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A GENERAL CONSIDERATION OF THE CALCIUM AND PHOSPHORUS IN THE RATION OF GROWING CATTLE

by

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PREFACE

To present a masterful treatise on the subject of this paper would require, 1st. technical training of the highest order in chemistry and physiology such as one man can hardly hope to attain; 2d. the collection of experimental data requiring the energies of a whole department rather than a single man and covering years rather than months.

In the light of present knowledge any consideration of this subject must be very largely theoretical and cannot honestly lay claim to exactness or conclusiveness.

With a full realization of these facts the writer presents this paper.

CONTENTS.

A GENERAL CONSIDERATION OF THE CALCIUM AND PHOSPHORUS IN THE RATION OF GROWING CATTLE.

LITERATURE.

Of What Use in the Body are Minerals in General?

1. In speaking of the mineral constituents of foods Howell says,- "The salts have no importance as sources of energy. Whatever chemical changes they undergo are not attended by any liberation of heat energy -- none at least of sufficient importance to be considered. They have, however, most important functions. They maintain a normal composition and osmotic pressure in the liquids and tissues of the body, and by virtue of their osmotic pressure they play an important part in controlling the flow of water to and from the tissues. Moreover these salts constitute an essential part in the composition of living matter. In some way they are bound up in the structure of the living molecule and are necessary to its normal reactions or irritability. Even the proteins of body liquids contain definite amounts of ash, and if this ash is removed their properties are seriously altered, as is shown by the fact

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1. Howell, Textbook of Physiology - p. 901.

that ash free native proteins lose their property of coagulation by heat. The globulins are precipitated from their solutions when the salts are removed."

1. "Mineral salts are of service in the movement of liquids thruout the body and its tissues, for example, from the alimentary canal into the blood and also the reverse of this action, and from the blood into the tissues and from the tissues into the blood, and from the blood into the kidneys. These results seem to be produced at least in part, by the reactions between the cell proteids and the mineral salts acting upon them in dilute solution, in some cases causing increased penetrability by the liquids and dissolved substances, and in others decreasing penetrability by precipitation of the proteids."

2. "Physiological specifity is a property especially of the mineral nutrients, tho the relative amounts of proteids, carbohydrates and fats and the mechanical character and palatability of the foods produce less fundamental specific effects. Fats and in a sense proteids must share with the minerals any credit for exercising specific influence in the structure of the body, meaning to distinguish between physiological action and chemical constitution."

3. "The importance of the mineral salts in the vital processes of the animal cell lies almost entirely in their

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1. Ohio Bul. 201, p. 139
2. Ohio Bul. 201, p. 134
3. Ohio Bul. 201, p. 137

physical or physico-chemical properties. The chemical reactions in the body which constitute the physical basis of life take place between substances in solution, and it is by means of the electrical charges carried by the particles in solution that reactions are brought about.

"Very slight amounts of the mineral salts, acids or alkalis, in water, enormously increase its power to conduct electrical currents. Many of the organic compounds of cells do not posess this capacity and hence show less pronounced chemical properties. Their molecules are usually vastly larger and more complex than those of the inorganic compounds, and the speed with which they carry electrical charges is correspondingly slow, with such as possess this property at all. Accordingly they are, as compared with the inorganic constituents of the cell, chemically inert.

"The mineral elements in the body are most of them strongly acid or basic and their compounds have a tendency to become exceedingly active when in dilute solution, also the small size of the molecules of their simpler compounds allows them to pass freely thru cell membranes that are impenetrable to many of the larger molecules of the complex organic compounds.

"The mineral substances of animal tissues exist not merely in solution but partly in firm sombination with

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the organic constituents. These mineral substances render chemically active the large and inert organic complexes to which they are bound." Mann is quoted as saying,- "So-called pure ash free proteids are chemically inert and in the true sense of the word, dead bodies. What puts life into them is the presence of electrolytes, that is bodies capable, as are inorganic compounds in solution, of carrying electric charges."

1. "The fatty acids of the food fat and those resulting from the action of enzymes upon neutral food-fats unite with the alkali salts of the bile, the pancreatic juice and the intestinal juice to form soaps, which emulsify the remaining neutral fats and thus, by breaking them up into fine particles, facilitate their digestion by enzymes. This digestion is a splitting of the neutral fats into fatty acids and glycerine. --- The fatty acids and soaps produced by the digestion of the fats --- are absorbed mostly dissolved in the bile. --- Thus mineral salts are fundamentally involved in the digestion of fats."

While in a paper of this kind one is not so much interested in the action of minerals in general as in the action of some specific ones, the foregoing shows the fundamental character of the role which the minerals play even tho their total amount is slight.

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1. Ohio Bul. 201, p. 140

1. According to the work of Lawes and Gilbert the ash of the entire body of a calf contains of calcium more than fifty per cent, and of phosphorus about thirty per cent so that in amount it is seen that these two elements rank first and it is only reasonable to suppose that they are of similar importance physiologically. For that reason these two minerals will be dealt with in the main.

Of What Special Use is Calcium?

2. "VonNoorden, on the basis of Katz's work states that there are less than ten grams of calcium in the soft tissues of a human being and in the bones nearly one hundred times as much. It is this one per cent in the blood and tissues which plays so important a role in the control of muscular contractions, coagulation of the blood, etc.

3. "Solutions of calcium chloride injected directly into the circulation will shorten greatly the coagulation time of the blood, or may even cause intravascular clotting. Arthus and Pages showed that freshly drawn blood allowed to flow into an oxalate solution, in amounts such that the final concentration of oxalate is not less than 0.1 per cent, will remain unclotted indefinitely, but may be made to clot at any time by the addition of a suitable amount of calcium

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1. Lawes & Gilbert, Composition of Animals.
2. Ohio Bul. 201, p. 146
3. Howell - Physiology, p. 450.

salt. That this effect is not due to an excess of the added oxalate is proved by the fact that the oxalated blood or the plasma obtained from it by centrifugalization may be dialized against a large bulk of solution of sodium chloride, 0.9 per cent until the oxalate is removed. This dialized plasma will remain unclotted indefinitely but will coagulate promptly upon the addition of small amounts of calcium chloride."

1. "We may say that the presence of sodium, calcium and potassium in normal proportions are an absolutely necessity for heart activity. A striking experiment which shows the importance of the calcium is to irrigate a terrapin's heart with blood-serum from which the calcium has been removed by precipitation with ammonium oxalate. In spite of the fact that all other constituents of the blood are present the heart ceases to beat, and normal contractions can be started again promptly by adding calcium chloride in right amounts to the oxalated blood."

Of What Special Use is Phosphorus?

2. Hammersten states that phosphorus is perhaps necessary to the growth and division of the cell inasmuch as this division is dependent upon the phosphorus contain-

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1. Howell - Physiology, p. 562 - 563.
2. Hammersten - Physiological Chemistry, p. 139.

ing nucleus.

If this is true phosphorus lies at the very base of life itself for without cell division growth or reproduction is impossible.

How is the Ash Assimilated and Excreted?

1. Henry states that so far as is known mineral matter or ash of foods is absorbed principally from the small intestine and is usually unchanged in chemical composition.

2. "It is probable, indeed certain, that most of the calcium salts ingested simply pass thru the body without entering into its structure. They are eliminated unchanged and unused in the feces or urine. A small portion, however, must be absorbed and used and a corresponding amount must be eliminated as a true waste product of tissue metabolism. Voit, by experiments upon isolated loops of the intestine, has shown that some calcium is constantly eliminated from the inner surface of the intestine. The amount is small not exceeding perhaps 0.15 to 0.16 grams per day. There is some evidence that the amount of calcium in the tissues increases with age. This is certainly true of the bones, which become exceedingly brittle in advanced life,

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1. Henry, "Feeds & Feeding", p. 30
2. Howell, Textbook of Physiology, pp. 903-904.

and is evident also in the arteries whose elasticity diminishes as the calcium salts deposited in their coats are increased."

1. "In herbivora nearly all of the phosphorus is excreted in the feces largely in the form of phosphates."

2. "In a cow the principal channel for the excretion of phosphorus was found to be the gut. There was also a constant excretion of calcium thru the gut, this being the main channel for this element."

3. "After the absorption of the soaps (formed from the interaction of fatty acids and alkalis) fatty acids and glycerine resulting from this process and the re-formation from them of neutral fats, the alkalis absorbed with them are re-excreted into the intestine and are used again and again in the same way."

4. "The data embodied (in Wis. Research Bul. 5) emphasize and extend what has previously been shown to be true with other animals namely, that the nitrogen and phosphorus excretion have no close direct relation to each other. --- That there is a definite and more or less constant metabolism of the ash elements of the cell which bears

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1. Ohio Bul. 207, p. 25
2. Wis. Res. Bul. 5, p. 183
3. Ohio.Bul. 201, p. 140
4. Wis. Res. Bul. 5, p. 181.

a definite relation to the amounts of nitrogen suffering degradation in cellular metabolism is entirely possible."

This latter view seems highly probable. However, it seems surprising that the nitrogen and phosphorus are not eliminated in proportionate amounts. It lends color to the idea that the minerals in the process of elimination may in part be reabsorbed from the gut and used over and over again.

1. "According to Albu and Neuberg the amount of calcium absorbed from the intestine is influenced by the other salts present, sodium chloride increasing its resorbtion and alkalis diminishing it."

