A REVIEW OF LITERATURE ON MINERAL NUTRITION IN SWINE

AND

THE EFFECT OF MINERAL ON THE SIZE AND BREAKING STRENGTH OF BONE IN FATTENING SWINE

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A REVIEW OF LITERATURE ON MINERAL NUTRITION IN SWINE AND THE EFFECT OF MINERAL ON THE SIZE AND BREAKING STRENGTH OF BONE IN FATTENING SWINE

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GOODWELL, OKLAHOMA
1929

Submitted to the Department of Animal Husbandry
Oklahoma Agricultural and Mechanical College
In Partial Fulfillment of the Requirements
For the Degree of
MASTER OF SCIENCE
1937

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INTRODUCTION

One of the most serious losses that is suffered by hog raisers and shippers is caused by hogs becoming crippled, leg bones becoming fractured, vertebrae fractured, or ligaments torn. Professor Wiley of Purdue University shows that "cripples" from the country's commercial hog crop cause a loss of three to three and a half million dollars a year.

Animals require for their proper growth and development twelve or fifteen, or possibly more, mineral elements, retaining daily during active growth two or three ounces for every thousand pounds of live weight. The largest requirement of mineral matter by growing, breeding, and lactating animals is for bone growth, or for the secretion of a food (milk) capable of supporting vigorous bone growth in their young.

About 85 percent of the ash of bones is calcium phosphate. Hence, quantitatively, the most urgent need for mineral matter by farm animals is for calcium and phosphorus. It has been estimated that over 80 percent of the mineral matter retained in the bodies of growing animals is calcium and phosphorus.

It may be stated as a general proposition that the leguminous roughages are adequate sources of calcium and phosphorus, except possibly under conditions of excessive demands for bone-forming materials, as with high-producing cows. The non-leguminous roughages are much inferior in this respect, particularly as regards their content of calcium.

REVIEW OF LITERATURE

Breaking Strength of Swine Bones

Rice[1] states that in experiments at the Nebraska Station, as well as the Ohio Station, it has been shown that mineral supplements and feeds rich in minerals do not have an appreciable effect, if any at all, on the dimensions or the volume of the bones, but that they may markedly increase the density, the thickness of wall, the hardness and the breaking strength. As Forbes has well said, big bone can be obtained by breeding for it, but dense bone only by feeding for it. The following figures taken from the Nebraska report show clearly the favorable effect of certain rations on the breaking strength of bones.

Table 1. Comparative Breaking Strength of Bones of Hogs on Various Rations

Average Breaking Strength per 100 Pounds Live Weight

Ration	Femur	Tibia	Humerus	Ulna-radius	All bones
Corn alone	276	252	434	341	325
Corn 75, shorts 25	343	309	555	376	396
Corn 25, skim milk 75	462	360	685	529	509
Corn 90, tankage 10	559	409	740	611	580
Corn 90, ground bone 10	646	465	898	715	681

[1] John B. Rice, The Value of Mineral Supplements in Swine Feeding, University of Illinois Agricultural and Experiment Station Bulletin 250, May 1934.

An increase in strength of more than 100 percent was secured by the feeding of ground bone with corn, and only a slightly smaller increase by the feeding of tankage. These increases are much larger than those reported by Forbes, who, however, started his experiments with heavier pigs, weighing 100 pounds or more. There seems to be no definite upper limit to the storage of minerals in the skeleton and to the increased density and strength associated with it.

As Howard[2] has shown by the following figures, there seems to be no relation between the amount of mineral fed and the circumference of the fore shin.

	Average initial circumference of fore shin	Average final circumference of fore shin	Average gain in circumference of fore shin
Lot I	13.18 c.m.	16.19 c.m.	3.01 c.m.
Lot II	13.52 c.m.	16.26 c.m.	2.74 c.m.
Lot III	13.59 c.m.	15.90 c.m.	2.31 c.m.
Lot IV	13.61 c.m.	16.20 c.m.	2.59 c.m.
Lot V	13.27 c.m.	16.06 c.m.	2.79 c.m.
Lot VI	13.44 c.m.	15.93 c.m.	2.49 c.m.

