, on the average, was distinctly better than their mates. They seemed to be fatter, and it was generally agreed their appearance gave every indication that their carcasses would grade higher than those of steers not receiving the calcium supplement.

The differences which were so apparent on foot could not be recognized in the carcasses. It will be noted from table 17 that while the high-calcium steers averaged slightly higher in carcass grade the differences were of doubtful significance. Photographs also fail to show any differences in the carcasses (figs. 10, 11, and 21, Appendix). The photographs reveal the lack of finish of all the carcasses, this deficiency being quite noticeable over the rounds. The apparent advantages on foot may have been the result of more "bloom" and certain other evidences of greater thrift and growthiness associated with a better state of calcium nutrition.

Body Measurements

Several body measurements were taken at the beginning and close of the experiment, and the results are summarized in tables 18 and 19. There were no appreciable differences in the increase in length of back, width at hips, and width at heart. The steers on the high level of calcium intake showed a geater increase in the height measurements taken at the elbow, shoulders and hips. They also made a larger growth in circumference of the heart and paunch. These results are in line with the increase in body weight and indicate that the low-calcium ration did not supply enough calcium for maximum development.

TABLE 18. *The effect of the calcium intake in the nutrition of calves*

Length of back and height at elbow, shoulders and hips.

Experiment 2.

Pair No.	Calcium intake.	Length of back.		Height at elbow.		Height at shoulders.		Height at hips.	
		Initial.	Final.	Initial.	Final.	Initial.	Final.	Initia.	Final.
		cm.	*cm.*	*cm.*	*cm.*	*cm.*	*cm.*	*cm.*	*cm.*
1......	Low............................	57.4	69.3	60.3	65.4	96.8	109.8	101.2	114.5
	High...........................	56.1	68.7	57.7	61.7	94.2	112.0	102.3	117.5
2......	Low............................	56.1	66.1	59.5	59.7	95.3	107.2	101.7	112.6
	Hgh............................	57.4	71.8	59.3	62.2	97.2	111.1	100.4	115.5
3......	Low............................	61.3	75.7	62.0	55.7	97.8	108.0	103.1	109.4
	High...........................	58.1	73.5	59.5	61.4	100.0	107.7	102.2	114.0
4......	Low............................	58.7	79.8	57.3	63.3	94.7	109.1	101.7	113.2
	High...........................	53.6	77.8	57.7	63.7	97.4	110.8	103.0	117.2
5......	Low............................	58.7	75.0	57.4	64.9	95.9	107.9	103.7	114.6
	High...........................	56.4	76.1	58.6	64.0	101.3	112.6	104.2	119.4
6......	Low............................	63.7	70.0	61.3	64.3	101.5	111.2	105.5	116.6
	High...........................	58.7	64.8	58.5	63.6	98.0	112.7	101.0	116.6
Average..	Low............................	59.3	72.7	59.6	62.2	97.0	108.9	102.8	113.5
	High...........................	56.7	72.1	58.6	62.8	98.0	111.2	102.2	116.7
Increase..	Low............................	....	15.0	....	2.6	....	11.9	....	10.7
	High...........................	....	15.4	....	4.2	....	13.1	....	14.5

TABLE 19. *The effect of the calcium intake in the nutrition of calves*

Width at hips and heart and circumference of body at heart and paunch.

Experiment 2.

Pair No.	Calcium intake.	Width at hips.		Width at heart.		Heart circumference.		Paunch circumference.	
		Initial.	Final.	Initial.	Final.	Initial.	Final.	Initial.	Final.
		cm.	*cm.*	*cm.*	*cm.*	*cm.*	*cm.*	*cm.*	*cm.*
1......	Low............................	32.2	38.8	29.8	37.2	127.3	156.2	150.1	174.4
	High...........................	31.1	40.1	29.7	39.1	130.5	158.1	148.8	182.7
2......	Low............................	31.5	39.1	31.6	38.3	128.5	156.2	150.2	172.2
	High...........................	34.4	43.4	33.0	40.7	134.0	162.7	160.7	186.6
3......	Low............................	33.0	40.0	28.5	37.7	139.9	161.9	152.1	176.0
	High...........................	32.2	40.4	32.0	40.9	133.6	163.2	152.6	185.0
4......	Low............................	31.0	39.8	28.7	39.2	131.7	158.1	150.1	174.9
	High...........................	32.4	39.3	31.0	40.0	131.1	161.3	143.8	169.7
5......	Low............................	32.4	40.8	29.0	40.1	136.1	163.9	148.7	174.8
	High...........................	31.1	41.6	30.4	42.5	132.3	166.6	150.1	190.7
6......	Low............................	32.6	40.6	28.5	40.2	134.8	165.0	153.9	177.1
	High...........................	31.5	41.5	31.5	41.0	133.6	164.8	148.8	182.2
Average..	Low............................	32.2	39.9	29.4	38.8	133.1	160.2	150.8	174.4
	High...........................	32.2	41.1	31.3	40.7	132.7	162.8	151.6	182.8
Increase..	Low............................	....	7.7	....	9.4	....	25.1	....	23.6
	High...........................	....	8.7	....	8.4	....	30.1	....	31.2

TABLE 20. *The effect of the calcium intake in the nutrition of calves*

Dressing percentage and weight of heart, liver, spleen and hide compared to the dressed body weight.

Experiment 2.

Pair No.	Calcium intake.	Dressing percentage.	Percentage of dressed body weight.			
			Heart.	Liver.	Spleen.	Hide.
1	Low...........	57.73	0.66	1.92	0.45	9.55
	High...........	61.16	0.75	1.83	0.35	8.26
2	Low...........	62.56	0.66	1.66	0.36	9.60
	High...........	61.13	0.65	1.68	0.37	8.31
3	Low...........	60.15	0.61	1.59	0.29	9.27
	High...........	62.56	0.56	1.44	0.30	8.77
4	Low...........	62.71	0.62	1.53	0.41	7.75
	High...........	62.19	0.80	1.57	0.38	8.91
5	Low...........	59.42	0.78	1.80	0.44	9.13
	High...........	62.70	0.58	1.62	0.37	8.24
6	Low...........	62.14	0.34	1.52	0.37	8.22
	High...........	61.43	....	1.65	0.40	8.72

Dressing Percentage and Weight of Internal Organs

An inspection of the data given in table 20 shows no differences between the two groups in dressing percentage and weight of heart, liver, spleen and hide. There was some evidence in Experiment 1 to indicate larger livers in the steers fed the basal ration of corn, silage and cottonseed meal without the calcium supplement, but in this experiment, the pairs were evenly divided in this respect and such differences as existed were quite small.

Blood Analyses

The calcium content of the blood serum of the steers used in this experiment is given in table 21. The values are within the range believed to be normal for cattle and there is no indication that the calcium level of the ration influenced the calcium content of the blood.

Similar results were noted with respect to the phosphorus content of the blood serum, table 22. The initial values show more variation than those for subsequent periods. However, the values throughout are normal and show no unusual deviations from normal.

There was some evidence in this experiment, as in Experiment 1, that the less tractable individuals were those on the low-calcium intake. An attempt was made to pair the more nervous individuals. It will be noted from figure 8 that at least one of the steers appeared to be as wild at the close of the experiment as he was at the beginning. His mate also was wild at the beginning but responded better to handling and was quite docile at the close of the trial. Until some method is devised whereby such differences can be

TABLE 21. *The effect of the calcium intake in the nutrition of calves*

Calcium content of the blood serum of steers.

Experiment 2

(*Results expressed in milligrams per 100 c.c. of serum.*)

Pair No.	Calcium level.	Period.								Average.
		Initial.	1.	2.	3.	4.	5.	6.	7.	
1	Low	13.41	11.00	13.05	12.35	11.9	13.42	13.32	10.9	12.42
	High	13.05	10.30	10.05	11.21	11.6	12.01	12.20	10.1	11.33
2	Low	11.33	11.00	12.44	11.97	11.0	12.31	12.42	11.0	11.68
	High	12.87	11.00	11.35	12.45	10.3	11.91	11.98	10.1	11.48
3	Low	12.41	11.40	11.95	11.87	11.3	12.52	14.69	11.7	12.23
	High	13.41	12.90	11.45	11.40	10.7	12.11	13.00	11.8	12.10
4	Low	13.59	9.90	11.85	11.97	10.9	13.31	12.66	11.4	11.95
	High	14.68	11.10	12.15	11.97	10.7	13.43	12.20	11.5	12.22
5	Low	13.69	11.60	11.05	12.16	11.5	12.21	13.21	12.1	12.19
	High	15.59	9.20	11.65	11.87	11.3	11.91	11.41	12.1	11.88
6	Low	12.14	10.90	11.56	11.40	11.3	11.91	13.80	11.0	11.75
	High	13.78	11.60	11.05	11.97	11.3	12.01	10.39	11.4	11.69
Av.	Low	12.76	10.97	11.98	11.95	11.32	12.61	13.35	11.35	12.04
	High	13.90	11.02	11.30	11.81	10.98	12.23	11.86	11.17	11.78

Table 22. *The effect of the calcium intake in the nutrition of calves*

Phosphorus content of the blood serum of steers.

Experiment 2

(Results expressed in milligrams per 100 c.c. of serum.)

Pair No.	Calcium level.	Period.								Average.
		Initial.	1.	2.	3.	4.	5.	6.	7.	
1	Low	8.6	6.6	7.1	8.0	8.3	7.0	8.6	6.8	7.63
	High	10.7	7.3	8.0	8.7	10.0	9.1	10.4	6.4	8.83
2	Low	6.1	6.7	7.1	8.0	8.0	7.5	6.9	6.0	7.04
	High	10.1	8.2	8.5	8.4	8.5	8.6	9.2	8.3	8.73
3	Low	7.5	7.4	6.6	8.0	9.4	7.4	9.8	7.7	7.98
	High	9.8	7.8	7.7	9.2	8.5	7.8	10.4	7.9	8.64
4	Low	10.8	9.1	8.0	10.0	10.9	9.7	11.5	8.7	9.84
	High	10.1	8.6	7.2	8.4	8.7	8.8	8.0	7.7	8.44
5	Low	9.1	7.2	7.3	9.0	9.0	6.9	9.5	8.5	8.31
	High	10.9	7.6	7.9	8.4	9.4	8.4	8.5	8.2	8.66
6	Low	9.2	7.5	7.3	8.0	7.8	7.8	9.2	7.7	8.06
	High	11.1	7.9	8.1	9.9	9.9	7.8	8.1	7.5	8.79
Av.	Low	8.55	7.42	7.23	8.50	8.90	7.72	9.25	7.57	8.14
	High	10.45	7.90	7.90	8.83	9.17	8.42	9.10	7.67	8.68

TABLE 23. *The effect of the calcium intake in the nutrition of calves*

Hemoglobin content of the blood of steers.