Of What Importance is the Balance Between Acid and Base?

2. "The main facts in physiology regarding acid and alkali mineral elements are as follows,- There are in all foodstuffs and in the living tissues of animals, mineral elements in organic combination, which upon oxidation in the body, yield inorganic acids. The animal must be protected from these acids which would produce profound disturbance if allowed to circulate thru the body. To this

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1. Ohio Bul. 207, p. 48
2. Ohio Bul. 207, p. 24

end they are neutralized with substances possessing a basic reaction and then, in their neutral conditions, are either excreted or used for nutrients."

1. "The organic acids of foodstuffs, such acids for instance, as the citric, malic and tartaric acids of fruits are mostly oxidized in the animal body to carbon dioxide and water, in which compounds they are excreted; but there are formed within the body, mineral acids which cannot be decomposed and eliminated in this way. These acids must be neutralized in order to protect the animal from a disturbance of conditions essential to the continuance of vital reactions."

2. "The capacity of the animal body to neutralize and eliminate alkali seems to be entirely adequate. In practice animals do not experience injurious excess of alkali as they do of acid."

3. "In considering this matter of balance between mineral acid and mineral base in animal nutrition, we must think of the acids as produced (1) by the destruction or katabolism of the body proteins, (2) by the oxidation of food proteids, and (3) to a slight extent by the decom-

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1. Ohio Bul. 207, p. 49
2. Ohio Bul. 207, p. 51
3. Ohio Bul. 207, p. 32

position of sodium chloride in the formation of gastric juice."

1. "A very slight disturbance by the acids of the reaction of the blood must result in a complete disappearance from it of carbon dioxide. Thus it becomes a matter of much importance to the animal that the neutrality or slight alkalinity of the blood be abundantly safeguarded.

"In herbivora this is accomplished by the formation of carbonates in the body by the oxidation of the abundant organic-acid-salts of sodium, potassium, calcium and magnesium which are found in vegetable foods, and under ordinary circumstances the carbonates thus formed are quite sufficient to meet the needs of the animal. In this class of animals there is very slight provision for any other method of neutralization of the acids."

"Because of the practical inability of herbivora to neutralize acids with ammonia ---there comes a time, with increased consumption or production of non-oxidizable acids when the animal is no longer able to maintain the neutrality of its blood and tissues. At this point acute symptoms of acid intoxication ---appear and death may follow quickly with symptoms of asphyxia."

2. "---It would appear that the ash of milk is mark-

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1. Ohoo Bul. 207, p. 29
2. Ohio Bul. 207, p. 46

edly alkaline and from this it is probably safe to conclude that the food of animals should possess an excess of mineral bases in the ash. This assumption seems particularly justifiable when we consider the fact that on the basis of Lawes' and Gilbert's work mineral base predominates in the ash of animal bodies and further when we consider the probability as shown by Soxlet that the calcium content of milk constitutes the limiting factor in the production of growth and that the storage in growing animals is more largely of basic than of acid minerals."

It seems to be true that in order to carry on the normal processes of life the reaction of the body liquids be under quite delicate control. It seems that the only danger in practice lies in the liability of an over-abundance of acid being produced. There seems to be no danger of too much alkali being present.

The chief base used out of the food is calcium and the chief acid is phosphorus. There is, however, no hint in literature as to the proper proportion of calcium to phosphorus for feeding other than that there should be present in feeds proportionately more calcium than is present in milk. The ratio between calcium and phosphorus in milk is 1.29:1. It has also frequently been noted that in mineral starvation the calcium and phosphorus of the body

seems to be broken down in the proportion of tri-calcium phosphate or calcium 1.9 to phosphorus 1. It does not necessarily follow from this, however, that this is the proper proportion in which to supply these minerals.

Are Inorganic Minerals Available to Cattle?

1. "We have no data as to the relative usefulness of organic and inorganic calcium compounds, but it is very well established that inorganic calcium compounds are digested and assimilated by animals."

2. "If the amount of lime and phosphoric acid in the food is not sufficient, it can be increased by the addition of phosphate of lime. In many cases there is only a lack of lime, so that chalk which is cheaper can be used instead of the phosphate."

3. "Inorganic phosphates are readily digested and assimilated and may be retained in the body and used for the various functions, including growth of bone, in which inorganic phosphates would appear to have a use. One must bear in mind that three-fourths of the mineral matter of

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1. Ohio Bul. 201, p. 146
2. Kellner, Scientific Feeding of Animals, p. 98
3. Ohio Bul. 201, p. 148-9

the body is inorganic calcium phosphate, found mostly in the bones, and that even in the flesh about half of the phosphorus is inorganic. A considerable part of the phosphorus of milk is also inorganic. It is true, however, that inorganic phosphates, particularly those of the stronger bases, are chemically inactive in the body. The field of their usefulness would seem to be restricted not so much by the fact that they are inorganic as by the fact that the mineral bases with which they are united have stronger affinities for the phosphorus than are possessed by the organic complexes which have need for phosphorus.

"There is, however, a difference of opinion among physiologists as to whether or not any inorganic phosphates are useful in the synthesis of organic phosphorus compounds in the animal body."

1. "Bone meal when added to a ration which was low in calcium and phosphorus, greatly increased the ash and strength of the bones, but did not increase the percentage of protein in the growth produced; in fact there was a slightly smaller proportion of spleen, lungs and muscles in the increase produced by the bone meal ration than by the ration lacking this bone meal and which at the same time was abnormally low in calcium and in phosphorus. This

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1. Ohio Bul. 201, p. 135.

was probably due to the neutralizing of the hydrochloric acid of the gastric juice by the mineral compounds of the bone meal fed, thus interfering with the digestion of the proteids.

"These facts indicate that bone meal will not serve all the bodily needs for phosphorus."

1."The phosphorus of bone meal appears not to add to the muscle producing capacity of a low phosphorus ration; in fact there is some evidence to suggest that it interferes, to a slight extent, with the utilization of protein. Bone meal, however, contributes directly and conspicuously to the ash, density and breaking strength of bone.

"Bone meal does not diminish the tendency of pigs fed on a low phosphorus ration to make fat from the protein of the food.

"The muscles of pigs which received bone meal were lower in ash and percentage of phosphorus in the ash, than the muscles of pigs which had received a low phosphorus ration lacking in bone meal."

2."Other forms of calcium phosphate are better relished and more completely digested by animals than are bone meal or bone flour. Precipitated calcium phosphate made from bones in the process of gelatine manufacture is quite readily digestible.

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1. Ohio Bul. 213, p. 304
2. Ohio Bul. 201, p. 162

"Inorganic calcium as found in chalk and bone preparations seems to be able to furnish all the needs of hogs for extra calcium with the grain foods."

1."On a ration extremely low in phosphorus pigs made as large gains up to 75 or 100 pounds when starting at weights of from 40 to 50 pounds as animals receiving an abundance of this element. After reaching this point loss of weight began, followed by collapse.

"When such low phosphorus rations as induced the above symptoms were supplemented with calcium phosphates no untoward results appeared. Animals fed a low phosphorus ration supplemented with calcium phosphates made as vigorous development as others receiving their phosphorus supply wholly in organic form.

"Precipitated calcium phosphate--a mixture of di- and tri-calcium phosphates-- gave no better results than did floats a crude tri-calcium phosphate."

2."The phosphorus in wheat bran is easily soluble in water and has been found to have a marked capacity to support muscular growth in hogs. In the same experiments bone phosphorus produced no preceptible increase in muscular growth. Phosphorus in both forms contributed to the development of the bones."

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1. Wis. Res. Bul. 1, p. 37
2. Ohio Bul. 201, p. 163

1."The amount of phosphorus retained by growing pigs was not so much influenced by the form of phosphorus administered as by the vigor and rate of development of the animals." In fact calcium phosphate in the crude form (floats) was retained more closely than any other kind.

2.A. Köhler in an experiment with lambs found that the phosphoric acid of bone ash and steamed bone was retained by lambs to the extent of 13 to 14 per cent. Precipitated calcium phosphate was retained four times as completely, or to the extent of 52 to 56 per cent.

3."About one-half or one third only of the calcium and phosphorus of vegetable foodstuffs is utilized by animals, so that in computing rations it is necessary to allow for at least two or three times as much of these elements as the animal requires in the vital processes.

"In the choice of compounds of phosphorus to feed to animals we have to bear in mind the following conditions:

1. The principal need of phosphorus in the body is for inorganic phosphorus.

2. The smaller amount of organic phosphorus needed goes largely to support the formation of muscle, nervous tissue, gland cells, milk and reproductive substance.

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1. Wis. Res. Bul. 1, p. 34
2. Kellner, "Die Ernahrung der landw. Nutztiere," p. 390.
3. Ohio Bul. 201, p.p. 149-50

(3) Inorganic phosphorus seems to be able to supply the bodily need for inorganic phosphorus only.

(4) Organic phosphorus can supply all of the bodily needs for phosphorus, both organic and inorganic, if the necessary bases are present.

(5) The phosphorus of vegetable foods is very much more largely organic than inorganic and hence in case of a deficiency of phosphorus in a ration the probability is that the principal lack will be satisfied by inorganic phosphates.