Data on the breaking strength and wall thickness of the tibia are given in Table 2. The wall thickness and circumference were obtained from a transverse section taken from the smallest part of the tibia. This section was about midway between the two ends of the bone. The

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[2]Maurice B. Howard, The Effect of Mineral on the Size and Breaking Strength of Bone in Fattening Swine, Oklahoma Agricultural and Mechanical College, Master's Thesis, 1931, p. 50.

Table 2. The Breaking Strength, Circumference, and Wall Thickness of Tibia

Lot and pig number	Breaking strength	Circumferences	Average wall thickness
Lot I pig 303	565 lbs.	6.35 c.m.	3.20 m.m.
Lot II pig 459	895 lbs.	6.70 c.m.	3.80 m.m.
Lot III pig 461	630 lbs.	6.25 c.m.	2.80 m.m.
Lot IV pig 32	550 lbs.	6.10 c.m.	3.12 m.m.
Lot V pig 490	690 lbs.	6.40 c.m.	3.41 m.m.
Lot VI pig 498	680 lbs.	5.80 c.m.	3.82 m.m.

average wall thickness was determined by taking three measurements from different sides of the section with a micrometer caliper and taking the average of the three measurements. No determinations relative to the density, volume, or percent of ash of the tibias were made.

As shown in Table 2, there is quite a difference in the breaking strength of the tibias. Should there be any reason to suppose that the skeletal framework of these hogs was representative of their respective lots, it would be entirely in order to offer some explanation or to draw some conclusions in regard to these data. However, if these figures happened to be an average of the different lots, it is only due to chance that they were secured.

Table 3. Mineral Feeding in Dry Lot
Summary for Test of 1908-1909*

Average live weight	Av. breaking strength of bones: Lbs.	Av. breaking strength of bones: Per 100# live weight	Av. length of bones in mm.	Av. circumference of bones in mm.	Av. weight of bones in grams	Av. volume of bones in c.c.	Av. specific gravity of bones	Av. wall thickness of bones in mm.	Percentage mineral matter in green bones
				Lot I. Corn					
150	567	368	16.3	74	595	426	1.22	3.4	33.96
				Lot II. Corn and Tankage					
218	824	387	17.1	77	641	498	1.34	4.2	40.06
				Lot III. Corn, Alfalfa Meal and Bone Meal					
187	888	479	16.7	82	694	513	1.35	4.9	43.35

*Source: Nebraska Experiment Station, 24th Annual Report of the Station, Lincoln, Nebraska.

Table 3 gives a summary of the tests made at the Nebraska Experiment Station[3] in 1908-1909 to determine the effect of mineral and protein when fed as a supplement to corn and the breaking strength and development of bones in hogs. For the data used in the table, the figures in Lot I represent the average of those hogs fed on corn only, Lot II the average of the various lots fed on corn and tankage, and Lot III the average of those lots where bone meal was used in the ration.

It will be observed that the heaviest hogs at the end of the experiment were those fed a ration containing tankage as a supplement. There is a slight increase in the circumference of the bone where hogs have been fed on mineral and tankage over those fed corn alone. There is a decided increase in the percentage of mineral of the bones where hogs have been fed mineral matter and tankage in addition to corn. It will also be observed that the breaking strength of the bones has been greatly increased by the use of bone meal and tankage. The wall thickness was much greater where mineral matter or tankage was added to the ration, than where straight corn was fed.

Sotola and associates[4] give the content for calcium and phosphorus of some of the common feeds as shown in the following list, the content being parts per 100 pounds dry substance. These figures show the calcium deficiency of the cereal grains. It can be seen that one pound of alfalfa hay contains as much calcium as eighty pounds of corn. A ration

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[3] Effect of Protein and Mineral on the Development of Swine, Oklahoma Agricultural Experiment Station, Bulletin 144, p. 32, May, 1922.

[4] J. Sotola, R. T. Smith, E. V. Ellington, and L. W. Cassell, Washington Experiment Station Bulletin 127, p. 7, April 1924.