Experiment 2

(*Results expressed in milligrams per 100 c.c. of blood.*)

Pair No.	Calcium level.	Period.								Average.
		Initial.	1.	2.	3.	4.	5.	6.	7.	
1	Low	12.49	10.25	12.12	13.40	12.34	13.42	12.50	15.70	12.78
	High	10.79	9.55	10.72	15.00	13.92	14.00	12.95	11.80	12.33
2	Low	9.09	12.12	10.72	14.91	13.92	11.09	8.44	12.89	11.65
	High	14.46	12.12	12.70	16.71	14.39	13.25	13.50	14.20	13.92
3	Low	11.65	11.42	11.45	14.90	13.40	11.46	12.12	13.37	12.47
	High	13.41	10.49	10.95	14.68	14.39	11.18	11.65	11.70	12.31
4	Low	12.71	12.58	12.70	16.56	16.94	13.53	13.50	13.48	14.00
	High	13.52	14.56	15.49	17.33	17.94	15.05	13.35	15.10	15.29
5	Low	13.63	14.56	12.93	16.89	14.28	12.11	11.65	13.93	13.75
	High	10.68	9.90	9.32	12.00	12.00	10.47	11.65	12.70	11.09
6	Low	11.20	9.90	9.55	12.30	11.49	10.32	10.30	13.82	11.11
	High	13.76	12.12	12.23	14.67	12.00	11.41	10.70	14.89	12.72
Av.	Low	11.80	11.81	11.58	14.83	13.73	11.99	11.42	13.87	12.63
	High	12.76	11.46	11.90	15.07	14.11	12.56	12.30	13.40	12.94

measured and recorded, conclusions are not justified with reference to the effect of the calcium intake on the nervous stability of fattening calves. The observations made in these experiments suggest, however, that a study of the matter might yield interesting and valuable information.

Because the preliminary studies made in Experiment 1 indicated the possibility of an inverse relationship between the calcium content of the ration and the hemoglobin content of the blood, determinations of blood hemoglobin were made at regular intervals in this experiment. The results are given in table 23 and indicate no relationship whatsoever between the calcium intake of the rations used and the hemoglobin content of the blood. The highest values were recorded for the third period, the samples being taken on February 13. There is a possibility that the increase at this time was caused by the seasonal influences. However, if the hemoglobin level tends to rise during the winter months, it would seem that the increase would have been noted earlier.

Effect of Rations Upon the Bones

Physical measurements on two leg bones, humerus and femur, and two ribs, fifth and thirteenth, from each carcass included weight, specific gravity and breaking pressure. The data are given in table 24. Twenty-four comparisons were made with the six pairs of steers in respect to weight of bones, and in 22 cases the heavier bone was taken from the steer on the high calcium intake. In 21 out of the 24 paired observations, higher specific gravity values were recorded for the bones from the high-calcium group. Likewise the breaking pressure indicated significant differences in the bones of the two groups, with the high-calcium steers having the advantage in 21 of the 23 comparisons. Thus the differences in physical measurements were rather consistently in favor of the high-calcium group and indicate definitely that the basal ration containing only 7.2 grams of calcium (0.17 percent of the dry ration) was inadequate for maximum skeletal development.

The results of the chemical analyses given in table 25 also show that the addition of ground limestone to the basal ration was responsible for a better state of calcium nutrition. The ash content of the bones of the high-calcium steers averaged 2.66 percent more than that of the low-calcium individuals. The standard deviation of the differences is 1.41 and "Student's" Z value 1.9. With N=6 and Z=1.9 the odds are 243 to 1 that the mean difference was not due to chance.

TABLE 24. *The effects of the calcium intake in the nutrition of calves*

Weight, specific gravity, and breaking strength of the leg and rib bones.

Experiment 2

Pair No.	Calcium intake.	Bones.	Weight.	Specific gravity.	Breaking strength.
			Grams.		*Pounds.*
1	Low	Humerus	1055	1.234	1405
		Femur	1343	1.218	2145
		5th rib	118	1.204	235
		13th rib	81	1.328	240
	High	Humerus	1115	1.268	1545
		Femur	1507	1.258	2940
		5th rib	129	1.066	235
		13th rib	67	1.288	270
2	Low	Humerus	987	1.243	2280
		Femur	1313	1.236	2455
		5th rib	127	1.210	215
		13th rib	65	1.250	230
	High	Humerus	1131	1.293	4290
		Femur	1493	1.209	3180
		5th rib	125	1.344	260
		13th rib	83	1.431	430
3	Low	Humerus	1068	1.225	1975
		Femur	1313	1.225	....
		5th rib	145	1.208	210
		13th rib	50	1.282	130
	High	Humerus	1070	1.329	3570
		Femur	1443	1.316	3815
		5th rib	131	1.351	230
		13th rib	58	1.450	215
4	Low	Humerus	1052	1.242	1275
		Femur	1432	1.303	3460
		5th rib	129	1.240	160
		13th rib	39	1.182	120
	High	Humerus	1278	1.286	2585
		Femur	1670	1.290	3435
		5th rib	138	1.327	350
		13th rib	85	1.441	350
5	Low	Humerus	1115	1.236	2690
		Femur	1443	1.222	2910
		5th rib	142	1.203	205
		13th rib	93	1.274	175
	High	Humerus	1173	1.295	3135
		Femur	1470	1.277	2975
		5th rib	151	1.325	455
		13th rib	103	1.392	260
6	Low	Humerus	1132	1.215	2320
		Femur	1367	1.210	2225
		5th rib	130	1.215	180
		13th rib	62	1.240	135
	High	Humerus	1049	1.298	4010
		Femur	1418	1.285	3470
		5th rib	131	1.310	230
		13th rib	84	1.424	290
Av.	Low	Humerus	1068.1	1.233	1990.8
		Femur	1368.5	1.236	2199.2
		5th rib	135.2	1.213	199.2
		13th rib	65.0	1.259	171.6
	High	Humerus	1136.0	1.295	3189.2
		Femur	1500.2	1.272	3302.5
		5th rib	134.2	1.287	293.3
		13th rib	80	1.404	302.5

TABLE 25. *The effect of the calcium intake in the nutrition of calves*

Ash, calcium, and phosphorus in the dry, fat-free bones, Experiment 2.

Pair No.	Calcium intake.	Ash.	Calcium.	Phosphorus.
		Percent.	*Percent.*	*Percent.*
1	Low	56.58	20.93	10.72
	High	56.71	20.88	10.65
2	Low	55.18	20.38	10.34
	High	57.83	21.66	10.98
3	Low	57.24	21.29	10.67
	High	58.97	21.94	11.06
4	Low	54.81	20.80	10.49
	High	58.49	21.68	11.06
5	Low	55.83	20.51	10.63
	High	59.11	21.66	11.10
6	Low	53.74	19.98	10.49
	High	58.20	21.67	10.96
Av.	Low	55.56	20.65	10.56
	High	58.22	21.58	10.97

Digestion and Mineral-Balance Trials

Following the 190-day feeding period in Experiment 2, digestion and mineral-balance trials were conducted with three pairs of steers. The chief basis for the selection of the steers to be used in these trials was the disposition of the steers themselves. Thus the three pairs selected were the most docile steers in the experiment. It was felt that quiet individuals that could be handled easily would soon become accustomed to the harness and other equipment that were to be used. Such proved to be the case, and no difficulty was experienced with any of the steers.

General Routine and Procedure

That the steers were reasonably comfortable and contented is illustrated in figure 3. It will be noted from these pictures that the steers could lie down in a comfortable position. As a matter of fact, they had become so well accustomed to the harness in the training period prior to the digestion and balance-trials that only minor adjustments of the harness and other equipment were necessary while the trials were in progress. Six stalls used during the regular feeding period were converted into metabolism stalls. The feces and urine were collected in a basement room (fig. 2). The conversion of the regular stalls into a unit suitable for metabolism studies was easily accomplished. Square pieces of boiler plate sealed in the gutter were removed so that the feces could drop directly from the feces bags into cans used for collection in the basement. Threaded plugs were removed from the floor, providing an outlet to the basement for the rubber hose used in collecting the urine.

The feed intake during the trials was maintained at a level established during the preliminary period. Previously, the rations had been adjusted so as to obtain complete consumption of the feeds. The same daily ration was supplied to Pairs 2 and 3, and the amounts of silage and cottonseed were also the same for Pair No. 6. The corn allowance for this pair was adjusted at a lower level than for the other pairs, however, in order to insure complete consumption of the ration. The similarities in the amounts of the different feeds in the rations of the three pairs of steers lessened the chances for error in the actual weighing of each day's feed.

Sufficient amounts of corn, cottonseed meal, ground limestone and salt for these trials were set aside at the outset of the experiment. A uniform sample of each was secured for analysis at the beginning of the digestion and balance trials. Furthermore, the supply of each feed set aside at the outset to be used in the digestion and balance trials was itself a sample of a much larger supply used during the regular 190-day feeding experiment. Therefore, the chemical composition of the corn, cottonseed meal, ground limestone and salt used in the digestion and balance trials and in the regular experiment was the same.

It was manifestly impossible to follow this procedure in the case of silage. The silage used in the ten-day trials and in the regular feeding period was from the same silo, but could not be assumed to be of the same chemical composition. During the regular 190-day feeding trial, samples of silage were taken each week, weighed before and after drying and stored in a closed, dry container. The composite sample was analyzed at the conclusion of the feeding period. The same general procedure was followed in sampling the silage used during the digestion trials except that the samples were taken daily instead of once each week. The analyses of the feeds used during the ten-day balance trial are given in table 26.

Attendants were on duty 24 hours each day. The steers were fed at 6:30 a. m. and 6:30 p. m. Collections of urine and feces were started at 2 p. m. the first day and discontinued at that hour on the last day of the trials. The feces and urine were weighed and sampled beginning at 2 p. m. each day. Prior to this at 1 p. m., the feces bags were removed and feces adherring thereto removed and placed with the day's collection. While this was being done the steers were curried and brushed and adjustments, if necessary, made in the harness. The stalls were also swept at this time.

On the fourth day of the trials, the low-calcium steer in Pair No. 2 and the high-calcium steer in Pair No. 3 were observed to urinate while lying down. A small but insignificant amount of urine was lost because the rubber funnels were not in the proper position to direct all of the urine to the containers in the basement. As a precautionary measure following this observation, all of the steers were made to get up every one and one-half hours whenever they did not do so of their own accord. There were no further losses of urine.

TABLE 26. *The effect of the calcium intake in the nutrition of calves*

Analyses of feeds, Experiment 2.