(6) Inorganic phosphorus is cheaper than organic and if fed in assimilable form and in combination with the bases that are needed, it will probably supply any ordinary deficiency in the phosphorus of the ration."

1."The marked reduction in the quantity of ash of the animal receiving an insufficient supply of calcium phosphates, together with the ability of the animal to build up a skeleton very rich in calcium phosphate when an abundance of the latter is supplied in inorganic forms, strongly points to the possession of a synthetic power by the animal which enables it to convert inorganic forms of phosphorus into organic forms needed by its body."

2."The experiments of McCollum with rats, where the diet consisted of simple proximate food constituents, (with

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1. Wis. Res. Bul. 1, p. 37
2. Wis. Res. Bul. 17, p. 178

at least only traces of ash left in them) and inorganic salts, but provided with flavoring material, growth was sustained for a long time". From this the conclusion is drawn that "If proper intake of food can be secured, the inorganic bases and phosphates, in simple salt like combinations, can perform the same functions as when they are a part of the organic structures of the ration."

It seems to have been proven beyond doubt that inorganic calcium and phosphorus are available to the animal for meeting by far the greater part of its bodily needs. There seems to be doubt as yet whether inorganic phosphorus will meet all of the animal needs for phosphorus or only part of them. The experiment by McCollum with rats seems to indicate strongly that inorganic minerals are all that are needed. However, this point is still unsettled. As far as is known no work has been done to determine whether inorganic calcium is able to meet all of the animal's needs for calcium. It is probable that what is true of phosphorus in this respect is also true of calcium.

Köhler's experiments with lambs indicate that there is a very large difference in the availability of different forms of calcium phosphate. However, since his results are measured just from the amounts ingested and excreted each day they should not be taken too seriously. In the Wisconsin experiments floats, a crude form, was re-

tained more thoroly than either the organic or more refined inorganic forms. The question of the availability of different forms is still an open one.

Do the Bones Act as a Storehouse for Calcium and Phosphorus?

1."A source of acid-neutralizing material in all animals is the calcium salts of the bones and other tissues. Where a ration characterized by a deficiency of mineral base is fed during a considerable period of time, as for instance in feeding corn to swine, the withdrawal of mineral matter from the bones and the prevention of its deposit within them, may effect not only the size and strength of the bones but the size and general style of development of the animals.

"O. Wellman found that calcium and phosphorus excreted from the body during fasting comes from bone substance and S. W. Patterson, in experiments with rabbits fed an oatmeal and cornmeal, that the deficiency of these foods in calcium results in a loss of calcium from the bones."

2."The excess of magnesium in proportion to calcium in foods appears to cause a counteractive liberation of

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1.Ohio Bul 207, p. 31-32
2. Ohio Bul. 213, p. 302.

calcium from the tissues, especially the bones, and thus we may produce malnutrition of the bones merely by the excessive use of a food characterized by disproportionate amounts of magnesium and calcium."

1."The percentage of ash in the skeletons of pigs on the depleted phosphorus ration was reduced to nearly one half that of pigs receiving a normal ration, or a phosphorus poor ration supplemented by an inorganic phosphate.

"When the animals were starving for phosphorus they drew this element from the skeleton, but removed calcium and phosphorus in the proportions found in tri-calcium phosphates."

2. At Wisconsin in an experiment with a cow on a low phosphorus ration, the intake of calcium was at no time equivalent to the output.

"The output was approximately 50 grams daily while the intake was but 25 grams. ---The period of feeding covered a period of 110 days and consequently entailed an approximate loss of 2500 grams, or five and one-half pounds of lime. Data from the Rothamsted Experiment Station on the ash constituents of various animals affords an approximate estimate of the total lime in the animal. At the beginning of the experiment it was about 24.2 pounds. This

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1. Wis. Res. Bul. 1, p. 37
2. Wis. Res. Bul. 5, p. 183 & 186.

means that during the period of the experiment there had been a loss of about 25 per cent of the entire lime content of the animal. ---This large loss above that used for milk production could have had no other source than the skeleton.

"These data support what previous experiments with pigs have shown, namely that the skeletal tissue can vary its ash content within wide limits, thereby acting as a source of supply over considerable periods of time for certain ash constituents which may be deficient in the food.

"During periods of low phosphorus feeding there was constantly an increased output of calcium in the urine, apparently again involving the metabolism of a calcium-phosphorus entity. The total output of calcium during these periods was greater than during periods of high phosphorus feeding."

1."The 'margin of safety' provided in the skeletal tissues in the animal precludes against immediate disasterous results consequent on a sudden deficit in the intake of calcium or phosphorus."

It seems to be true that the bones act as a sort of storehouse for calcium and phosphorus and doles these

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1. Wis. Res. Bul. 5, p. 188.

out to the body in the time of need. But it seems that they must be removed in proportionate amounts so that it would be possible to deplete the bones of both merely by a shortage in the ration of one. A shortage in phosphorus would lead to an excessive excretion in calcium and vice versa. Just how great a percentage of the calcium and phosphorus may be removed by this means is not known, but it may be more than one-fourth of that present in the body.

What Are the Effects of a Ration Low in Calcium and Phosphorus?

1."In comparing rations of corn alone with rations of corn supplemented with wheat middlings, linseed oil meal, tankage, soy beans and germ oil meal, all rations except the corn being compounded to have the same nutritive ratio, the proteid increase was in general, in accord with the organic phosphorus content of the rations. The development of fat was in the inverse order; that is where the protein of the ration was accompanied by the proper mineral elements a certain amount of proteid tissue was produced; where the protein of the food lacked the necessary mineral accompanyments, its nitrogenous portion was excreted, and the remainder used for the production of fat and energy.

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1. Ohio Bul. 213, p. 302.

"A ration which was very low in phosphorus, potassium and calcium, but which contained an abundance of protein and other organic nutrients, made very little increase in muscles and bone ash."

1."Osteomalacia often results from a deficiency of calcium and phosphorus in the food. If the deficiency of mineral nutrients is not pronounced but is long continued the symptoms will be merely lack of development of parts requiring the most mineral nutriment, namely the bones. The animal will lack size. Muscular growth and other proteid increase is also interfered with on two accounts, first, because of the lack of mineral constituents of proteid tissues and second, because the acids resulting from the breaking down of proteids in the life processes interfere with the carrying off of carbon dioxide by the blood by uniting with the alkali carbonates which normally figure in that process. This causes a retention of carbon dioxide in the tissues and blocks the process of oxidation. In mild afflictions the growth made by the animal consists very largely of fat; first, because the food is deficient in the mineral substance essential to the construction of proteid increase and second, because oxidation processes are so interfered with that no alternative remains in the disposi-

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1. Ohio Bul. 201, p. 140 - 141.

tion of the nutriment but to make it into fat. In severe cases symptoms of asphyxia develop."

1."The lack of mineral matter in a hog's ration often results in the animal breaking down on the way to market. It is often responsible also for the breaking down of sows with litters. The secretion of milk calls for more calcium and phosphorus than corn contains. To make good the deficiency the sow takes calcium phosphate from her bones. This appears to cause a weakening of the tendenous attachments but may proceed until the shaft of the leg bone fractures. These cases of breaking down of brood sows are curable without especial difficulty, by taking away the pigs and feeding foods rich in calcium and phosphorus.

"A young hog in one experiment after several weeks on a low ash ration, broke a leg but made a complete recovery after a number of weeks on a high ash ration."

2."Judging by the results of the experiments which were made with small animals (rabbits and dogs), a deficiency of food calcium does not effect body weight or growth in general provided the deficiency is not too great. The ill effects of such a deficiency are confined almost exclusively to the skeletal system and resemble clinically and anatom-

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1.Ohio Bul. 201, p. 163
2.H. Aron and R. Sabener E. S. R. 20, p. 170.

ically the pathological condition known as rickets. Chemical analyses showed that such bones had normal weight but contained a larger proportion of water, and less dry matter than normal bones and that the dry matter was deficient in mineral constituents. It was apparent therefore that deficiency in food calcium caused the formation of bones with excess of water and with organic material insuffiently calcified."

1."On a ration extremely low in phosphorus (and low in calcium also) pigs made as large gains up to 75 and 100 pounds, when starting at weights of from 40 to 50 pounds as animals receiving an abundance of this element. After reaching this point loss of weight began, followed by collapse."

It seems that the bad effects of a ration too low in calcium and phosphorus to meet the needs of the animal are not noticeable at first. The animal may grow normally and make normal gains for awhile. During this time the bones are evidently being depleted of minerals. Later the animal begins to show signs of weakness in the bones and usually becomes unthrifty. The length of time that an animal will continue to gain normally on a low calcium and phosphorus ration will of course depend on how

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1. Wis. Res. Bul. 1, p. 37.

deficient the ration is in minerals.

As we have seen, the same effect would be brought about by a deficiency in one of these minerals as in both, unless perhaps a great preponderance of phosphorus in proportion to the calcium present might produce symptoms of poisoning as has been suggested by some.

How Does the Amount of Calcium and Phosphorus Compare in Feeds for Cattle?

1."The mineral content of any species of plant varies considerably as affected (1) by the composition of the soil and soil water, (2) by the various factors controlling transpiration of water by the plant and (3) by loss of mineral substance either thru shedding of parts or thru the leaching effects of dews and rains.