Feeds	Calcium	Phosphorus	Total Ash
Corn	.014	.303	1.410
Barley	.047	.400	2.624
Wheat	.056	.425	1.866
Peas	.094	.400	2.753
Wheat Middlings	.108	.984	4.630
Tankage	3.242	1.789	17.050
Skim Milk	1.336	.979	7.168
Linseed Meal	.403	.786	6.463
Cotton seed Meal	.291	1.489	7.629
Alfalfa Hay	1.130	.238	6.890
Wheat Straw	.217	.038	3.650

composed of cereal grains is deficient in calcium, but when supplemented with tankage, alfalfa hay or skim milk, it will contain calcium in sufficient quantities. Calcium can be supplied to animals in the form of ground limestone, air slacked lime, crushed oyster or clam shells, whiting, chalk, marl, precipitated calcium carbonate, raw rock phosphate floats, spent bone black or bonemeal.

Mineral supplements containing phosphorus are bonemeal, spent boneblack, rock phosphate, or any of the bone preparations.

Sodium and chlorine can be supplied in the form of common salt. It is easiest fed if kept before the animals all the time.

Stiffness in Swine

Maynard, Goldberg, and Miller[5] claim that both livestock men and experimenters have long been familiar with the fact that pigs in confinement, fed on certain rations, frequently become stiff; that this stiffness may develop to the point where the pig is neither able to rise or to stand; and that the trouble, unless relieved, destroys the usefulness of the animal. The trouble has been referred to be a variety of names, such as lameness, paralysis, rickets, and rheumatism. It most frequently occurs with growing pigs, but brood sows suckling litters also are subject to it.

In 1921 several cases of stiffness developed in a group of pigs on experiment in the agricultural college herd at Cornell University. In referring to what was then known regarding the trouble, it appeared that, although practice had shown that the stiffness could generally be prevented or even overcome by proper selection of the ration, neither the etiology nor the specific pathology blamable for the lameness had been worked out satisfactorily. Hence, an investigation was begun to obtain more exact information as to the dietary relationships and the pathology involved.

A survey indicates that the development of stiffness has been reported with a variety of diets and thus attributed to a variety of causes. Similarly, the pathological findings that have been reported as accompaniments of the external symptoms are by no means in agreement.

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[5] L. A. Maynard, S. A. Goldberg, and R. C. Miller, A Study of the Dietary Relationships and the Pathology of Stiffness in Swine, Cornell University Agricultural Experiment Station Memoir No. 86, pp. 3-29, February 1925.

These facts would lead to the conclusion that the external symptoms under discussion do not have a specific etiology, and are not accompanied by a specific pathological picture. However, the definiteness of this conclusion is limited by the fact that many of these experiments were not sufficiently well controlled because of a lack of knowledge of some of the recently discovered factors in nutrition. This fact will be considered in reviewing certain of these experiments which show the different dietary deficiencies and pathological findings that have been reported as associated with the development of stiffness.

Herter[6] in 1898 studied the effect of a fat-free diet on pigs by feeding skim milk as the sole ration for one year, and reported that the development of stiffness and hemorrhagic eruptions of the skin were the external symptoms. On pathological examination, lesions were found in the spinal cord and the bones of the skull were seen to be porous and brittle. Constipation was constantly present, as would be expected from the nature of the diet, and this trouble may have been a factor in production of the stiffness. Skim milk is clearly unsatisfactory in other respects as the sole ration for swine.

Maynard and his associates have summarized the work of several investigators who have considered stiffness to be a manifestation of scurvy. Holst and Frolich (1912),[7] in connection with their studies of guinea-pig scurvy, produced similar symptoms in pigs on the following diets: rye bread; rye bread and cooked beef; polished rice, cooked

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[6] Ibid.

[7] Ibid.

dried fish, and potatoes. The symptoms were: loosening of the front teeth, bleeding of the gums, petechiae of the skin, subcutaneous hemorrhages, and changes in the bone marrow. Stiffness usually occurred, and on miscroscopic study it was considered to be the nature of polyneuritis. Hence the authors believed the trouble in pigs to be a boundary case between typical scurvy and beriberi. It is clear that the rations used with the possible exception of the one containing fish, were low in calcium and phosphorus, as well as in vitamins.