FEED CONSTITUENT.	Water.	Crude protein.	Ether extract.	Crude fiber.	N-free extract.	Ash.	Calcium.	Phosphorus.
	Percent.	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*
Atlas sorgo silage	74.32	2.19	0.83	6.32	14.58	1.75	0.067	0.033
Cottonseed meal	7.44	44.94	6.77	10.41	23.59	6.85	0.200	1.290
Corn	12.21	11.88	4.15	2.15	68.06	1.55	0.020	0.325
Ground limestone	....	....	....	....	....	....	38.650	0.008
Salt	....	....	....	....	....	....	1.018	0.000
Water	....	....	....	....	....	....	0.0024	0.000

At the beginning of these trials, there was no bedding or padding of any kind on the concrete floors of the stalls. The steers' hoofs wore off considerably as the trials progressed, but there appeared to be no discomfort from this cause except in the case of the high-calcium steer of Pair No. 6. His ankles became swollen and it appeared painful for him to get up and down. The situation was helped considerably by fastening several pieces of heavy burlap to wooden frames on the floor. This burlap mat stayed in place and seemed to make both members of Pair No. 6 more comfortable.

Metal pans shaped to fit the mangers were used in watering the steers. The water left was weighed back each morning to insure a fresh supply. Water was available to the steers at all times except when they were eating.

Body Weights and Feed Consumed

The weights of the steers and the amount of feed consumed during the digestion and balance trials are shown in table 27. Each steer lost a few pounds during the ten-day period, the amounts ranging from 5 to 15 pounds. In general, it may be said that all of the steers came through the trial in good condition.

There was considerable variation in the amount of water drunk by the different steers, but nothing to indicate that the calcium intake is related in any way to the question of thirst. In two of the pairs, the steer on the high calcium intake drank more water than the steer with which he was paired, but the reverse was true in the case of the third pair.

Both members of each pair were given the same amounts of the different feed constituents and there was no refused feed to weigh back.

TABLE 27. *The effect of the calcium intake in the nutrition of calves*

Body weights and total feed consumed during the ten-day balance trial.

Experiment 2

Pair No.	Calcium level.	Weight at start.	Weight at close.	Total feed consumed.					
				Silage.	Cottonseed meal.	Corn.	Ground limestone.	Salt.	Water.
		Pounds.	*Pounds.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
2	Low	635	625	27216	6804	31751	....	284	142070
	High	715	710	27216	6804	31751	450	284	183455
3	Low	695	680	27216	6804	31751	....	284	176475
	High	705	690	27216	6804	31751	450	284	252935
6	Low	695	680	27216	6804	34019	....	284	159605
	High	705	690	27216	6804	34019	450	284	136197

TABLE 28. *The effect of the calcium intake in the nutrition of calves*

Analyses of the feces voided during the ten-day balance trial.

Experiment 2

Pair No.	Calcium level.	Amount voided.	Water.	Crude protein.	Ether extract.	Crude fiber.	N-free extract.	Ash.	Calcium.	Phosphorus.
		Grams.	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*
2	Low....................	46007	78.13	4.96	1.03	3.48	10.94	1.46	0.069	0.127
	High...................	46758	81.26	4.01	0.95	3.11	9.59	2.08	0.281	0.203
3	Low....................	44652	79.62	4.70	0.98	3.49	9.67	1.53	0.066	0.141
	High...................	42848	77.28	4.96	0.90	3.51	11.27	2.08	0.308	0.208
6	Low....................	50897	77.78	5.17	0.87	3.28	11.51	1.39	0.051	0.113
	High...................	48643	78.83	4.50	0.84	3.08	10.95	1.80	0.259	0.186

Weight and Composition of Feces and Urine

An examination of the data given in table 28 shows some variation in the weight of feces voided by the different steers, but it, does not appear that the calcium intake was responsible for the differences. The moisture content of the feces likewise was quite uniform, ranging only from 78 to 81 percent. The most striking differences shown by these analyses are in percentages of ash, calcium and phosphorus. The ash content of the feces of the calves on the low-calcium intake ranged only from 1.39 percent to 1.53 percent, compared with a range of 1.80 to 2.08 percent for those on the high-calcium intake. Similarly the percentage of the calcium in the feces was significantly greater for the high-calcium steer of each pair. Thus from these data it would seem that a considerable portion of the calcium supplement added to the basal ration was voided in the feces. It is also interesting to note that, on a percentage basis, the feces of the steers on the high-calcium level were also higher in phosphorus. It is obvious, of course, that the value of the data given in table 28 lies chiefly in connection with the calculation of digestion coefficients and balances of calcium and phosphorus. They are presented in this paper primarily for that purpose and as a matter of record.

The percentages of calcium and phosphorus in the urine and the amounts of urine voided are given in table 29. A comparison of the

TABLE 29. *The effect of the calcium intake in the nutrition of calves*

Analyses of the urine voided during the ten-day balance trial.

Experiment 2

Pair No.	Calcium level.	Amount.	Calcium.	Phosphorus.	Nitrogen.
		Grams.	*Percent.*	*Percent.*	
2	Low............	62525	0.0015	0.1440	0.799
	High............	112139	0.0037	0.0283	0.494
3	Low............	101578	0.0028	0.0850	0.531
	High............	186342	0.0017	0.0190	0.275
6	Low............	77148	0.0014	0.1390	0.631
	High............	51850	0.0022	0.0436	0.944

amounts of urine voided with the water intake (table 27) shows a close relationship, as would be expected under normal conditions such as prevailed in these trials. Here again the analyses are necessary in the calculations that are to follow, but in themselves are not particularly significant, especially in view of the large difference in the amount of urine voided.

Retention of Calcium and Phosphorus

The calculations just referred to are summarized in table 30. The calcium and phosphorus intakes are compared with the amounts excreted in the urine and feces, and the amount of each element retained is also shown in the table. It will be noted that the average calcium intake for the ten-day period was only 45 grams for the

TABLE 30. *The effect of the calcium intake in the nutrition of calves*

Calcium and phosphorus balances during the ten-day trial.

Experiment 2

Pair No.	Calcium level.	Calcium.				Phosphorus.			
		Intake.	Excreted.		Retained.	Intake.	Excreted.		Retained.
			Urine.	Feces.			Urine.	Feces.	
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
2	Low	44.49	0.94	31.74	11.81	199.94	90.03	58.43	51.48
	High	219.41	4.15	131.39	83.87	199.98	31.73	94.92	73.33
3	Low	45.32	2.84	29.56	12.92	199.94	86.34	62.74	50.86
	High	221.08	3.17	131.97	85.94	199.98	35.40	89.12	75.46
6	Low	45.36	1.08	25.96	18.32	207.31	107.24	57.51	42.56
	High	218.73	1.14	125.99	91.60	207.35	22.61	90.48	94.26
Av.	Low	45.04	1.62	29.09	14.35	202.39	94.53	59.56	48.30
	High	219.74	2.82	129.78	87.14	202.43	29.91	91.31	81.02

"lows'' while it was 220 grams for the "highs." The calcium intake of each individual was very close to the average intake for his particular group.

The amounts of calcium excreted in the feces are also within a very narrow range, averaging 29 grams for the lows and 130 grams for the highs. Only very small amounts of calcium were excreted in the urine and in each pair the larger amount was excreted by the steer on the high-calcium intake. The average amounts were 1.6 grams for the lows and 2.8 grams for the highs.

All six steers were in positive calcium balance and consistent differences were observed in the amounts retained. The average retention of calcium for the ten-day period was 14.35 grams for the low-calcium group, while it was six times that amount or 87.14 grams for the high-calcium group. Despite the fact that there are only three pairs of observations, the differences are so uniformly consistent that with "Student's" method the probability is 0.9998, which means odds of almost 5,000 to 1 that the mean difference was not due to chance. Hence, while the data are admittedly few, the uniformity of the values obtained suggest strongly that the retention of calcium was increased significantly when one-tenth pound finely ground limestone was added to the basal ration of ground shelled corn, silage and cottonseed meal.

The phosphorus intake was also the same for both members of each pair, the average being 202.4 grams per steer. It will be noted from table 30 that in each pair less phosphorus was excreted in the feces by the low than the high-calcium steer. On the other hand, just the reverse was true for the amount of phosphorus excreted in the urine. Here again reasonably consistent values for the ten-day period were obtained, the average being 95 grams for the low-calcium group and 30 grams for those on the high-calcium intake.

The higher retention of calcium by the steers receiving the calcium supplement seemed to be associated in each pair with a higher retention of phosphorus. The variation in the differences were sufficiently great, however, that odds of only 23 to 1 that the mean difference was not due to chance are indicated from calculations by the method of "Student."

Coefficients of Digestibility

The amounts of the different nutrients consumed, voided, and apparently digested together with the coefficients of digestibility are given in table 31. It will be observed that the digestion coefficients for the crude protein ranged from 65.81 percent to 74.75 percent, which indicates reasonably efficient utilization of this nutrient. In two of the pairs the steer on the high-calcium intake had the higher coefficient of digestibility for crude protein, while in the other pair the low-calcium steer held a slight advantage. In each pair, the steer on the high-calcium intake had higher coefficients of digestibility for ether extract and crude fiber than did the steer on the low-calcium intake with which he was paired. Calculated in accordance with "Student's" method, the probabilities are .9808 and .9615 that the mean difference in the coefficients of

TABLE 31. *The effect of the calcium intake in the nutrition of calves*

Amounts of the different nutrients consumed, voided and apparently digested by each steer during the ten-day trial.

Experiment 2

Pair No.	Calcium level.	Crude protein.	Ether extract.	Crude fiber.	N-free extract.
Nutrients consumed (grams)					
2	Low	7425.77	2004.19	3111.00	27182.88
	High	7425.77	2004.19	3111.00	27182.88
3	Low	7425.77	2004.19	3111.00	27182.88
	High	7425.77	2004.19	3111.00	27182.88
6	Low	7695.21	2098.31	3159.76	28726.48
	High	7695.21	2098.31	3159.76	28726.48
Nutrients voided in feces (grams)					
2	Low	2281.95	473.87	1601.04	5033.17
	High	1875.00	444.20	1454.17	4484.09
3	Low	2098.64	437.59	1558.35	4317.85
	High	2125.26	385.63	1503.96	4826.97
6	Low	2631.37	442.80	1669.42	5858.24
	High	2188.94	408.60	1498.20	5326.41
Nutrients apparently digested (grams)					
2	Low	5143.82	1530.32	1509.96	22149.71
	High	5550.77	1559.99	1656.83	22698.79
3	Low	5327.13	1566.60	1552.65	22865.03
	High	5300.51	1618.56	1607.04	22353.91
6	Low	5063.84	1655.51	1490.34	22868.24
	High	5506.27	1689.71	1661.56	23400.07
Coefficients of digestibility (percent)					
2	Low	69.25	76.36	48.54	81.48
	High	74.75	77.84	53.26	83.50
3	Low	71.74	78.17	49.91	84.12
	High	71.38	80.76	51.66	82.24
6	Low	65.81	78.90	42.17	79.61
	High	71.55	80.53	52.59	81.46

digestibility for ether extract and crude fiber, respectively, are not due to chance variations. Therefore, in view of the limited number of animals concerned, it is doubtful if any significance can be attached to the differences in the coefficients of digestibility for these two nutrients. Particularly is this true since Evans *(32)* reported no enhanced effect on the digestibility of the nutrients on adding calcium carbonate to a swine ration markedly deficient in lime. Also, Woodman and Evans *(93)* found that the digestibility of forage by sheep is not influenced by a deficiency in calcium and phosphorus.