"A general method is to be seen in the distribution of the mineral substances in the various parts of the plants. Leaves as a rule are rich in ash because of the mineral substances carried there in solution and left behind by the transpiration of the water. Seeds and roots are comparatively poor in ash because of the storage in them of ash-free carbohydrates and fats and low-ash proteids.

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1. Ohio Bul. 201, p. 151

"The ash constituents of seeds and leaves differ in a general way, the mineral elements in the seeds being largely those which are essential to the growth of the young plant, while a considerable part of the ash of leaves may be considered as residual and in no way essential. The mineral constituents of grains are much more largely organic than are those present in leaves."

1."It is a well known fact that in many regions malnutrition of the bones, is caused in all of the larger farm animals in dry seasons, thru the abnormally low calcium and phosphorus content of the grass and other forage at such times.

"This poverty of the grass in bone food seems to be due to the lessened transpiration of water by the grass during a drought. There seems to be less transpiration per pound of growth of dry substance in a dry year than in a wet one, other things being equal, and thus less mineral is carried into the plant in solution in the soil water.

"Von Seelhorst found that in a dry soil clover contained 15.5 -- 18.1 per cent less phosphorus than in wet soils, and that fertilizing the crop also increased the percentage of phosphorus.

"Bongartz concluded that the epidemic of osteomalacia in the spring of 1894 was due to the drought of

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1. Ohio Bul 201, p. 170.

1893. He quotes analyses by Stutzer showing that the phosphorus content of common foodstuffs was abnormally low in this dry season.

Phosphorus, parts per 1000

Feed	1894	normal
Stock beets	.19	.35
Straw	.37	1.09
Hay	1.27	1.88
Wheat bran	11.13	11.74

"At the Hawaiian Experiment Station, Shorey found that sisal grown on a coral limestone soil contained 40 per cent of lime in the ash, while the same species of plant grown on another soil which was poor in lime contained only 7 per cent of lime in the ash."

1."Blue grass samples at all the same stage of growth, from Ohio and Kentucky vary in ash between 4.80 and 8.66 per cent, in calcium between .135 and .424 per cent, and in phosphorus between .164 and .403 per cent."

2."An abundance of **moisture during** growth increases, to a slight extent, **the phosphorus content of grass and** certain other forage plants.

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1. Ohio Bul. 222, p. 52
2. Ohio Bul. 222, p. 53.

"Soils which are naturally rich produce blue grass which is high in content of mineral elements, but manure and other fertilizers when applied to poor soils also produce blue grass which is rich in mineral elements."

Reference to a table in Ohio Bulletin 201 which gives the mineral composition of common feeds, shows us that potassium is easily the most abundant mineral in common cattle feeds, with calcium, mangesium and phosphorus next in quantity and probably about equal in amount.

As has been shown (see page 5) the mineral matter of cattle is made up to a far greater extent of calcium and phosphorus (83--90 %) than of the other minerals. This shows at once that the animal must exercise a selective action in the retention of the mineral elements.

Analyses show us that the mineral content of feeds is quite variable. It is quite common to see an analyses of some one feedstuff showing twice as much calcium as another. A far greater variation is shown in roughages than in grains due perhaps partly to the variety of stages in which roughage may be cut and cured as well as to the factors already noted. Such a wide variation in any of the more common constituents of feeds is almost unheard of.

Not much is said about the low calcium content of roughages as contributing to epidemics of osteomalacia but from a study of the American analyses of feedstuffs

TABLE I.

Composition of some common feedstuffs compiled from American Analyses.

Feed	Percent Ca.	Percent Phos.	Grams per 100 lbs. Ca.	Grams per 100 lbs. Phos.	Ratio between Phos.	Ratio between Ca.
Corn	.015	.294	6.804	133.358	1	.051
Oats	.086	.344	39.009	156.038	1	.249
Bran	.157	1.067	71.215	483.991	1	.147
Linseed meal	.375	.752	170.100	341.107	1	.489
Cottonseed meal	.222	1.179	100.699	534.794	1	.197
Gluten Flour	.084	.183	38.102	83.009	1	.459
Gluten Meal	.084	est.140	38.102	63.504	1	.600
Cottonseed Hulls	.129	.109	58.514	49.442	1	1.183
Timothy	.336	.197	152.409	89.359	1	1.706
Cowpea hay	.908	.227	411.869	102.967	1	4.000
Red Clover	1.544	.240	700.358	108.864	1	6.433
Alfalfa	1.251	.230	567.453	104.328	1	5.439
Stover	.565	.278	256.284	126.101	1	2.032
Silage	.207	.048	93.895	21.773	1	4.312
Green corn	.187	.046	84.823	20.866	1	4.065
Alfalfa	.758	.139	343.829	63.050	1	5.453
Milk	.106	.082	48.082	37.195	1	1.292

it would seem that this element is subject to quite as large variations as is the phosphorus. It seems to be quite reasonable to suppose that the lack of calcium is as much the cause of outbreaks of osteomalacis as is the lack of phosphorus.

Table I brings out the fact that the leguminous hays are high in ash and especially high in the proportion of calcium to phosphorus. Timothy hay and corn stover contain very much less calcium and phosphorus and the proportion between these two elements is more nearly equal.

All of the concentrated feeds contain relatively more phosphorus to calcium than do the roughages. Corn is characterized by its very low calcium content and its very low proportion of calcium to phosphorus. Oats are also low in calcium altho the proportion of calcium to phosphorus is considerably greater than is true of corn. Bran, a feed which is popularly supposed to be very high in mineral matter, is not high in its calcium content but does contain a very high percentage of phosphorus in comparison to the calcium content. Of the high protein feeds gluten flour and gluten meal contain much the less ash. Cottonseed meal contains a very high phosphorus percentage in comparison to the calcium.

In milk the calcium is considerably more abundant than phosphorus. The ash analyses of feeding stuffs are,

considering their importance, very scarce. It is impossible to find any published analyses of some rather common feeds.

How Much Mineral Matter Do Growing Cattle Require?

1."The maintenance requirement of mineral matter is comparatively slight; for growth it is very much greater; greatest among rapidly growing animals such as swine and poultry, and among mature animals such as laying hens and milking cows which are fed for proteid increase."

2. An experiment by Soxlet with a 2-3 weeks old calf weighing about 110 pounds and fed 8093 grams of milk daily containing 62 grams of total ash furnishes the following data concerning the retention of minerals,-

Daily mineral intake and retention.

Ash in Milk.	In milk Grams	Retained Grams	Retained Percent
Whole ash	62.05	32.89	53.0
Calcium	10.54	10.23	97.0
Magnesium	.82	.25	30.5
Potassium	13.04	2.70	20.7
Sodium	3.50	1.02	29.1
Iron	.07	.0265	38.0
Phosphorus	8.25	5.98	72.5
Chlorine	6.75	.26	3.8

1. Ohio Bul. 201, p. 160
2. Kellner, "Die Ernahrung der landw. Nutztiere", p. 461

1.Kellner, reasoning from the very small excretion of calcium in this experiment, concludes that more calcium, if present in the milk, would have been used and with it a correspondingly large percentage of the phosphorus. Kellner recommends the addition to milk for a calf of 15 grams calcium carbonate daily.

2.K. Fittcher made an investigation with 27 calves to compare the feeding value of raw milk, with cooked milk both with and without the addition of certain minerals. The minerals added were sodium chloride, calcium citrate, monocalcium phosphate, and calcium chloride respectively.

The cooked milk with the addition of two grams of sodium chloride to the liter gave the best results. There seemed to be no advantage in adding the calcium salts as far as gains were concerned. The experiment lasted about five months.

The results of this experiment should not be taken as final as the amount of calcium salts added was approximately only .04 to .06 per cent.

3.J. Lehmann experimenting with a five months old healthy calf weighing 143.5 kg. which was fed daily 2 kg. timothy hay, 10 kg. whey, .5 kg. rape seed meal cake and .5 kg. crushed barley showed that the animal made use of the lime and phosphoric acid in the ration as given in the following table,-

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1. Kellner, "Die Ernährung der landw. Nutztiere", p. 472
2. Kellner, " " " " " p. 466
3. Kellner, " " " " " p. 471

	Lime grams.	Phosphoric acid grams
Took in the feed	24.5	39.2
Gave out in dung and urine	14.2	21.0
Retained in the body	10.3	18.2
Per cent retained in the body	42.0	46.0

H. Weiske in a similar experiment with two 5-6 months old calves given a ration composed of meadow hay, chaff, oats, crushed corn and rape got the following results,-

	Lime, grams		Phosphoric acid, grams	
	No. 1	No. 2	No. 1	No. 2
In the feed daily	26.7	31.4	32.7	34.2
In the excreta	13.1	14.3	14.4	11.9
Retained in the body	13.6	17.1	18.3	22.3
Per cent retained	51	54	56	65

The per cent retained in this experiment may be taken as the very highest since in another part of this same experiment where the intake of calcium and phosphorus was still less the per cent excreted was still higher.

These experiments show that only about half of the calcium and phosphorus of ordinary feed will be retained by growing cattle.

From these experiments Kellner estimates that 40 to 60 grams of lime and phosphoric acid each must be fed daily in the ration of a calf not getting milk.