Plimmer (1920)[8] also advanced the idea that the stiffness was due to scurvy. He reported the development of this trouble with a ration of cooked food which consisted of meal, middlings, and turnips. The stiffness was overcome by the use of uncooked food with the addition of more fresh turnips, some skim milk, and buttermilk. It is evident that the curative ration provided also more calcium and phosphorus.

Morrison, Hart, and associates[9] at the Wisconsin Experiment Station, have made a comprehensive study of the relation of diet to the development of stiffness, from which they evidently conclude that the trouble is rickets.

Morrison, Bohstedt, and Fargo (1922)[10] have reported that a group of pigs fed yellow corn and skim milk developed normally, but in a group fed white corn and skim milk many became rachitic because of a lack of fat-soluble vitamin. The addition of cod liver oil to the white corn ration caused a slow recovery from the stiffness. The in-

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[8] Ibid.

[9] Ibid.

[10] Ibid.

clusion of chopped alfalfa in the white corn ration prevented the development of the trouble.

Experimental studies in the winter of 1921-22, in connection with an experiment, were carried on, in which four pigs, twelve weeks of age, were fed a ration of approximately equal parts of yellow hominy feed and pasteurized skim milk. In addition, they had access to a mineral mixture of charcoal, ground limestone, and salt. Three of these pigs became stiff after approximately ninety days, and two of them were able neither to rise nor to stand. To the ration of these two four ounces of carrots per day and two percent of a mixture of bone meal and calcium carbonate were added. The change of ration over a period of seven weeks put the pigs back on their feet and caused a resumption of their growth. At this time one of the pigs, now able to get around freely but still somewhat stiff, was killed and the leg bones were examined. There were healed erosions of the femoro-patellar joint and of the femorotibial joints, and an increased amount of connective tissue around the hip joints. There was a fracture of both femurs, with beginning callus formation. The bone at the place of fracture was very dense, indicating increased calcification, as would be expected in a healed fracture.

Bohstedt, Bethke, Edgington, and Robison[11] say that grains or seeds and their products are deficient primarily in minerals, and usually in vitamins and proteins. A serious shortcoming in any one of these three is sufficient to cause stunted growth or worse consequences. Salt, or

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11 G. Bohstedt, R. M. Bethke, B. H. Edgington, and W. L. Robison, Minerals and Vitamins in Rations of Pigs, Ohio Agricultural Experiment Station Bulletin Reprinted from Bimonthly Bulletin, pp. 71-75, May-June, 1927.

sodium chloride, is of course a leading deficiency, but this deficiency can easily be met.

Pigs that have become paralyzed, in that they are unable to move their rear quarters, have puzzled veterinarians and animal husbandmen for many years. One of the causes assigned to such instances was kidney worms. In these experiments at the Ohio Station it was found that such cases of posterior paralysis were associated with broken vertebra that would squeeze the spinal cord, thus paralyzing the rear quarters by stopping nerve impulses traveling between the brain and the rear quarters of the animal. No kidney worms were found on autopsy of such posteriorly paralyzed pigs. The ration alone was at fault.

Do minerals improve a grain ration? During four experiments at the Ohio Station the mere addition of two pounds of ground limestone to one hundred pounds of a mixture of white corn, middlings, oilmeal, and salt fed in dry-lot made the difference between a reasonable degree of success and failure, as follows:

Table 4. The Effect of Adding Minerals to
A Grain Ration Fed in Dry-Lot
An Average of Four Experiments, Using a Total of 56 Pigs

Ration	Av. length of experiment	Average daily gain	Feed req. 100 lb. gain	Mortality
Grain mixture	156 days	0.66 lb.	548 lb.	9
Grain mixture and ground limestone	156 days	1.00 lb.	454 lb.	1

The pigs in these experiments were kept in concrete or brick-paved pens. Nine of the grain-fed pigs died, in most cases from pneumonia as the immediate cause. It is known that a vitamin deficiency is a contributory factor to the onset of penumonia.