RESULTS OBTAINED IN EXPERIMENT 3

Experiment 3 was started November 22, 1938, and closed June 10, 1939. Two lots, each consisting of ten Hereford steer calves, were used (fig. 14, Appendix). Both lots were group-fed. The study was undertaken to check the results obtained in the two paired feeding experiments, particularly with reference to the effect of the calcium intake on growth and carcass quality. In addition, this experiment afforded an opportunity to study the effect of the calcium intake on the appetite.

Feeds similar to those fed in Experiment 2 were used in this experiment. As a matter of fact, the silage, corn and ground limestone were exactly the same. The cottonseed meal was from another source, but differed little in composition from that used in Experiment 2. The analyses of the feeds used in this study are given in table 32.

One group of steers received ground shelled corn, Atlas sorgo silage and cottonseed meal, while the other group received these basal feeds plus one-tenth pound finely ground limestone per head daily. Silage was full fed throughout the entire experiment, but the amount decreased as the amount of corn was increased. Both groups were started on one pound of ground shelled corn per head daily. Increases of one pound per head daily were made every five to seven days, and on the fiftieth day both groups were given free access to ground shelled corn in self-feeders. From that time on, both groups received the same amounts of silage and cottonseed meal. Thus if the calcium intake was to have any influence on the appetite, it would show up in the amount of corn consumed, since the steers were given an opportunity to consume as much of this feed as they wished.

Both groups were fed in an open shed (fig. 14). Water meters were installed so that an accurate record could be kept of the amount of water drunk. No bedding was used in order to avoid the possibility of materials being consumed that were not included in the experiment. The lack of bedding material such as straw had no influence on the comfort of the steers, since the shed was dry most of the time and the weather was reasonably mild.

TABLE 32. *Analyses of the feeds used in the study of the effect of the calcium intake in the nutrition of calves*

Experiment 3

(Group feeding)

FEED CONSTITUENT.	Water.	Crude protein.	Ether extract.	Crude fiber.	N-free extract.	Ash.	Calcium.	Phosphorus.
	Percent.	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*
Atlas sorgo silage	73.45	2.35	0.66	6.84	14.81	1.89	0.122	0.050
Cottonseed meal	6.61	43.25	6.52	10.86	26.40	6.36	0.196	1.327
Ground shelled corn	12.21	11.88	4.15	2.15	68.06	1.55	0.020	0.325
Ground limestone	....	....	....	....	....	....	38.650	0.008
Water	....	....	....	....	....	....	0.0024	....

Body Weights and Gains

Weights, gains and dressing percentages are given in table 33. It will be observed that the average daily rations were virtually the same, despite the fact that corn was self-fed after the fiftieth day. It was quite apparent in this experiment, as in the two paired feeding experiments, that the calcium intake has no effect on the appetites of the steers.

TABLE 33. *The effect of the calcium intake in the nutrition of calves*

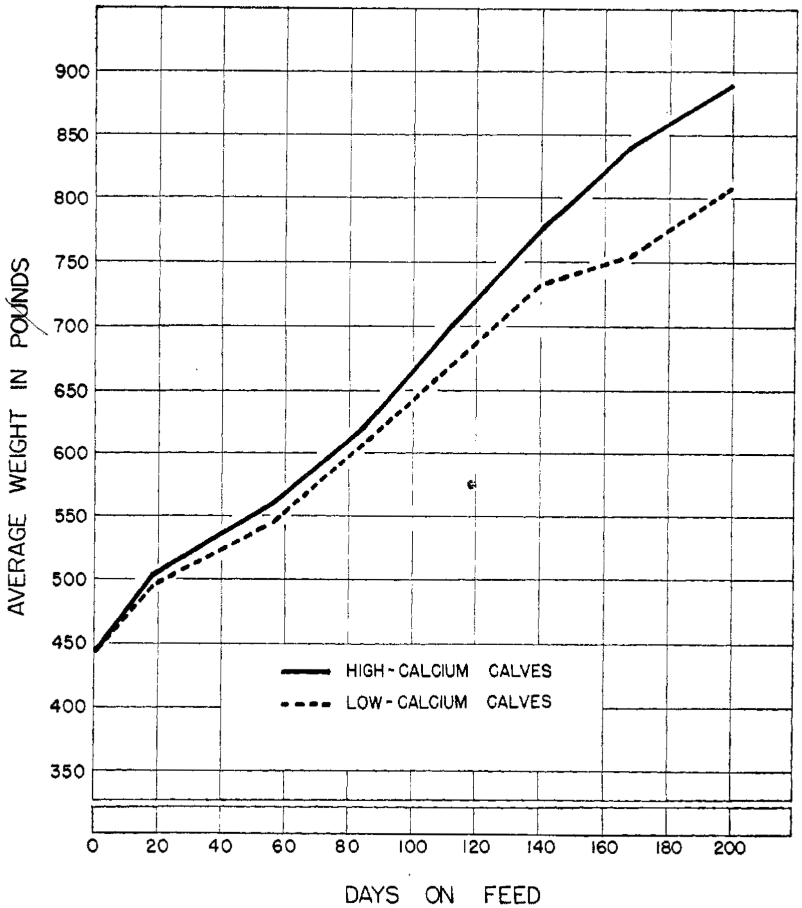
Weights, gains and dressing percentages in Experiment 3.

Lot number	1	2
Number of steers in lot	10	10
	Pounds.	*Pounds.*
Initial weight	440.67	440.00
Final weight	812.00	886.75
Total gain	371.33	446.75
Daily gain	1.86	2.23
Average daily ration:		
Ground shelled corn	10.66	10.63
Atlas sorgo silage	11.19	11.21
Cottonseed meal	1.42	1.43
Ground limestone	0.00	0.10
Water	40.91	40.29
Feed per 100 lbs. gain:		
Ground shelled corn	573.94	475.93
Atlas sorgo silage	602.83	501.73
Cottonseed meal	76.43	63.49
Ground limestone	0.00	4.49
	Percent.	*Percent.*
Dressing percentage	62.60	62.70
Selling price per cwt	$10.00	$10.50

The low-calcium steers drank 0.6 pound more water per head daily than the high-calcium steers. This difference is so small that it is believed not to be significant.

The amounts of corn consumed in this experiment demonstrate conclusively that when steers are full fed in groups without disturbing influences, they consume much more feed than when fed individually.

The steers in both groups averaged 440 pounds at the beginning of the test and were continued on feed for a period of 200 days. The steers in Lot 2, fed the calcium supplement, made larger gains from the beginning than those in Lot 1 fed the basal ration only (Graph 3).



GRAPH 3.—The effect of calcium intake on the body growth of calves. (Experiment 3.)

Consumption and Utilization of Feed

The steers in Lot 2 made an average daily gain of 2.23 pounds, while those in Lot 1 gained only 1.86 pounds per head daily. This difference of 0.37 pound in the average daily gain is particularly significant in view of the fact that approximately the same amount of feed was ingested by both groups. Manifestly, therefore, the steers getting the calcium supplement utilized their feed more efficiently than did those fed only corn, silage and cottonseed meal. An examination of the data given in table 33 shows that Lot 2 required 4.49 pounds of ground limestone to produce 100 pounds of gain, yet this small amount apparently was responsible for lowering the feed required for 100 pounds of gain by the following amounts: Ground shelled corn, 98 pounds; silage, 101 pounds; and cottonseed meal, 13 pounds.

Both groups were in vigorous, thrifty condition at the close of the experiment. The steers in Lot 2, however, appeared thicker and somewhat fatter and had noticeably more "bloom" than those in Lot 1. Some observers were also of the opinion that Lot 2 was heavier boned than Lot 1. These apparent advantages resulted in a higher selling price for Lot 2 when the groups were sold separately on the Kansas City market.

These apparent advantages shown by Lot 2 are also reflected in the slaughter grades listed in table 34, although it will be noted that on foot, each group was graded choice on the average, but with Lot 2 having the advantage.

Effect of Rations Upon the Carcasses

There was no difference in the dressing percentages of the two groups (table 33). Nor was there any difference in the grades placed on the carcasses by two official government graders stationed at Kansas City (table 34). The differences which were so apparent on

TABLE 34. *Slaughter and carcass grades of steers used in Experiment 3.*

Steer No.	Total gain (Pounds).	Grades.	
		Slaughter.	Carcass.
Lot 1, low calcium			
46	456.67	9.3	14.0
51	342.50	11.3	12.0
63	340.00	15.3	12.0
73	344.17	12.0	14.0
97	385.83	8.0	12.0
98	375.83	11.3	12.0
105	373.33	11.3	12.0
125	378.33	13.3	12.0
132	376.67	13.3	14.0
134	330.00	12.0	14.0
Average	371.33	11.7	12.8
Lot 2, high calcium			
43	434.17	10.3	10.0
49	392.50	12.0	16.0
67	475.00	12.0	14.0
81	471.67	10.0	14.0
89	438.33	9.3	12.0
90	420.00	12.0	14.0
103	494.17	8.0	12.0
117	355.00	13.3	12.0
144	440.00	10.0	8.0
147	546.67	8.0	16.0
Average	446.75	10.5	12.8

NOTE: The slaughter grades are the average of the grades placed on the steers at the close of the experiment by three members of the Department of Animal Husbandry, Kansas State College. The carcasses were graded by two official government graders stationed at Kansas City. A description of the grades is given in table 5.

foot could not be recognized in the carcasses. Authorities on dressed beef stated emphatically that if the carcasses of Lots 1 and 2 were mixed together, beef experts could not, sort, them into their respective lots.

The similarity in the grades of the carcasses of these lots and the fact that, the dressed yields were virtually the same, prompted Armour's head beef man to say that there was no difference in the two lots, of cattle, and instead of having been purchased at $10 and $10.50 per cwt., each lot should have been purchased at $10.25 per cwt.

Thus the carcass studies did not reveal the differences for the significantly greater gains made by Lot 2, fed the calcium supplement. Perhaps the calcium supplement was responsible for heavier bones and greater muscular development and these account for the striking differences on foot.

Calcium Intake Compared With the Estimated Requirements

On the basis of the estimated requirements for fattening beef steers it can be seen by referring to table 35 that the ration fed Lot 1, the low-calcium group, was deficient in calcium.

The dry ration fed to this group contained only 8.9 grams of calcium, while the estimated requirement for fattening steers of this weight is 18.6 grams. The calcium-phosphorus ratio of this basal ration was 0.33:1 and for a ration conforming to the estimated requirements, 1.15:1. Adding one-tenth pound ground limestone to the basal ration (Lot 2) raised the calcium level to 26.4 grams. This was considerably more than the estimated requirement for calcium, but since the phosphorus content of the basal ration was high, the calcium-phosphorus ratio of the ration fed to Lot 2, the high-calcium group, was approximately 1:1, or very nearly the same as that of a ration conforming to the estimated requirements.