As far as is known now the most satisfactory way of reaching approximately the calcium and phosphorus requirements per pound of gain for a growing calf, is to calculate the amount of calcium and phosphorus in the gain in weight and divide this by the pounds of gain. The result will then equal, according to Weiske's experiment, 52.5 per cent of the calcium required and 60.5 per cent of the phosphorus required.

This calculation has been made using the actual gains in weight made by the Jersey heifer No. 14 and the Holstein heifer No. 222 from birth weight up to the age of two years. The results are given in Table 2.

Table 2.

Estimate of Minerals Required per Pound of Gain.

	No. 14		No. 222		Average		Ratio.	
	Gms.Ca.	Gms.P.	Gms.Ca.	Gms.P.	Gms.Ca	Gms.P.	P.	Ca.
Actually in lb. of gain	6.955	3.688	7.008	3.711	6.981	3.699	1:1.887	
Required to supply this -milk	7.170	5.087	7.224	5.119	7.147	5.103	1:1.400	
Required to supply-in hay & grain	13.248	6.095	13.349	6.134	13.298	6.114	1:2.174	

TABLE 3.

Feed to age 2 years	No. 14 Feed	Ca. in Gms.	P. in Gms	No. 222 Lbs. Feed	Ca. in Gms.	P. in Gms.
Birth weight	55	313	175	90	512	286
Wt. at 2 yrs.	607	4152	2211	706	4829	2571
Milk, pounds	2880	1385	1071	3022	1454	1124
Alfalfa hay	7855	44577	8193	8301	47108	8658
Green alfalfa	186	640	117	1414	4854	892
Cowpea hay				154	634	159
Total mineral in hay		45217	8310		52597	9709
Ratio		5.441	1		5.417	1
Minerals of milk retained		1344	777		1410	815
Minerals of hay retained		23739	5028		27613	5874
Total minerals retained		25083	5805		29023	6689
Minerals est. in gain		3839	2036		4317	2286
Difference		22244	3769		24706	4403

In Table 3 the minerals present in the calf at birth and the minerals present in the body at the age of two years are calculated from the percentage composition of the new born calf (Vannatti) and the half ox (Lawes & Gilbert).

The minerals retained in milk and hay are computed from data obtained in experiments by Soxlet and Weiske respectively.

Will Ordinary Rations Supply Enough Calcium and Phosphorus for Growth?

Supposing that these requirements are approximately correct it is of interest to note how common rations for growing cattle compare in calcium and phosphorus with these requirements.

Among the experimental animals at the station are the Jersey heifer No. 14 and the Holstein No. 222. These two heifers had been raised up to the age of two years on alfalfa hay as the only food besides the milk received for the first six months. The exact amounts of both milk and hay consumed by these animals are known as they were never turned on pasture.

These heifers were at all times thrifty, vigorous and in good physical condition.

The data from these two animals are used in making out Table 3.

While the growth produced from this ration is seen to be only medium it is clear that the limiting factor is neither calcium nor phosphorus as these were supplied in abundance. A lack of energy was probably the limiting factor.

This table also bears out the opinion already expressed, namely that there may be a large amount of cal-

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TABLE 4.

In this table the gain and the milk fed are taken to be the same as for the animals in Table 3.

Feed to age 2 years	Jersey			Holstein		
	Lbs. Feed	Ca. in Gms.	P. in Gms.	Feed Lbs.	Ca. in Gms	P. in Gms.
Silage	8600	8075	1875	9600	9014	2093
Cotton S. Meal	1135	1142	6070	1270	1278	6792
Bran	719	511	3480	897	639	4341
Total mineral in hay and grain		9728	11425		10931	13226
Ratio		.851	1		.826	1
Mineral retained in hay and grain		5107	6912		5739	8002
Mineral retained in milk		1344	777		1410	815
Total mineral retained		6451	7689		7149	8817
Mineral est. in gain		3839	2036		4319	2286
Difference		2612	5653		2832	6631

cium present in proportion to the phosphorus if both are abundant, without producing ill effects.

In Table 4 the rations are compounded so that they contain the same protein and energy as the original ration. The protein in this original ration is undoubtedly high and there is reason to expect just as large gains from a ration containing considerably less protein in proportion to the energy.

Table 4 shows that a high protein ration mixed from bran and cottonseed meal and with silage as the only roughage will furnish mineral matter in abundance. However, the ratio of calcium to phosphorus is probably too low for the best results as will be pointed out later.

As it was very evident that the original alfalfa ration was much narrower than need be for good results and as there was no accurate data available regarding the food requirements of growing cattle it was deemed advisable to make out some rations that would have a wider nutritive ratio.

The rations in Tables 5 and 6 are computed to contain the same energy as the original alfalfa ration of Table 3, and the protein is calculated at the rate of .735 pounds to the pound of gain which is the rate it was fed to the corn products lot of the Wisconsin research (see Table 8).

TABLE 5.

The gains are taken to be the same as with the original alfalfa ration. (See Table 3).

Feed to age two years	Jersey			Holstein		
	Lbs. Feed	Ca. in: Gms.	P. in Gms.	Lbs. Feed	Ca. in: Gms	P. in Gms.
Timothy	5000	7620	4470	6000	9144	5364
Cotton S. Meal	776	781	4150	965	971	5165
Corn	455	31	606	300	20	400
Total mineral in hay and grain		8432	9226		10135	10929
Ratio		.914	1		.927	1
Mineral retained in hay and grain		4427	5582		5321	6612
Mineral retained in milk		1344	777		1410	815
Total retained		5771	6359		6731	7427
Minerals in est. Gain		3839	2036		4317	2286
Difference		1932	4323		2414	5141

TABLE 6.

The gains are taken to be the same as with the original alfalfa ration. (See Table 3).

Feed to age two years	Jersey			Holstein		
	Lbs. Feed	Ca. in: Gms.	P. in	Lbs. Feed	Ca. in: Gms.	P. in Gms.
Stover	5000	12815	6305	6000	15378	7566
Cotton S. Meal	728	732	3893	803	808	4294
Corn	890	61	1186	927	63	1236
Total mineral in roughage & grain		13608	11384		16249	13096
Ratio		1.195	1		1.240	1
Retained in roughage and grain		7144	6887		8531	7923
Retained in milk		1344	777		1410	815
Total retained		8488	7664		9941	8738
Est. minerals in gain		3839	2036		4317	2286
Difference		4649	5628		5624	6452

Table 7

Feed to Two Years of Age.

Rations	Pounds	Minerals in Feed Grams Ca.	Minerals in Feed Grams P.	Ratio P.	Ratio Ca.	Total Minerals Retained in Roughage, Grain - Milk. Ca.	Total Minerals Retained in Roughage, Grain - Milk. P.	Sufficient for Pounds Gain Ca.	Sufficient for Pounds Gain P.
Cowpea Hay	6500	26767	6688						
Corn	2000	136	2666	1	2.816	15501	6455	2220	1745
Clover Hay	6500	45519	7072						
Corn	2000	136	2666	1	4.688	25355	6688	3632	1805
Alfalfa Hay	6500	36881	6779						
Corn	2000	136	2666	1	3.919	20711	6510	2967	1760
Timothy Hay	5500	8382	4911						
Corn	2000	136	2666	1	1.124	5849	5380	841	1454
Corn Stover	5500	14091	6935						
Corn	2000	136	2666	1	1.482	8846	5605	1267	1515
Silage	7000	6573	1526						
Alfalfa	5000	28370	5215	1	5.183	19722	4874	2134	1315
Silage	14000	13146	3052						
Corn	1200	82	1600						
Oats	600	234	600	1	2.409	8445	4176	1209	1129
Silage	14000	13146	3052						
Corn	1200	82	1600						
Cotton S. Meal	300	302	1604	1	2.163	8481	4580	1214	1238

Either of the rations given in Tables 5 and 6 furnish an abundance of mineral matter for normal growth. However, they might not give good results as the proportion of calcium to phosphorus is very low. If it were possible to feed a ration similar to either of these with good results it would lessen the expense of raising heifers very materially.

In Table 7 are given a number of rations that might be fed in ordinary farm practice. No account is taken of the balance of these rations and consequently no accurate estimation can be made as to the probable gains. For that reason the pounds of gain are estimated which the minerals present would be capable of producing (see Table 2) provided the protein and energy in the food were sufficient. This figure is obtained by dividing the grams of mineral retained in the feed by the mineral actually in a pound of gain.

This table indicates that there is very little possibility of any ordinary ration, if supplied in abundance, being too low in mineral matter to support normal growth. The phosphorus supply will practically never be deficient. The calcium is more likely to be low altho a shortage here is not at all probable in any ordinary ration, if liberally fed.

Table 8 computed from data in Wisconsin Research

Bulletin No. 17 shows some interesting indications regarding the mineral matter of rations.

In this experiment 5-6 months old calves were fed on rations made up entirely from products of the corn, oat and wheat plants respectively. Another group of calves was fed a mixture of equal parts of these three rations. The nutritive ratio was the same for each ration tho the energy values varied.

The results of the experiment show that the corn fed group not only made the largest gains but showed more thrift and vigor than did the other groups. Next in thrift and vigor stood the oats fed group, then the mixture fed group and last of all the group fed wheat products.