Several pigs became lame or crampy, and a few became severely paralyzed in their rear quarters. The addition of two pounds of limestone to every 100 pounds of the grain mixture enabled the pigs to gain 0.34 pounds more daily, to save 94 pounds feed for every 100 pounds increase in live weight, and to escape severe stiffness or paralysis, as well as lameness. Near the end of the tests, which averaged 156 days in length, two pigs had a staggering gait, and one severe crampiness, proving that a mineral addition alone could not prevent the effects of a vitamin deficiency.

The Mineral Problem in Swine Feeding

Rice[12] says that for physiological and economic reasons the major part of the ration of swine will always be grain, and the nutritive deficiencies of grains as feeds are therefore of first importance to swine feeders. The advantages of increasing the protein of cereal rations by the addition of suppliments rich in this nutrient, such as skim milk, tankage, linseed oil meal, soybeans, and soybean oil meal, seem now well established, and such supplements constitute an essential part of the most successful rations for swine.

It has been clearly shown by careful balance experiments that cereal feeds alone, and in particular corn, do not provide enough calcium to permit of any considerable retention of this element for the bone and tissue growth. In fact, Forbes[13] has contended that corn alone, or corn supplemented by the seed by-products, linseed oil meal and wheat middlings, cannot maintain the growing pig in calcium equilibrium.

Forbes has shown that when there is a decrease in the intake and retention of calcium there is a marked reduction in the retantion of sodium, potassium, magnesium and phosphorus. The mineral substances of the bone seem to be a mixture or loose combination of carbonate and phosphate, from which the carbonate at least can be selectively withdrawn.

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[12] Rice, op. cit., May 1924.

[13] E. B. Forbes et al., The Utilization of Calcium Compounds in Animal Nutrition, Ohio Agricultural Experiment Station Bulletin 347, p. 44, March 1921.

Table 5. Average Daily Gains of Calcium and Phosphorus in the Skeletons of Pigs on Rations of Corn and a Supplementary Feed*

Ration	Slaughter weight of pig	Average daily gain of calcium	Average daily gain of phosphorus
	Pounds	Grams	Grams
Corn alone	183	+0.069	+0.044
Corn and soybeans	172	-0.229	-0.086
Corn and oil meal	199	+0.220	+0.136
Corn and middlings	201	+0.081	+0.118
Corn and tankage	190	+1.202	+0.583
Corn and skim milk	216	+1.882	+0.900

*Source: Forbes, E. B., Ohio Agricultural Experiment Station Bulletin 285.

In experiments where mineral substances were fed, there was a marked retention in the sodium, potassium, magnesium and phosphorus, this retention being in harmony with the intake and retention of calcium.

Wiley[14] made a study at three of the principal terminal markets on the death and croppled losses of hogs, and found that the shipping hog crop of the country, in transit from local loading points to the terminal livestock markets, shows that 85,000 to 105,000 hogs die annually. At these markets approximately 140,000 to 175,000 hogs are classed as cripples. These estimates are based on a commercial crop of 40,000,000 to 50,000,000 hogs. The death loss for four years averaged 2.13 hogs for each 1,000 of local receipts and the crippled loss averaged 3.46 for the same period. The total loss on the country's

[14] James R. Wiley, Death and Crippled Losses in Shipping Hogs to Market, Indiana Agricultural Experiment Station Bulletin 318, p. 3, November 1927.

commercial hog crop is estimated to be from $3,000,000 to $3,500,000 a year.

Most roughages contain sufficient mineral for all classes of livestock, but since hogs are fed largely on concentrates and are often pushed for an early market under more or less artificial conditions, they suffer more than other classes of livestock from insufficient mineral.

Freeman[15] contends that all our grains are lacking in mineral matter for the pig's needs. Pasture helps to correct this deficiency, as do skim milk and tankage, but even with these supplements some additional minerals usually pay. A supply of minerals should be kept before swine at all times. This is especially important when pigs are fed on poor pasture or in a dry lot. Wood ashes, finely ground limestone, air slacked lime, bone meal and acid phosphate have given good results in experimental work in such combinations as:

1.	Pulverized limestone . . .	30 lbs.
	Bone meal.	30 lbs.
	Salt	30 lbs.
	Sulphur.	10 lbs.
2.	Wood ashes.	10 lbs.
	16% acid phosphate	10 lbs.
	Salt	1 lb.
3.	Pulverized limestone . . .	10 lbs.
	16% acid phosphate	10 lbs.
	Salt	1 lb.
4.	Air slaked lime.	10 lbs.
	Steamed bone meal.	10 lbs.
	Salt	10 lbs.