Blood Analyses

The blood of these steers was analyzed for calcium, phosphorus and hemoglobin at the beginning of the experiment and again at the close. The results of these analyses are given in table 36. All of the final values were higher than those at the beginning. However, the situation is the same in both lots and there was no indication that the calcium level of the ration had any effect. It is not clear why the values for the phosphorus, calcium and hemoglobin of the blood showed the slight increases observed in this experiment.

TABLE 35. *Calcium and phosphorus in the rations fed in Experiment 3 compared with the estimated requirements of fattening beef steers*

	Average body weight.	Dry matter daily.	Feed calcium daily.	Calcium in dry ration.	Feed phosphorus daily.	Phosphorus in dry ration.
	Pounds.	*Grams.*	*Grams.*	*Percent.*	*Grams.*	*Percent.*
Low-calcium group	627	6194	8.9	0.14	26.8	0.43
High-calcium group	664	6234	26.4	0.42	26.8	0.43
Estimated requirements	650	6738	18.6	0.28	16.2	0.24

NOTE: Computations of the estimated requirements are based on the data given in table 9, page 131, Bulletin 99 of the National Research Council by Mitchell and McClure.

GENERAL DISCUSSION OF RESULTS

The results of the three experiments will be brought together at this point and considered as a whole in order to pave the way for the summary and conclusions that are to follow.

Consumption of Feed

In this study with calves there was no indication that the level of calcium intake had any effect on the appetite. A definite check on this point was not possible in Experiments 1 and 2, since the paired-feeding method was used and, as a consequence, both members of a pair received the same amount of feed. However, careful observations were made as to the time required by the members of the different pairs to clean up their feed. There appeared to be no difference in this respect. Nor was there any evidence that the low-calcium intake made it more difficult to keep the steers on feed.

Experiment 3 afforded a better opportunity to study the effect of the rations on feed consumption because the ground shelled corn was self-fed to both lots. Consequently, the amount of corn consumed

TABLE 36. *The effect of the calcium intake in the nutrition of calves*

Analyses of the blood of the steers used in Experiment 3.

Steer No.	Phosphorus *Mg–100 c.c.*		Calcium *Mg–100 c.c.*		Hemoglobin *Gm–100 c.c.*	
	Initial.	Final.	Initial.	Final.	Initial.	Final.
Lot 1, low calcium						
46	10.3	7.47	10.0	11.0	11.77	13.68
51	9.6	8.28	9.9	9.8	11.18	13.48
63	7.8	7.65	11.0	11.0	10.72	12.86
73	9.0	8.28	10.8	11.0	12.35	12.11
97	8.4	7.74	10.8	11.5	11.18	13.48
98	9.0	8.10	10.6	10.5	12.35	13.40
105	9.2	6.39	11.0	12.2	11.77	13.18
125	9.5	8.73	10.4	10.7	13.05	15.72
132	9.6	7.38	10.6	12.2	12.23	13.51
134	9.1	7.83	10.6	11.2	13.75	16.08
Average	9.2	7.79	10.7	11.1	12.04	13.75
Lot 2, high calcium						
43	10.4	8.37	10.0	11.0	13.75	14.01
49	9.7	7.56	11.3	12.2	12.34	15.91
67	9.7	8.37	11.3	11.4	12.35	15.50
81	8.8	7.65	11.3	11.7	13.98	14.50
89	10.0	9.18	10.8	12.6	13.86	15.50
90	9.7	7.74	11.6	11.7	12.82	14.29
103	10.0	6.84	11.4	11.3	12.47	13.12
117	8.5	7.47	11.0	11.0	14.45	14.15
144	8.0	7.11	10.4	11.9	9.55	12.86
147	7.6	8.01	10.7	11.0	12.00	15.09
Average	9.2	7.83	11.0	11.6	12.76	14.49

was determined by the appetites of the steers. Virtually the same amount of corn was consumed by both lots, which confirmed the observations made in Experiments 1 and 2 that the calcium levels of these rations had no effect upon the appetites of the steers. While the low-calcium steers drank slightly more water than the high-calcium steers, the difference is so small that it is believed not to be significant.

The significance of these results with respect to consumption of feed becomes more apparent when it is realized that the low-calcium rations represent about as low a level of calcium intake as is likely to be encountered under usual conditions of fattening calves. In Experiments 1, 2, and 3, the calcium intake was 11.0, 7.2, and 8.9 grams per calf daily. Lower levels of calcium intake might affect the appetites of fattening calves and hence lower feed consumption, but it would not be easy to select a ration consisting of natural feeds that would contain appreciably less calcium than was contained in the rations used in these experiments.

These results are in agreement with those found in the literature. Workers in this field do not appear to have regarded loss of appetite as one of the important effects of feeding low-calcium rations. Fairbanks and Mitchell *(35),* however, observed that very low levels of calcium in the diet had an effect on the appetite of rats. Evans *(34)* observed that sows fed low-calcium rations suffered periodically from loss of appetite. The reports of these workers suggest that a similar effect might be encountered with the use of calf-fattening rations extremely low in calcium. However, the results of the study reported in this paper indicate definitely that for a ration to have such an effect, it would have to consist of feeds lower in calcium than corn, silage, and cottonseed meal.

Growth

The calves fed the calcium supplement made larger gains, on the average, in each of the three experiments than those fed the basal ration of corn, silage and cottonseed meal. The differences were not statistically significant in Experiment 1, but would be regarded as significant in Experiments 2 and 3. Growth curves based on average weights at progressive stages in the feeding period were much the same for Experiment 1 as for Experiments 2 and 3. The consistency of the differences is revealed by the percentage increases in average gains. In Experiments 1, 2, and 3, the high-calcium calves gained 12, 11, and 20 percent, more than the low-calcium calves, respectively. This remarkably close agreement was noted in the two paired-feeding experiments. The larger difference in Experiment 3, where the calves were group-fed, perhaps reflects the greater need for calcium when the feed intake is high and gains relatively rapid.

Similar comparisons have been made by McCampbell, Reed and Connell *(58)* and Baker *(6)*. Their results show that the average gains of the steers fed ground limestone in conjunction with corn, silage and cottonseed meal were 11 percent *(58)* and 15 percent *(6)* greater than those made by the steers fed only the basal ration.

Anderson and coworkers *(1, 2, 3)* found that adding ground limestone to a ration of corn, silage, prairie hay, and cottonseed meal increased the gain 13 percent, as an average for three trials. It will be noted that the basal ration used in these trials differed from the one used in the three experiments reported in this paper only in that a small amount of dry, carbonaceous roughage (prairie hay) was included in it.

Studies of a somewhat similar nature have been reported by several other investigators *(18, 19, 44, 55, 75, 76)*. In each case it was evident that larger gains in weight resulted from the addition of the calcium supplement. While the benefits of the supplement were not always measured directly, the results indicate a beneficial effect upon growth, particularly when interpreted in the light of other data found in the literature. It appears, therefore, that increased gains in weight of 10 to 20 percent may be expected when a calcium supplement is added to a calf-fattening ration consisting of grain, carbonaceous roughage and cottonseed meal.

Body measurements taken in Experiment 2 show that the high-calcium calves made greater increases in height and in circumference of the heart and paunch then did the low-calcium calves. That the high-calcium intake also resulted in heavier bones was indicated in the weights of the humerus, femur, fifth and thirteenth ribs from each steer slaughtered in Experiments 1 and 2. Further proof of the superior bones of the high-calcium steers was their uniformly higher content of ash and calcium and their greater breaking strength.

The results of these studies indicate definitely, therefore, that maximum gains in weight are not obtained when calves that are growing and fattening at the same time receive calcium deficient rations. This does not mean that relatively low levels of calcium intake may not suffice for growth without fattening. It was pointed out in the review of literature that little or no benefit results from the addition of a calcium supplement to a calf wintering ration of silage and cottonseed meal *(7, 8, 44, 57, 81,* and *82)*. It is likely that the satisfactory growth reported when rats were fed low-calcium diets also should be interpreted on this basis.

Utilization of Feed

In each of these three experiments, the high-calcium steers required less feed for 100 pounds gain than the low-calcium steers. This would be expected since the feed intake was the same for the two groups in each comparison, while the high-calcium steers made larger gains.

An inspection of the data obtained in the digestion trials conducted as a part of Experiment 2 indicates no significant effect of the calcium intake on the digestibility of the various nutrients. One possible exception is in the case of crude fiber, but further studies will be necessary before the point is proved. Particularly is this true in view of the fact that previous studies with swine *(34)* and with sheep *(90)* showed that digestibility is not influenced by the addition of lime to calcium-deficient rations.

While the data obtained in the balance trials are limited, their consistency indicates definitely that the retention of calcium and phosphorus was increased by adding ground limestone to the basal ration of corn, silage and cottonseed meal. The ash content of the bones also indicates that increased retention of these elements resulted from feeding the calcium supplement.

The more efficient utilization of feed by the high-calcium steers was well established by the results of these three experiments, but the reasons involved are still undetermined. Higher energy metabolism of the low-calcium calves may partially explain the difference. Whether the greater retention of calcium and phosphorus by the high-calcium calves contributed to their more efficient utilization of feed is not clear, but it seems reasonable to assume that it may have been a contributing factor.

Carcasses

The appearance of the steers on foot reflected the differences in gains. The high-calcium steers were given higher slaughter grades, and it was generally agreed that they were thicker and appeared fatter than the low-calcium steers. In Experiment 3, these differences were expressed in terms of selling price per 100 pounds when the two groups were sold on the Kansas City market at the conclusion of the experiment. The high-calcium steers brought fifty cents per 100 pounds more than the low-calcium steers, and commission salesmen and packer buyers who looked at the cattle were in complete agreement that this difference in price was fully justified.

The differences in dressing percentage were not significant either in the case of the steers in Experiment 3 slaughtered in Kansas City or of those from Experiments 1 and 2 slaughtered in the station abbatoir. Nor were the differences which were so plainly evident before the steers were slaughtered recognizable in the carcasses. The similarity in the finish, shape and quality of the carcasses of the two groups was shown in the carcass grades. Manifestly, these similarities in the carcasses meant that the low-calcium steers actually were worth just as much to the packer as the high-calcium steers.

Blood

Du Toit, Malin and Groenwald *(29)* demonstrated that low-calcium rations do not produce significant changes in the blood calcium of cattle. Similar observations were made in the three experiments included in the present investigation. The variations were well within the limits established by Palmer and Eckles *(64)* as normal for the calcium content of the blood of dairy cattle.

Phosphorus determinations on the blood were made in this study with fattening calves. Both groups in each experiment had normal amounts of inorganic phosphorus in the blood, and there was no evidence that the amount was influenced by the level of calcium intake at any stage of the feeding period.

The hemoglobin content of the blood was also determined. Variations were noted, but they did not appear to be associated with the level of calcium intake, season of the year or stage of the fattening period. Bechdel and coworkers *(10)* reported an anemic condition in rachitic calves, but it would appear that the calves in this study were far from rachitic even though they were fed relatively low-calcium ratione for prolonged periods.