The table shows that, according to calculation three of the groups were not building their bodies normally as regards the calcium content. The shortage is very small, however, being less than two pounds in each case. Even if this estimate were exactly accurate such a small shortage would not likely have been noticed by its effect on the animal. It may be said that the most serious effects actually did not come before the end of the first year, but after the animals had come into milk.

A study of (Table 8) will show that the thrift and vigor of the various groups were in exact accordance with the higher proportion of calcium to phosphorus. This

Table 8.

In This Table Only Data From The First Years Feeding Is Taken.

Groups	Feed Pounds	Gain Pounds	Average Intake in Grams Ca.	P.	Ratio P.	Ca.	Excess over Gain Ca.	P.	Energy Per lb. Gain Therms
Wheat	4507	353	3911	5630	1	.695	-896	1770	6.33
Mixture	4799	410	6015	6512	1	.924	-353	2232	6.25
Oats	4536	408	6624	6727	1	.985	132	2371	6.10
Corn	4917	471	7034	6577	1	1.069	- 67	2047	5.87

favorable effect could hardly be attributed to the amount of calcium and phosphorus consumed, for in proportion to the gains made, the oat fed group consumed more calcium and phosphorus than did the corn fed group. Neither could the favorable effect be attributed to the protein consumed as the nutritive ratio was the same in each ration.

Since the thrift and vigor of the different groups was in accord with the energy value of the rations it was thought that probably this might account for the better effect of the corn ration. However,this cannot be true for in considering the gain in weight the corn fed group used less energy than any of the other groups.

It seems probable that the effects of the various rations may be traced to the low proportion of calcium to phosphorus. By comparing the ratio of these two elements in these rations with the ratio as calculated to be most desirable for a pound of gain (see Table 2) we find that the corn ration contained only about one-half the optimum amount of calcium while the wheat ration contained only about one-third of the desired amount.

REPORT OF AN EXPERIMENT DESIGNED TO COMPARE RATIONS OF LOW AND HIGH ASH CONTENT FOR GROWING CALVES.

Object

The object of this experiment was to compare two rations, one of high calcium and phosphorus content and the other of low calcium and phosphorus content, in their effects upon growing calves.

Outline of Experiment

1. To feed one calf on a basal ration low in calcium and phosphorus.

2. To feed one calf on the basal ration to which calcium and phosphorus has been added in inorganic form.

3. To continue the feeding long enough to get marked effects.

4. To measure the results by general observations, by certain skeletal measurements, and by weights.

Calves -- Two pure bred Jersey heifer calves, numbers 85 and 86, were selected for the experiment. When weaned from skim milk 85 was 6 months, 19 days old and 86 was 4 months, 28 days old. Both calves were in a thrifty, vigorous, growing condition but were not fat.

Rations -- The basal ration was composed of a mixture of three parts gluten meal and two parts corn chop, with silage as the only roughage. This particular ration was selected because it furnished protein and energy in abundance, gave sufficient bulk to the ration and yet supplied mineral matter in small amount. To make the other ration 40 grams of steamed bone meal and 15 grams of chalk daily were added to the basal ration.

Feeding -- After weaning the calves were kept for several days on a ration of clover hay and a small amount of grain mixture made up of two parts corn chop and one part oats. They were then gradually changed to the basal ration. To make this change required four or five days.

As soon as the calves were established on the basal ration the bone meal and chalk was added to the ration for 86 and accurate weights of all feed were kept.

Stabling -- The calves were kept in small box stalls bedded with shavings, and were watered from pails so that they had no access to edible material other than the ration given.

Observations -- The calves were watched closely from day to day and at times were turned into the lot and their actions noted. Certain skeletal measurements were

taken at intervals. Weights were taken each Monday morning. The weights at the beginning and ending of the trial were taken for three days in succession and the average used.

Discussion of Results.

When the calves were first put on their respective rations they ate well but at the end of about a week both went off feed and did not regain their normal appetites again for about two weeks. The similarity of their behavior during this time is remarkable. They did not appear to be sick in any way, except as evidenced by a slight looseness of the bowels, but seemed merely to lose relish for their feed.

On these rations the dung of both calves became normally rather firm, was greenish black in color and gave off a sour odor.

As shown by Table I the gain in weight is very much in favor of 86. This calf made a gain of 1.68 pounds daily as against 1.33 pounds by 85. This difference in gain may probably be attributed to the addition of the bone meal and chalk. It cannot be traced to the protein or energy value of the rations as 85 consumed per pound of gain .71 pounds protein and 3.6 therms energy as compared

TABLE I.

A summary of the calcium and phosphorus intake of each calf from Dec. 16 - May 1.

	Calf 85			Calf 86		
		Intake in Gms			Intake in Gms	
	Pounds	Ca.	Phos.	Pounds	Ca.	Phos.
Wt. at beginning	263			229		
Wt. May 1.	444			457		
Feed, Gluten Meal	311	118	197	297	113	189
Corn Chop	207	14	276	198	13	264
Silage	1347	1265	294	1515	1423	330
Total intake of Ca. and P.		1397	767		1549	783
Ratio		1.82	1		1.96	1
Estimate of amt. retained		733	464		813	474
Grain in 136 days	181	966	550	228	1217	693
Difference in Ca. and P.		-233	-86		-404	-219
Bone Meal				5440*	1312	620
Chalk				2040*	816	

*Grams.

In this table the weights of the calves are the average of the weights on three successive days. The percentage of calcium and phosphorus contained in the different feeds is given in Table I, page 31. The amount retained is calculated from Weiske's figures. The composition of the gain in weight is considered the same as that of a fat calf analyzed by Lawes and Gilbert.

to .54 pounds protein and 2.9 therms energy per pound of gain for 86.

The difference in gain might possibly be due to better digestion by 86 or a lower maintenance requirement but these differences are probably very slight. It might also be possible that calf 86 made a higher protein increase or an increase containing a higher proportion of water than did 85 altho there is no evidence to support these views.

In Table I it is estimated that the shortage of calcium and phosphorus, as these minerals were supplied in the grain and silage, was approximately twice as great for 86 as for 85. Still 86 did not give as much evidence of injurious effects as did 85. This indicates that the calcium and phosphorus of the bone meal and chalk were being used to advantage.

It is doubtful whether enough calcium and phosphorus were added to the ration of 86 to meet all needs, for if the phosphorus of bone meal is retained only to the extent of 13 per cent as determined by Köhler (see page 17) there will still be a considerable shortage of phosphorus. If the same figure is used to figure the retention of calcium in the bone meal and chalk, calcium also appears to be lacking.

As shown by Table I calf 86 consumed a considerably larger amount of silage than did 85. From the first 85 showed a stronger liking for grain than did 86. This distaste for grain and favor for silage by 86 was at first attributed to the bone meal and chalk which were fed mixed dry with the corn chop and gluten meal. This seemed to be partly correct for when the bone meal and chalk were fed mixed with the silage the grain mixture was eaten readily altho the calf's preference for silage was still noticeable.

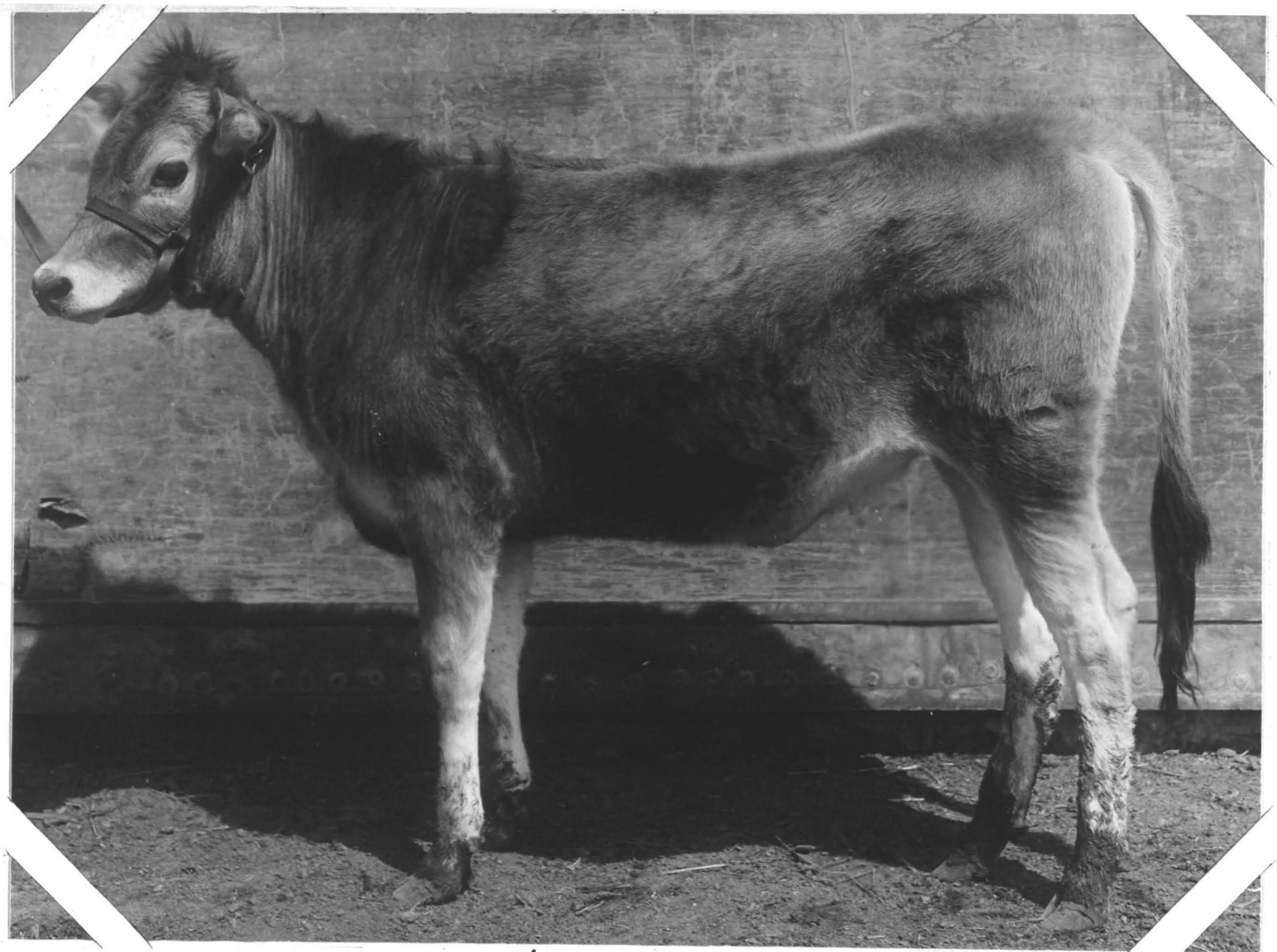
At all times after the first few weeks of the experiment 86 showed more life and vigor than did 85. When turned into the lot together 86 was markedly more active and playful and was always the agressor in the play between the two. This may have been due to the individuality of the two animals tho it seems unlikely that such a wide difference should exist.

