THE ROLE OF CALCIUM AND PHOSPHORUS IN ANIMAL NUTRITION

By FRANK T. BINGHAM, '25

The Health and Vigor of the Animal is Largely Dependent on the Proper Balance of Calcium and Phosphorus in the Body. Legumes Proved High in Calcium

ALL the mineral elements which go to make up the composition of the animal body, when taken as a whole, may be classified as ash. To enumerate the functions of each in detail would be the writing of a large and voluminous publication, so the writer will confine his efforts to the two most important elements, calcium and phosporus.

The elements which appear in the ash are iron, magnesium, calcium, potassium, sodium, chlorine, sulphur, phosphorus and a few others of less importance to us from the viewpoint of nutrition. Within the living body these elements exist in the form of inorganic salts or complex nitrogenous substances such as proteids.

Since calcium and phosporus might be termed economic factors to the farmer in the proper nutrition maintenance of his farm animals, it is well that these two particular elements be stressed for the sake of specificity.

As to quantity, calcium and phosphorus compose the major portion of the ash. Approximately three-fourths of the ash of the body is composed of calcium oxide. About seven-eights of the ash of the skeleton is calcium phosphate. If the ration does not supply these two elements in the right proportion, they may become the limiting factors in the growth of the animal's skeleton.

In like manner calcium and phosphorus are usually the limiting factors in plant growth, and the addition of these two elements in the form of commercial fertilizers oftimes remedies the deficiency. When calcium and phosphorus are lacking in the soil, the crop yield is not only lessened, but the feed value of the crop is impaired also. Then when these same crops are fed, the low mineral content becomes a limiting factor in the production of bone, muscle, milk, or eggs. This fact is illustrated by the small stature of animals that live on the more or less barren soils in various parts of the world. Thus it is apparent that the supply of calcium and phosphorus compounds in forage crops is of vast importance to those making stock feeding a business, and a system of agriculture that does not maintain a plentiful ash supply cannot be self-sustaining.

Two Year Old Hereford Steers Fed on a Ration of Hegari Which Furnishes Plenty of Calcium and Phosphorus in Addition to Fats, Carbohydrates and Proteins.

It is but recently that the importance of the mineral elements in foods has been allotted its rightful place. The reasons for this are several. First, it was long supposed that all feeds contained the ash elements in abundance. Next, it was thought that very little mineral food was required to nourish, for the ash content of the animal body was relatively small; and besides, it was known that the animal's system ordinarily held quite a supply of ash material in reserve and the effects of a low ash ration were not immediately apparent. Then to complicate the difficulty of estimating

the amount of ash material assimilated was the fact that waste ash elements were excreted into the intestines and appeared in the feces along with the unassimilated ash material. The result of this was that the ash requirements were usually underestimated. For these reasons knowledge concerning the mineral constituents of the body and in foods has not kept pace with advancing knowledge of the proteins, carbohydrates, fats, and the percentages necessary in a ration to best meet the needs of the body. Consequently feeding standards omit the ash requirements.

Although most feeds given livestock probably do meet the needs of the animals for ash, there are several, however, Indian corn for instance, that, being low in calcium and phosphorus, will not provide enough ash unless fed in conjunction with other feeds high in mineral content.

In our present day endeavor to secure rapid growth and early maturity there needs must be a demand for bone making material. The practice of milling grains gives products poor in ash, but comparatively rich in proteins and carbonhydrates. Ingle, as quoted in Forbe's Bulletin No. 121 of the Ohio Experiment Station, says: "Such concentrates as linseed cake, indian corn, oats, wheat, and barley; and such roots and roughages as turnips, mangels, corn stover and wheat straw generally carry as excess of phosphorus over calcium or lime." He (Ingle) also contends that this excess of phosphorus over calcium tends to waste lime or carry it out of the body to an excessive degree thereby making feedstuffs carrying such a proportion unfavorable to normal nutrition.

It will now be in place to state some of the leading uses of calcium and phosphorus in the animal body. Of course, the prime use of these two elements is in the building of the skeleton, since seven-eights of the body frame is compound of the two, or calcium phosphate. There is one-hundred times as much calcium in the bones as in the fleshy tissues, yet this small portion in the soft tissue is of vital importance, in that, in the absence of such there is a consequent drain upon the calcium of the skeleton for support in metabolism. For this reason, no doubt, we often see carnivorous animals chewing on bones, and, the writer has often observed range cattle at the same practice. It is an almost common sight in the drouth striken areas of the arid Southwest to see range animals munching on bones or licking old rusty iron in the endeavor to meet their mineral deficiencies.

The calcium of the flesh has an important function in muscle control and the coagulation of the blood. The physiologist Meltzer states in Sherman's "Chemistry of Foods and Nutrition," that calcium is capable of correcting the disturbances of the inorganic equilibrium in the animal body, whatever the direction of the deviation may be. He also contends that any abnormal effect which sodium, potassium, or magnesium may produce, whether the abnormality be in the direction of increased irritability or of decreased irritability, calcium is capable of restoring the normal balance.