SUMMARY AND CONCLUSIONS

The results are reported of a study undertaken to determine the effects of adding ground limestone to a calf-fattening ration comprised of ground shelled corn, atlas sorgo silage and cottonseed meal.

Three experiments were conducted involving the use of 44 grade Hereford steer calves. Six pairs of calves were fed individually in two experiments and two lots of ten steers each were fed in a third experiment. Three pairs of calves were used in digestion and balance trials.

The basal rations used in these experiments furnished calcium in the following amounts in grams per calf daily: 11.0; 7.2; and 8.9. The addition of the ground limestone increased the calcium contents of the rations to 28.6 grams, 24.8 grams and 26.4 grams, respectively.

The effects of adding ground limestone to this basal ration were: (1) Increased gains in weight; (2) more efficient utilization of feed; (3) increased retention of calcium and phosphorus; (4) higher slaughter grades; (5) heavier bones of higher specific gravity, greater breaking strength, and higher ash content.

The addition of ground limestone to this basal ration had no significant effect on (1) appetite; (2) thirst; (3) digestibility of nutrients; (4) dressing percentage; (5) carcass grade; (6) weights of heart, liver and spleen; (7) calcium and phosphorus content of the blood; (8) hemoglobin content of the blood.

The results obtained indicate that the fattening calf needs more than 11 grams of calcium daily.

APPENDIX

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FIG. 1. The beef cattle nutrition laboratory at the Kansas Agricultural Experiment Station.

FIG. 2. The basement of the beef cattle nutrition laboratory. This basement, 14 by 20 feet, is located directly beneath the six digestion stalls, facilitating the collection of urine and feces during digestion trials and mineral-balance studies. The electric drying oven is used to dry feces and to make moisture determinations of silage.

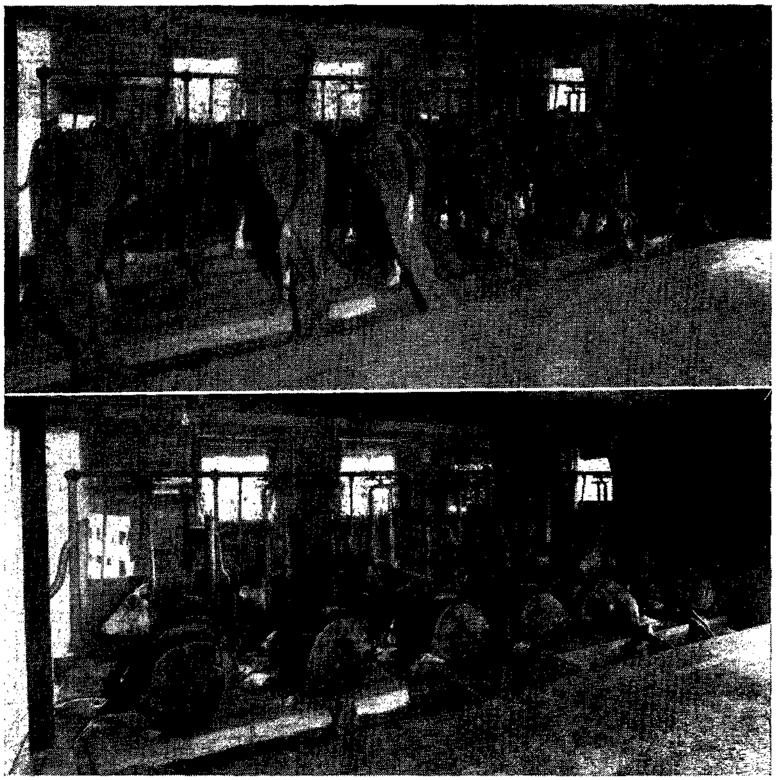

FIG. 3. Steers used in digestion and balance trials in stanchions at beef cattle nutrition laboratory. Note that the harness and other necessary equipment did not prevent the steers from lying down in a comfortable position.

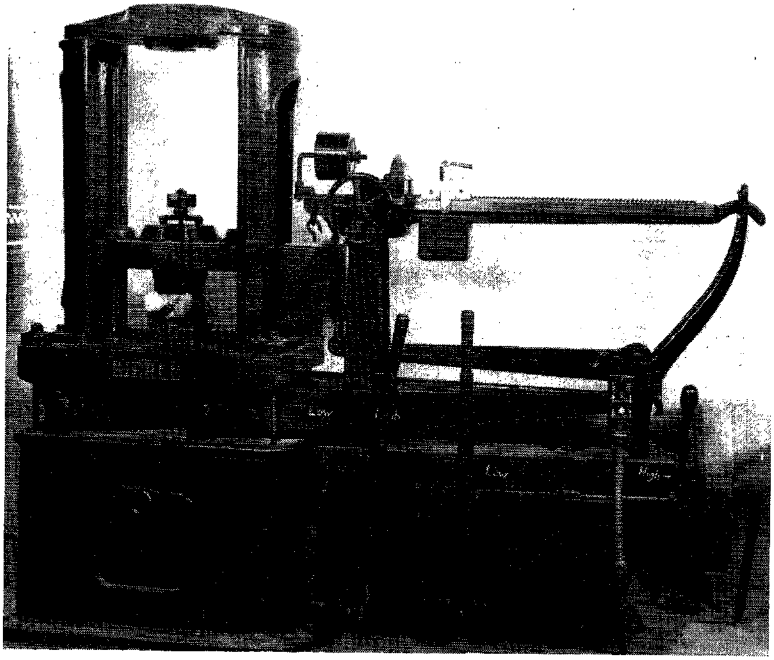

FIG. 4. Riehle testing machine used in determining the breaking strength of bones. This particular machine is a part of the equipment in the Division of Engineering of Kansas State College.

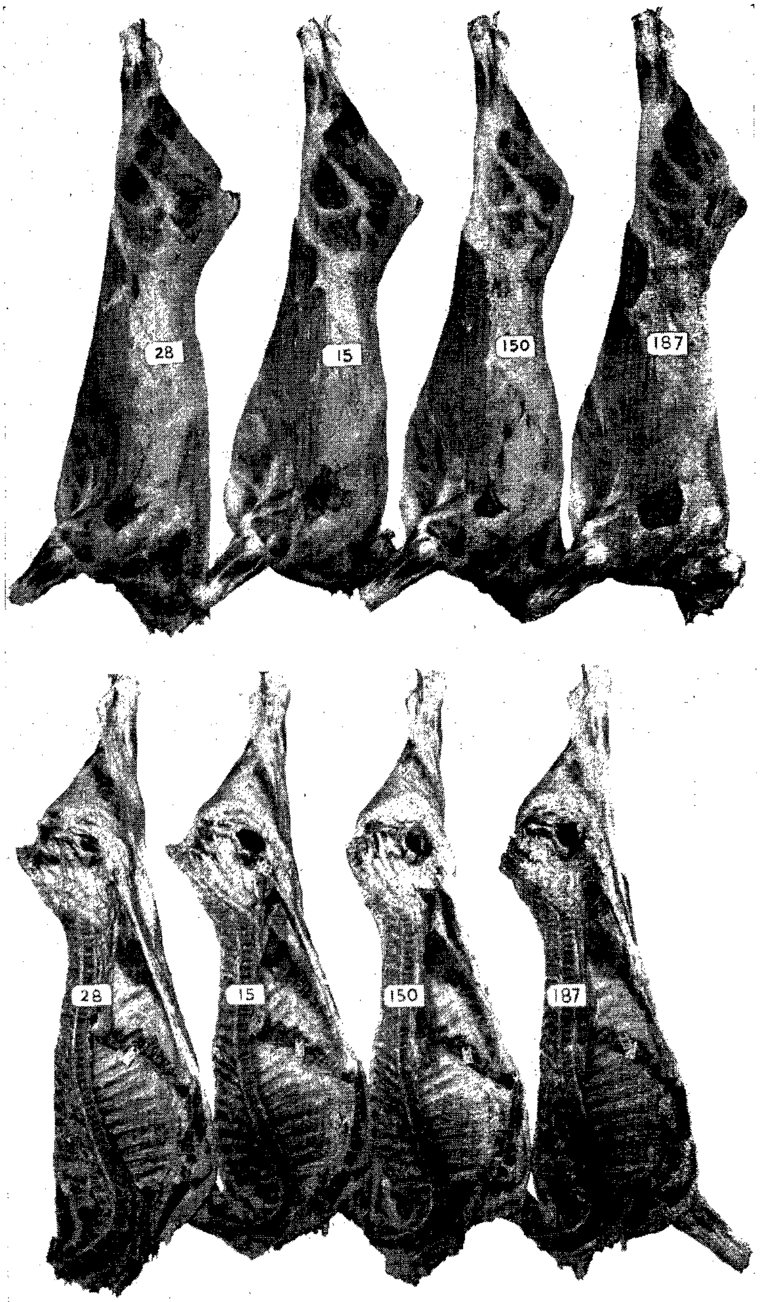

FIG. 5. Carcasses of steers slaughtered in Experiment 1. Carcasses 187 and 150 were from the low- and high-calcium steers, respectively, of Pair No. 5. Carcasses 15 and 28 were from the low- and high-calcium steers, respectively, of Pair No. 1.