The coat of 85 was in keeping with her actions. The hair stood on end, did not shed readily in the spring, and lacked the lustre of 86's hair. This again may have been due to individuality tho it seems improbable.

When the calves went on the experiment December 16th they were in very much the same condition as regards flesh. When the trial ended May 1 86 appeared fatter and considerably more plump than 85. (See photos.)

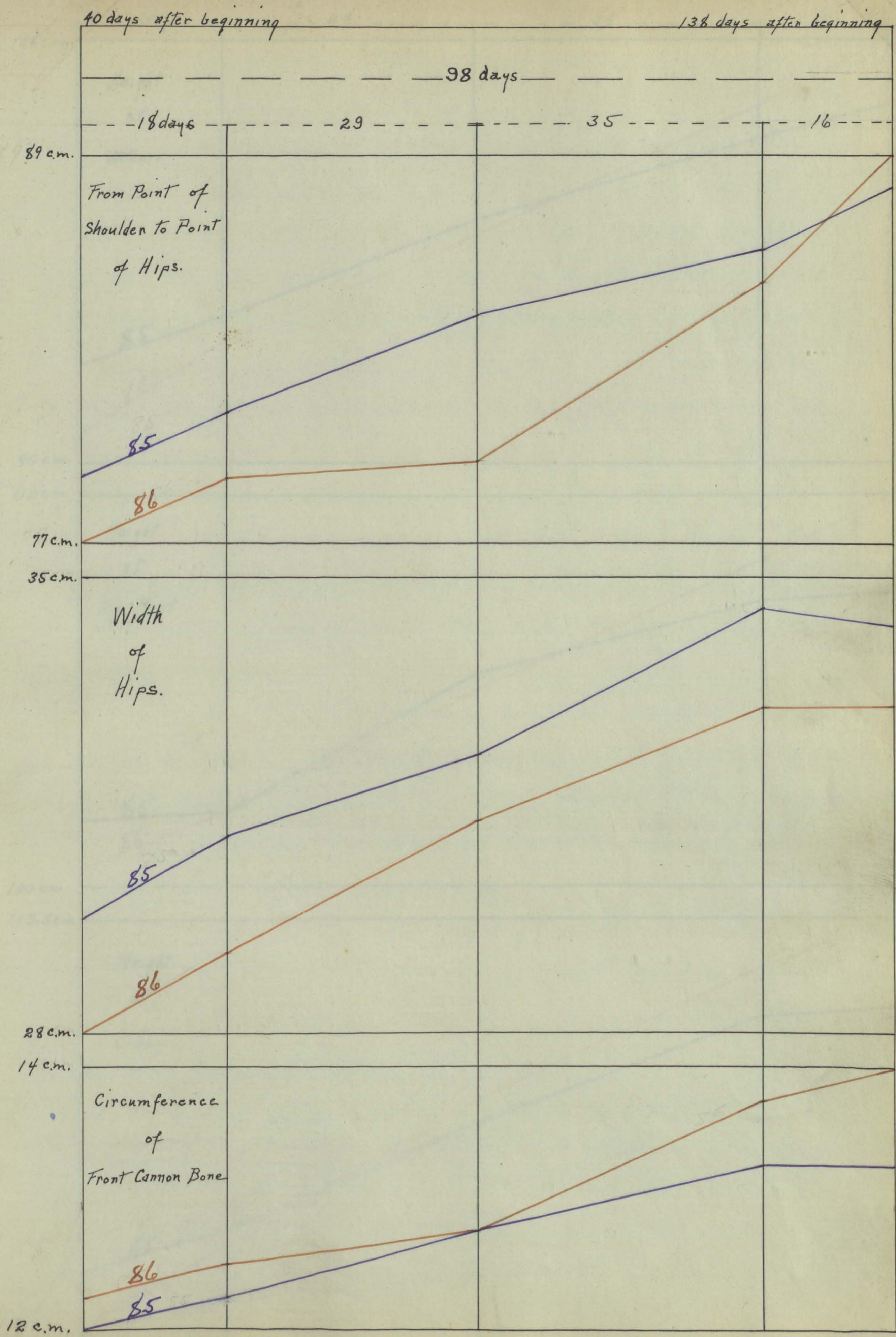
Calf 85. January 24th.

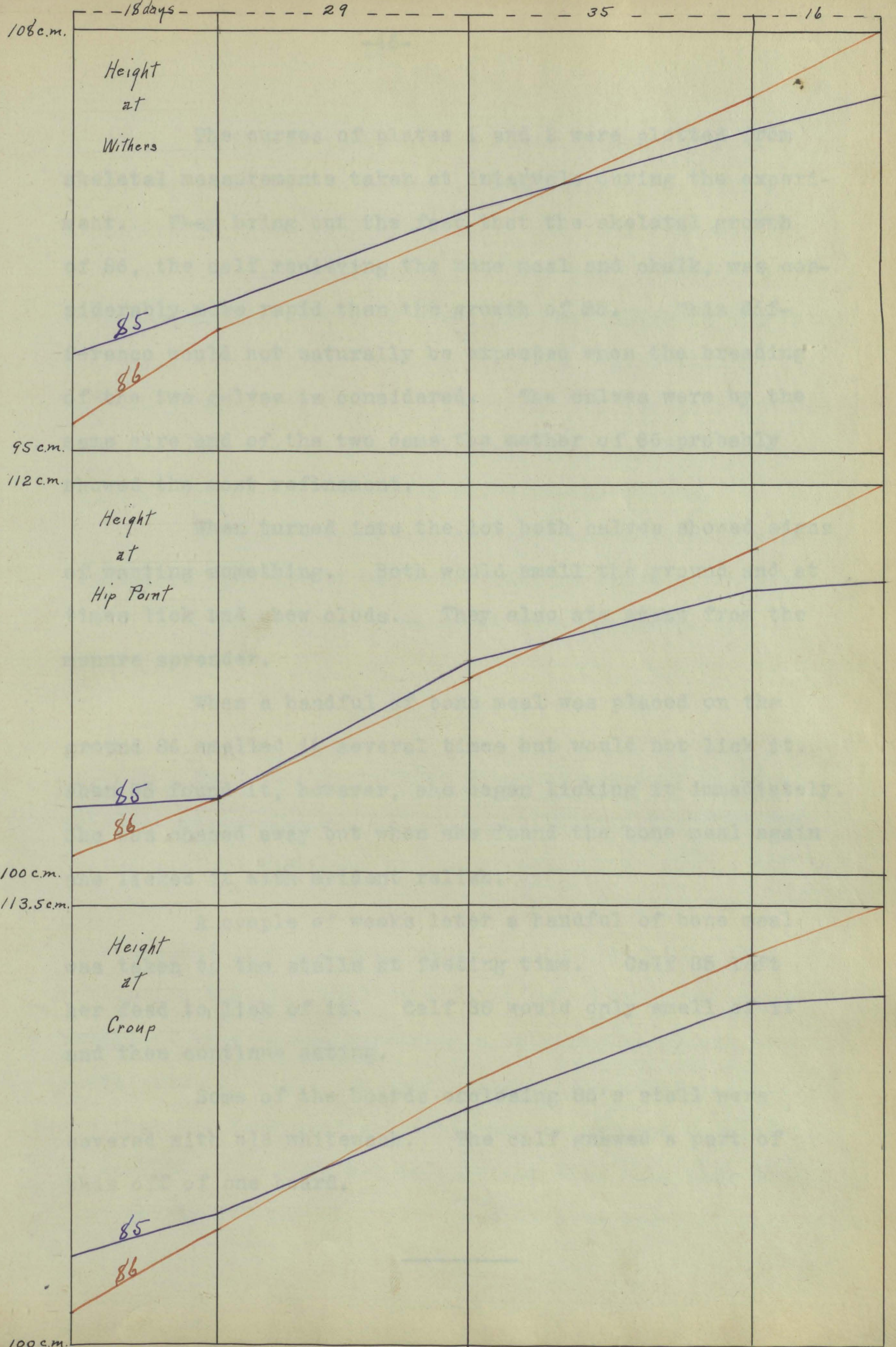
Calf 86. January 24th.