Experiments carried on continuously since 1908 at the Wisconsin Station by Hart, Steenbock, and Humphrey have shown clearly that the beneficial effects of leguminous roughages are due to their richness in lime. Dry cows fed oat or wheat straw, with grain by-products added to make a ration balanced according to feeding standards, have usually aborted or produced weak or dead calves. When calcium has been added to the ration in such forms as calcium phosphate or wood ashes the results have been greatly improved, but the calves have not been as vigorous as where alfalfa or clover hay has formed part of the roughage. Other roughages high in lime have also given good results, including stover, and hay grown on alkali soil. Numerous trials have shown that in forming a ration calcium must be considered.

Milk and the dairy by-products, skim milk and buttermilk, are also rich in calcium, but contain much less than legume hay. The legume seeds, and also cottonseed and linseed meal, are richer than the cereal grains.

In metabolism, all foods on oxidation give a waste of either acid or alkaline reaction. Those high in protein are most sure to be acid. Here it becomes the function of calcium to neutralize these acids which are detrimental unless eliminated. These acids usually appear in the form of sulfuric or phosphoric acid.

Phosphorus exists in the body in both an inorganic and organic form. The latter, we are taught in nutrition, enters into complex proteid form. This particular form of phosphorus makes up a minor portion of the whole, and its source of supply is the proteids of the foods. If the body is receiving proper nourishment in protein, all the requirements for organic phosphorus will be met.

In its inorganic state, phosphorus is found chiefly in the bones as calcium phosphate, yet quite a part of the phosphorus in the soft tissues is inorganic, and much of it is found in the makeup of inorganic salts in solution in the fluids of the body. The supply of inorganic phosphorus is the phosphate salts found in plants in the form of calcium phosphate.

Kohler, as quoted by Forbes of Ohio, states: "Lambs can assimilate and use calcium phosphate, bone ash and steamed bone meal." At the Wisconsin Station, Hart, McCollum and Fuller (per Henry and Morrison) found that pigs were able to assimilate inorganic phosphorus in the form of precipitated calcium phosphate, bone ash, or ground raw-rock phosphate. To illustrate the effects of rations low in calcium and phosphorus, an experiment conducted by the above men will be given:

Five pens of pigs were employed. To the first pen was fed a basal ration low in phosphorus. To the next three pens the basal ration was fed plus the following materials: precipitated calcium phosphate, bone ash and ground raw-rock phosphate. The last pen was used as a check pen and received an ordinary ration well balanced in calcium and phosphorus.

From the preceding table it is quite

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	Lot 1 No. (P) added	Lot 2 Ca (PO)	Lot 3 Bone ash	Lot 4 Ground rock phosphate	Lot 5 Check
Av. grms. (P) fed daily	1.12	5.29	5.45	5.20	5.28
Wt. of pigs at slaughter	77.	87.	85.	82.	87.
Av. gain per pig	32.	42.	35.	43.	58.
Wt. skeleton in grms.	870.	950.	950.	1450.	850.
Breaking strength of thigh bone. Lbs. per sq. mm.	.87	1.70	1.77	1.65	1.86
Percent ash in bones	33.	46.	53.	57.	54.

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evident that bone ash, precipitated calcium phosphate and raw-rock phosphate are good materials to balance rations low in ash, especially where corn is the chief diet.

These same investigators fed a cow a ration deficient in lime for a period of three and one-half months. The animal gave off daily 5.5 oz. more lime in milk and excrement than she received in her food. She gave off in three and one-half months, 25 per cent of all the lime in her body. Such a withdrawal of mineral matter is the cause of porosity and brittleness of bone. In certain localities where the hay and roughage is low in lime and phosphorus, farm animals are so effected by the lack of these elements that their bones are easily broken. Such occurances are most noticeable in years of drouth when little mineral matter is absorbed by the plants.

It is of interest to know that there is a direct relation between the amount of ash in the milks of various animals and the rapidity at which their offspring double in weight. The table below, made out by two German scientists in Bunge's laboratory indicates the relation.

Animal	Time in days for the new born animal to double in weight.	100 parts of milk.		
		Ash	CaO	P
Man	180	2·0	.021	2.22
Horse	60	0.4	.086	.057
Cow	47	0.7	.114	.087
Goat	22	0.78	.143	.122
Sheep	15	0.84	178	.127
Swine	14	0.80	.178	.135
Dog	....	1.33	.321	.222
Rabbit	6	2.5	.636	.437

The foregoing table shows that nature makes ample provision in the food of milk for the need of bone making materials that accompany growth. Hence, we can see how necessary it is that the ration carry a sufficient quantity of bone making material in order that the offspring be properly nourished without a serious drain upon the mother.

There is a vast difference in feeds as regards to calcium. Grain products, not including the outer coat, are particularly low in this element. The outer covering has the more mineral substance. Bran, for example, contains quite a high percent of calcium. Legumes and legume roughages are particularly high in calcium, while corn is comparatively low.

Since it is the problem of every farmer to keep up the size and quality of his animals it behooves him to consider the ash constituents of feeds as well as the carbohydrate, protein, and fat in the making of a perfect ration. And, at the present time, there is enough information available to every farmer concerning ash in animal nutrition to make it possible for him to feed his stock with a much greater degree of intelligence.