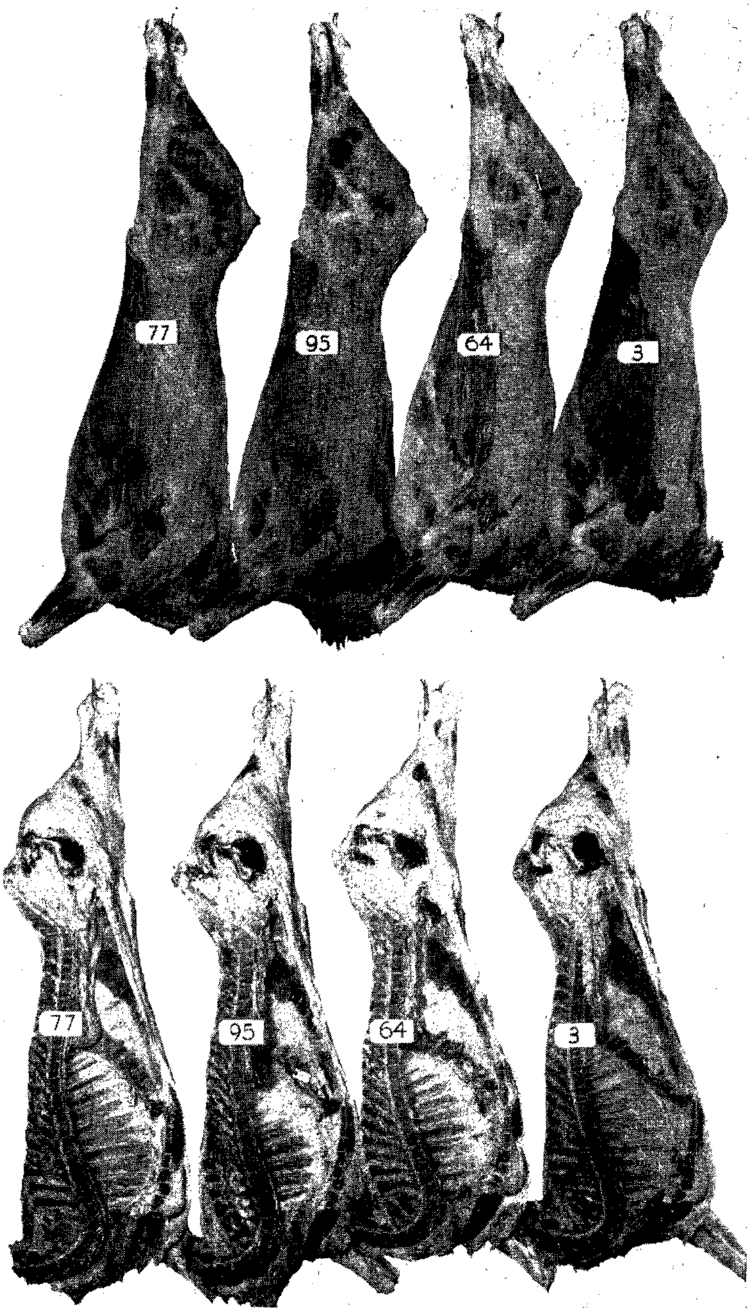

FIG. 6. Carcasses of steers slaughtered in Experiment 1. Carcasses 3 and 64 were from the low- and high-calcium steers, respectively, of Pair No. 6. Carcasses 95 and 77 were from the low- and high-calcium steers, respectively, of Pair No. 3.

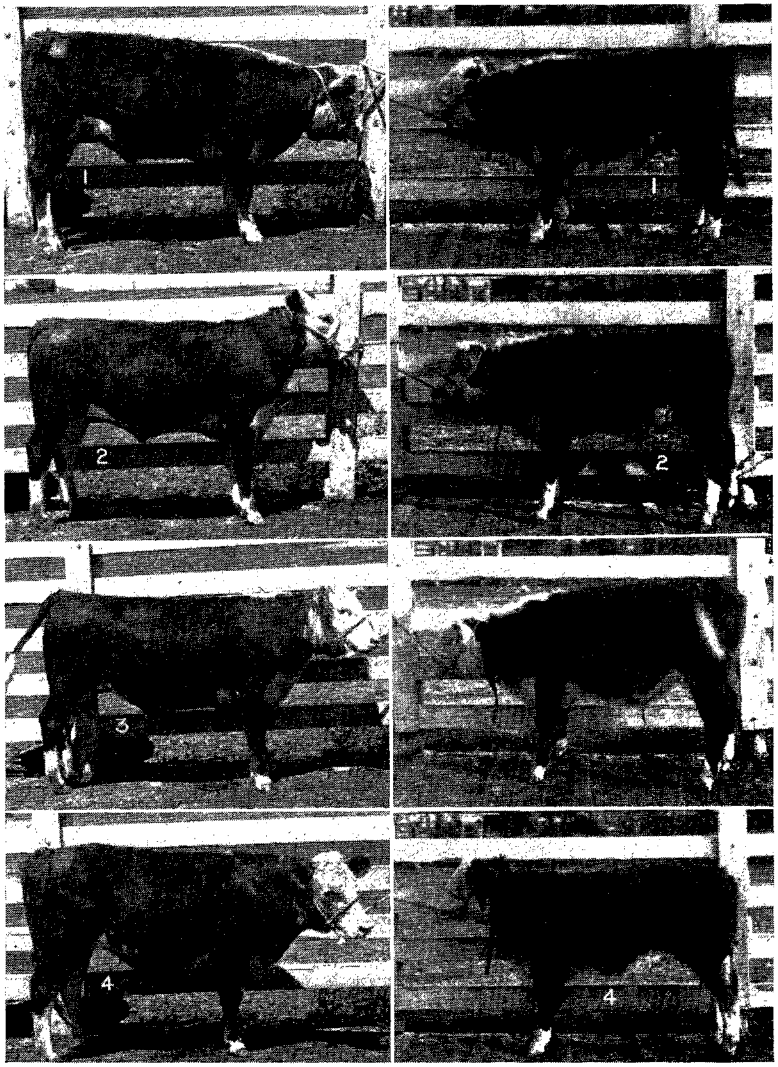

FIG. 7. Steer calves used in Experiment 2. The pictures on the right show the calves at the beginning and those on the left at the close of the experiment. Calf 1, high-calcium, and calf 2, low-calcium, are designated Pair No. 1; and calf 3, high-calcium, and calf 4, low-calcium, Pair No. 2.

FIG. 8. Steer calves used in Experiment 2. The pictures on the right show the calves at the beginning and those on the left, at the close of the experiment. Calf 5, high-calcium, and calf 6, low-calcium, were designated Pair No. 3. The order was reversed in the case of Pair No. 4, calf 7 being fed the low-calcium ration and calf 8 the high-calcium ration.

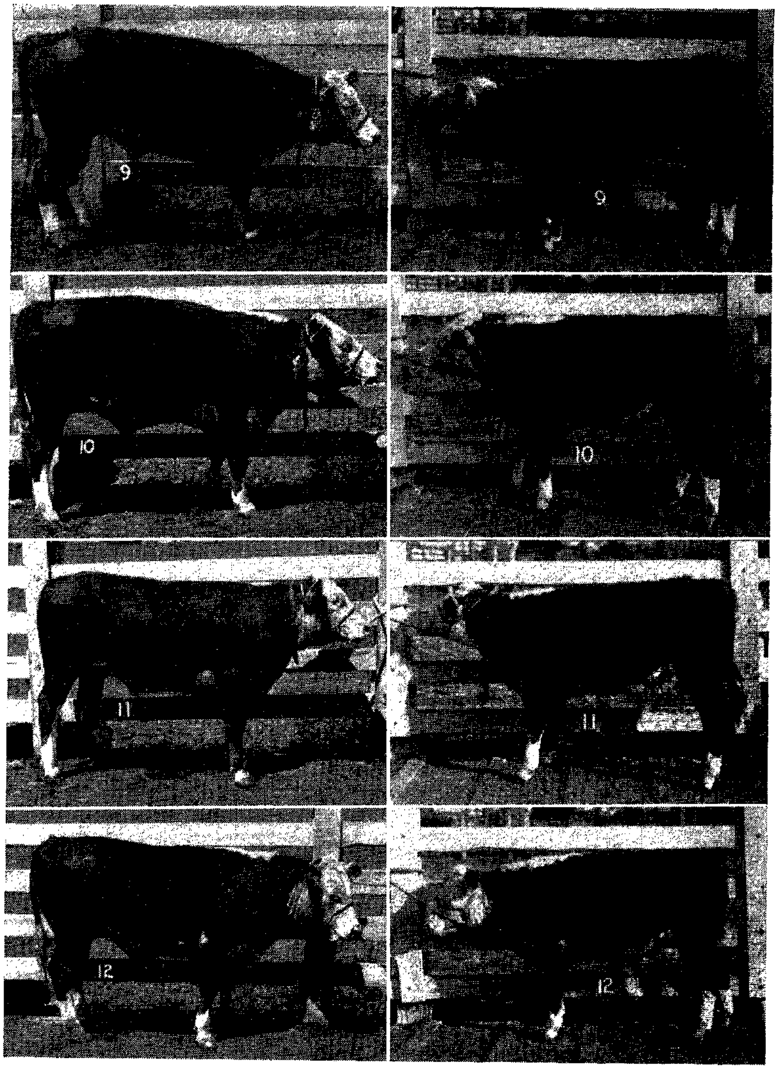

FIG. 9. Steer calves used in Experiment 2. The pictures on the right show the calves at the beginning and those on the left at the end of the experiment. Pair No. 5 consisted of calves 9 and 10 fed low- and high-calcium rations, respectively. Calves 11 and 12 were fed low- and high-calcium rations, respectively, and were designated Pair No. 6.

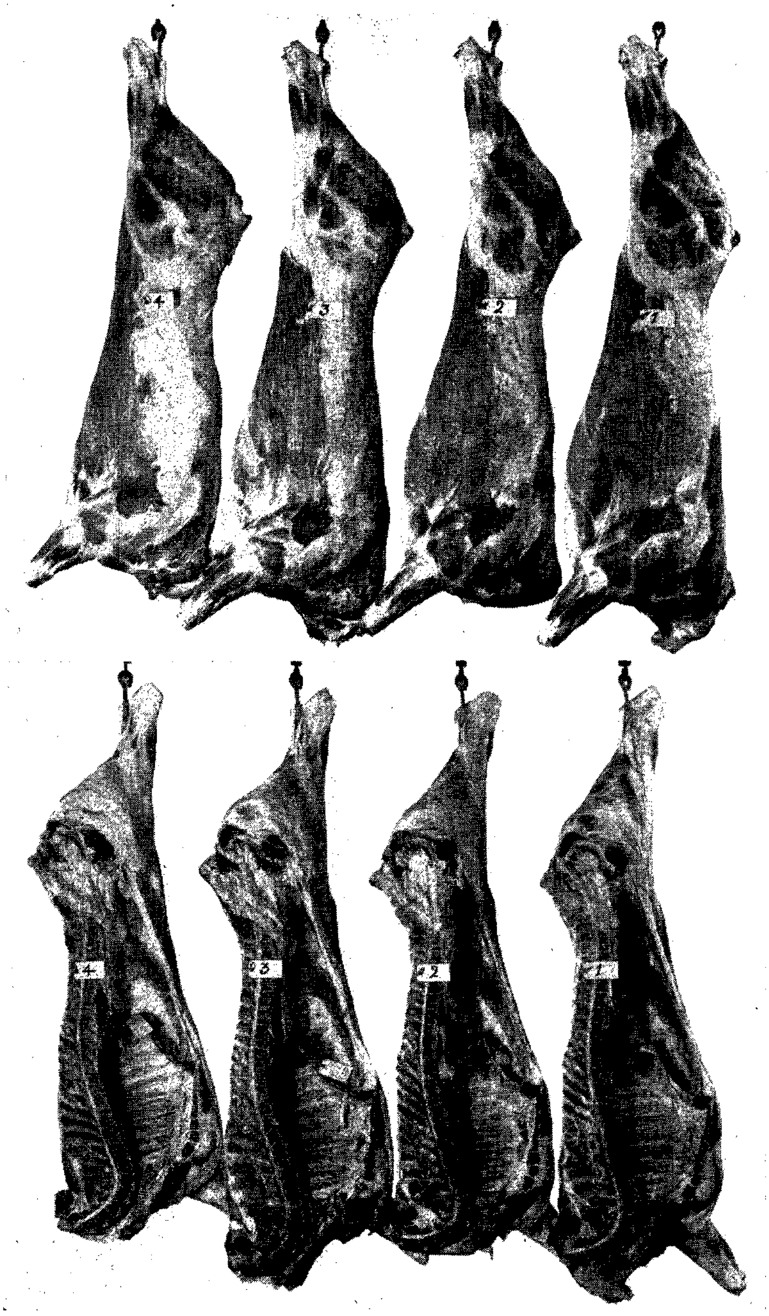

FIG. 10. Carcasses of steers slaughtered in Experiment 2. Carcasses 1 and 3 were from high-calcium steers and were paired with carcasses 2 and 4 from low-calcium steers. (Pair 1, steers 1 and 2; Pair 2, steers 3 and 4.) The carcass number corresponded with the steer number in these experiments.