Calf 85. April 16th.

Calf 86. April 16th.


40 days after beginning
138 days after beginning
98 days
18 days
29
35
16
89 c.m.
From Point of Shoulder to Point of Hips.
85
86
77 c.m.
35 c.m.
Width of Hips.
85
86
28 c.m.
14 c.m.
Circumference of Front Cannon Bone
86
85
12 c.m.



18 days
29
35
16
108 c.m.
Height at Withers
85
86
95 c.m.
112 c.m.
Height at Hip Point
85
86
100 c.m.
113.5 c.m.
Height at Croup
85
86
100 c.m.

The curves of plates 1 and 2 were plotted from skeletal measurements taken at intervals during the experiment. They bring out the fact that the skeletal growth of 86, the calf recieving the bone meal and chalk, was considerably more rapid than the growth of 85. This difference would not naturally be expected when the breeding of the two calves is considered. The calves were by the same sire and of the two dams the mother of 86 probably showed the most refinement.

When turned into the lot both calves showed signs of wanting something. Both would smell the ground and at times lick and chew clods. They also ate straw from the manure spreader.

When a handful of bone meal was placed on the ground 86 smelled it several times but would not lick it. When 85 found it, however, she began licking it immediately. She was chased away but when she found the bone meal again she licked it with evident relish.

A couple of weeks later a handful of bone meal was taken to the stalls at feeding time. Calf 85 left her feed to lick of it. Calf 86 would only smell of it and then continue eating.

Some of the boards enclosing 85's stall were covered with old whitewash. The calf gnawed a part of this off of one board.

In the 37 days between March 29 and May 5 calf 85 ate 9½ pounds of salt, or 4.1 ounces daily. Calf 86 at 6 pounds, or 2.6 punces daily. The salt was supplied in a small box at the side of the feed box. This high salt consumption cannot be accounted for unless it was taken to supply a craving for mineral matter. According to the view of Bunge[1] salt may be required in considerable amounts to compensate the animal for losses of common salt occasioned by large amounts of potassium salts in the ration.

The water drunk by each calf was weighed for three successive days and it was found that 85 drank on an average of 19.5 pounds, while 86 drank 21.8 pounds daily.

Conclusions.

This report includes data collected up to May 1 and must be considered only as a preliminary report. The calves will be continued on their respective rations until more marked results are obtained. Nothing definite can be concluded from the experiment up to this point. However, it appears that the lack of calcium and phosphorus in the ration of calf 85 was producing a detrimental effect as regards gain in weight, skeletal growth, and general vigor; and that the bone meal and chalk was being used to advantage by calf 86. It must not be regarded from this that 85 has done poorly but rather that 86 has thrived exceptionally well.

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1. Ohio. Bul. 201. p. 161.

A PLAN FOR FURTHER INVESTIGATION.

This literature reviewed in the first part of this paper suggests in general three questions the answering of which would involve three kindred lines of research. The questions raised are,-

1. Is the whole matter of calcium and phosphorus in the ration of growing cattle an important one in actual practice?

2. What is the proper balance between calcium and phosphorus in the ration of growing cattle?

3. What is the proper amount of calcium and phosphorus to feed or, on what level should they be furnished?

In the review of the literature some light has been thrown on the first of these questions. The point was brought out that the matter of calcium and phosphorus in the ration is not mearly so important in the case of growing cattle as in the case of growing swine. To settle this point the experiment now underway was planned (see preceding report). The tendency of this experiment is to indicate that the matter of calcium and phosphorus in the ration of growing eattle is not of much importance from the standpoint of the dairy farmer because any

ration ordinarily fed will supply an abundance of these minerals for normal growth. However, this whole question of calcium and phosphorus in the ration is of enough importance to warrant further investigation.

Logically the second question is the one which should be answered next. To this end the following experiment has been devised.

Plan of Experiment.

Object.

To determine the proper balance between calcium and phosphorus in the ration of growing cattle.

General Outline.

1. To feed one calf on a ration containing an abundance of calcium and phosphorus in proportion known to give good results.

2. To feed one calf a ration containing an abundance of calcium and phosphorus but having the phosphorus present in excessive amounts.

3. To continue the feeding long enough to get marked results.

4. To measure the results by general observations, weights, skeletal measurements and balance between intake

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and outgo of calcium and phosphorus.

It was planned to test only the effect of an excessive amount of phosphorus for two reasons. (1) Because the effect of an excessive amount of calcium has already been determined in the case of the alfalfa rations reported on page 36 . Alfalfa contains calcium in about as high a ratio to phosphorus as any ration it is possible to feed. (2) Because it is possible in practice to feed a ration containing an excessive amount of phosphorus. Corn, cottonseed meal, linseed meal, bran and soy beans -- all more or less common as feeds -- contain phosphorus in excessive amounts.

It was thought advisable to determine accurately the intake and outgo of calcium and phosphorus at some point in the experiment to find out whether calcium was excreted in excessive amounts due to the large amount of phosphorus present as was the case when insufficient amounts of calcium were fed to a cow along with an excessive amount of phosphorus. (See Wis. Res. Bul. 5).

Details of Experiment.

Calves -- In order to make the results comparable to the results of the experiment now in progress it was planned to use calves as much like those now in use as possible, that is, purebred Jersey calves about five months

old, and as nearly uniform in type and breeding as can be obtained.

Rations -- The rations were made as extreme as possible in the points to be tested. Incidentally the use of these rations may throw light on the question of cottonseed meal poisoning. They are made out to meet the requirements of a calf weighing 300-550 pounds, gaining 1.5 pounds daily. For such an animal one pound protein, five therms energy, 18 grams calcium and eight grams phosphorus is considered a liberal allowance. The rations are as follows,-

High Phosphorus Ration.

Feed	Pounds	Protein	Therms	Grams Calcium	Grams Phosphorus
Timothy	6	.123	2.013	9.144	5.358
Cottonseed Meal	2	.703	1.684	2.014	10.696
Corn	1	.068	.888	.068	1.333
Bran	1	.102	.482	.712	4.840
Chalk	15 gms.	----	----	6.000	-----
Potassium phytate	150 gms.	----	----	----	14.840
Total		.996	5.067	18.—	37.—
Ratio				.486	1

Balanced Ration.

Feed	Pounds	Protein	Therms	Grams Calcium	Grams Phosphorus
Timothy	6	.123	2.013	9.144	5.358
Cotton S.M.	2	.703	1.684	2.014	10.696
Corn	1	.068	.888	.068	1.333
Washed Bran	1	.066	.482	.725	.589
Chalk	40 gms.	----	----	16.000	----
Total		.960	5.067	28.—	18.—
Ratio				1.55	1

Note;- The calcium and phosphorus content of the various feeds, with the exception of the washed bran and the potassium phytate, is given in Table I page 31. The composition of the washed bran is taken from Wis. Res. Bul. 5, page 178. The composition of the potassium phytate is calculated from the table on page 184 of the same bulletin and directions for preparing this substance will be found on page 177. The name potassium phytate is used here to avoid confusion in reference altho according to Tech. Bul. 22 of Geneva, N. Y. Sta. this is not a phytate.

Feeding -- The calves should be accustomed to the ration gradually and accurate weights of all feed should be

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kept. Feeds should be given in accordance with the appetites of the calves but always in the proportion of 1 pound of grain mixture to 1½ pounds of hay. The chalk and phytate should be fed mixed dry with the grain.

It is expected that the calf will eat the phytate readily as it is reported to have a pleasant taste and smell and was fed to a cow at the Wisconsin Station without any trouble.

Stabling -- The calves should be kept at all times in comfortable box stalls bedded with shavings so that they will have access to nothing edible besides their rations.

Observations -- The calves should be observed and any change or abnormality noted. Weights should be taken each morning after the calves have been fed and before they have been watered. Certain measurements should be taken at intervals of a month. These measurements should be taken in the morning after feeding and before watering. The measurements to be taken are,-

1. Height at withers
2. Height at point between hip bones
3. Height at point of hip.
4. Width of hips
5. Circumference of chest
6. Circumference of barrel over last rib
7. Circumference of front cannon bone
8. Circumference of hind cannon bone

After the experiment has been in progress for some time the intake and outgo of calcium and phosphorus should be determined accurately for a period of a week.

If the results of this experiment justify it other rations, less radical in their ratio of calcium to phosphorus, should be tried and the proper balance between calcium and phosphorus arrived at in this way.

The object of further investigations on this subject after the proper balance has been determined should be to find out the actual amounts best suited to the needs of a growing calf. This can best be done by actually trying rations containing differing amounts of these substances rather than by paying too much attention to the excretion of calcium and phosphorus because, (1) these minerals may be used over and over again before being excreted, and (2) the balance between the different minerals may control the excretion to some extent.