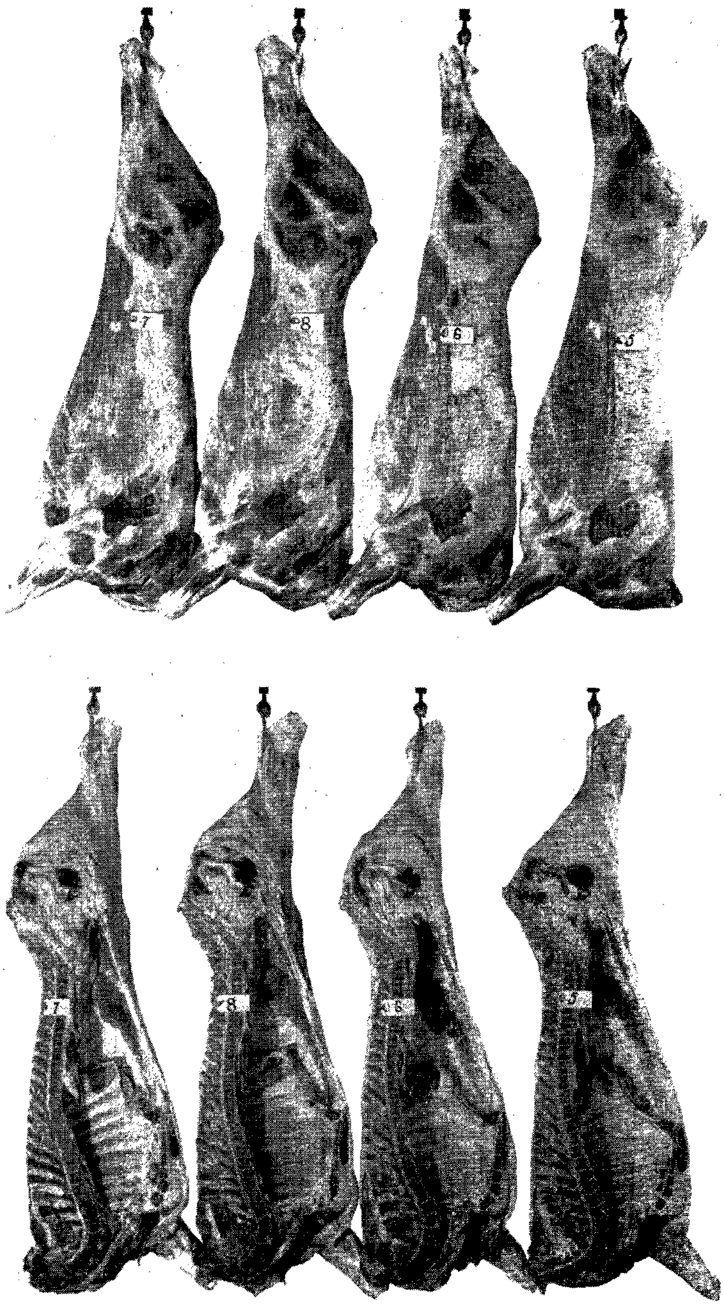

FIG. 11. Carcasses of steers slaughtered in Experiment 2.

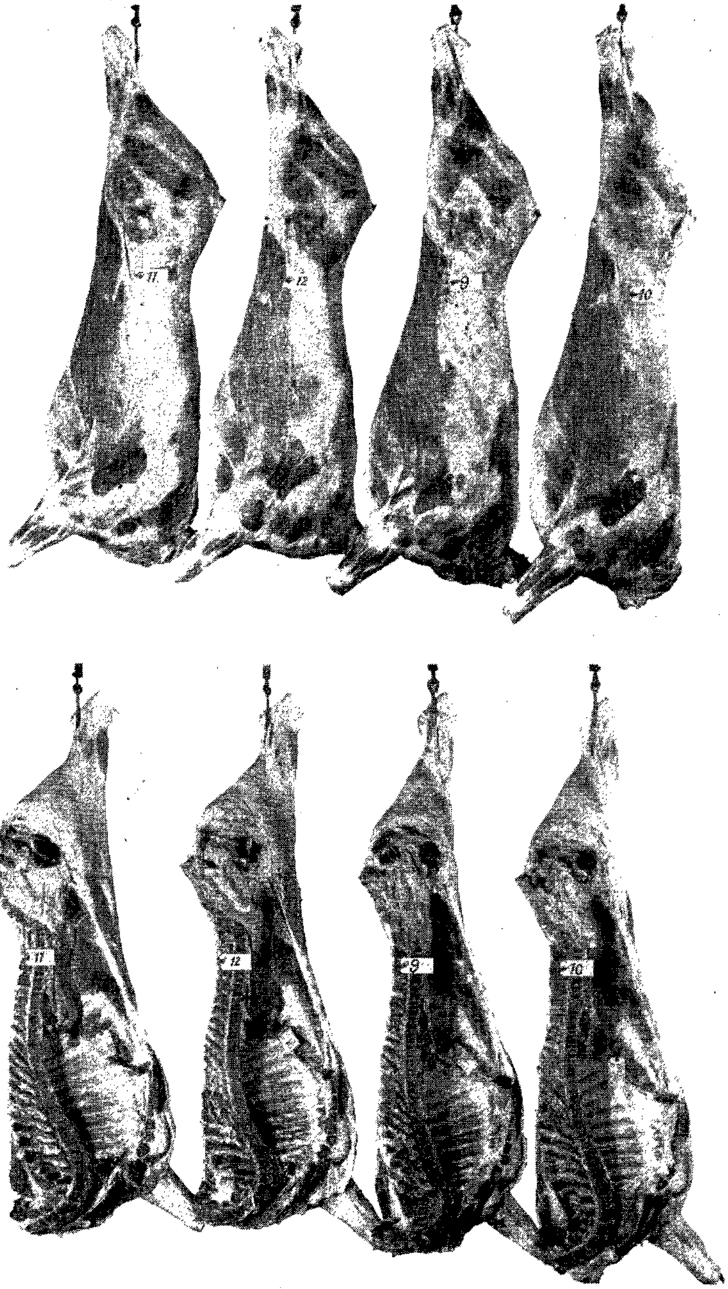

FIG. 12. Carcasses of steers slaughtered in Experiment 2.

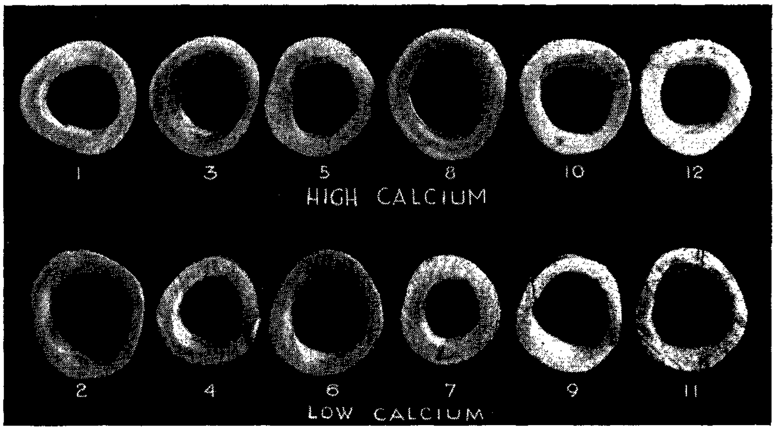

FIG. 13. Cross-sections of femurs from steers slaughtered in Experiment 2.

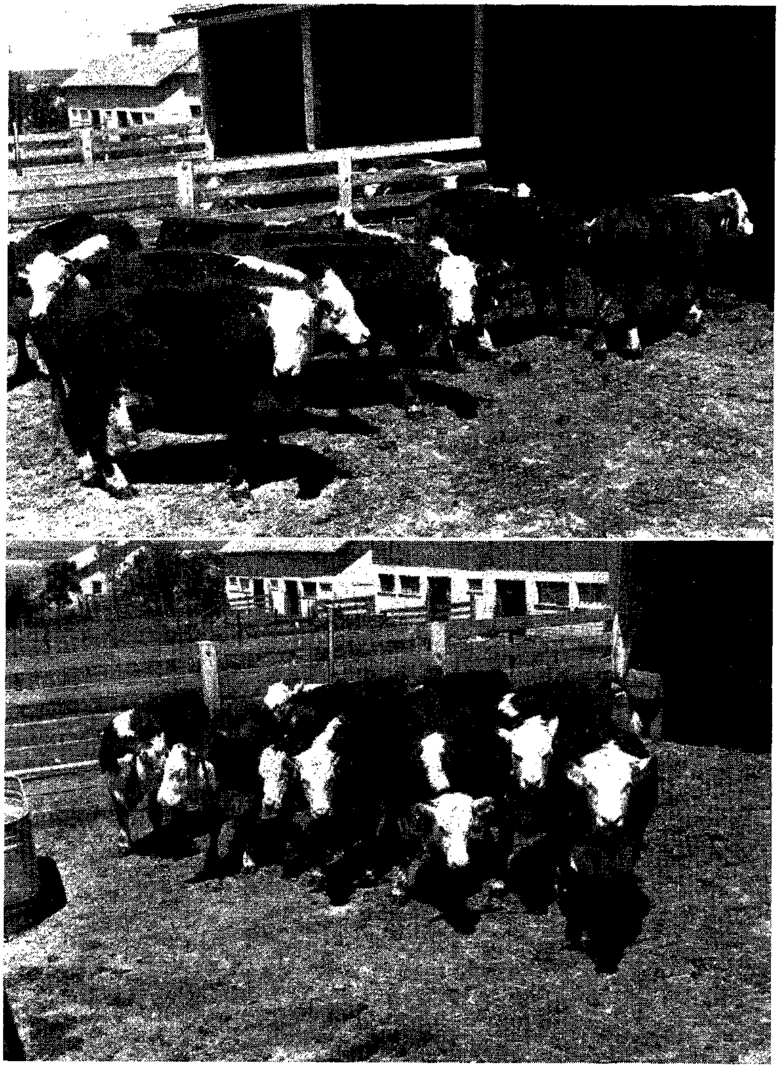

FIG. 14. Steers used in Experiment 3. The steers shown at the top of the page received the high-calcium ration and those at the bottom of the page received the low-calcium ration.