[15] Verne A. Freeman, Swine Feeding, Michigan Agricultural College Extension Division, Bul. No. 26, pp. 8-9, March 1925.

Freeman also states that if trouble with hairless pigs at birth has been experienced, one can be insured against it by feeding the brood sows iodine during pregnancy.

Thompson[16] found that the rate of gain was decreased by the addition to the ration of a mineral supplement and that the addition of mineral increased the amount of feed necessary to produce 100 pounds gain.

Lot number	Feed and supplement	Average daily gain	Average daily feed consumed	Feed per 100 pounds gain
1	Kaffir	.47	3.77	801.4
2	Kaffir and mineral	.38	3.20	842.0
3	Kaffir and shorts	1.04	4.80	459.5
4	Kaffir and tankage	1.39	6.05	396.0
5	Kaffir, shorts and mineral	.96	4.91	511.5

In the above experiment one percent mineral was fed which consisted of one part $CaCo_3$, and one part precipitated bone meal.

According to Ferrin,[17] corn alone is a high-priced feed. Protein and minerals must be added to make an economical ration. Ferrin also

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[16] C. P. Thompson, Effect of Protein and Mineral on the Development of Swine, Oklahoma Agricultural Experiment Station Bulletin 144, p. 19, May 1922.

[17] E. F. Ferrin, Care and Feeding of Swine, University of Minnesota, Agricultural Extension Division, Special Bulletin No. 74, p. 6, June 1928.

states that the feeding of a mineral mixture is one sign of a successful hog raiser. He further says that the feeds commonly fed to hogs have too little mineral matter to build the framework of an animal that grows as rapidly as a hog.

Godden and Husband[18] say that minerals are needed and are necessary for the maintenance of neutrality of the blood and lymph, this being essential for the normal acting of the body cells. Minerals are needed to maintain a proper physiological balance between the various mineral ingredients in the blood and for the process of digestion. In addition, the growing animal requires mineral ingredients for the formation of new tissue and especially for the skeletal framework.

Robison[19] carried on the following experiment. Pigs, averaging approximately 48 pounds, were divided into lots of seven pigs each and fed to an average final weight of 217 pounds per head. Corn, tankage, and linseed meal were fed in all lots and in addition lot 5 received ground alfalfa. The minerals fed in the respective lots were salt; salt and limestone, 20: 80; salt, limestone, and raw bone meal 20: 40: 40; salt, limestone, and iron oxide, 19.4: 77.6: 3; and salt. The average daily gains in the respective lots were: 1.32, 1.2, 1.19, 1.32, and 1.25 pounds per head.

The addition of limestone or limestone and raw bone meal did not improve either the rate or economy of gains, but the combination used

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[18] William Godden and Alfred D. Husband, Some Aspects of the Mineral Metabolism of Farm Animals, Journal of the Society of Chemical Industry, Vol. XLIV, p. 671, July 3, 1925.

[19] W. L. Robison, Minerals for Feeding with Corn, Tankage, and Linseed Meal to Pigs in Dry Lot, Experiment Station Record, Vol. 62, p. 66, 1930.

in lot 4 made as rapid and more economical gains than the ration fed lot 1. The salt and ground alfalfa fed in lot 5, while not producing as rapid gains, did produce more economical gains than the ration fed lot 1.

Basket[20] showed that sows on a ration of maize meal 65 percent, pollards (wheat bran) 25 percent, and meat meal 10 percent failed to develop strong healthy pigs at weaning time. These sows had been run on pasture until a few weeks before farrowing, then brought in and housed in concrete pens. Under this system of management the sows farrowed an average of seven pigs per sow, of which 2.4 pigs were raised to weaning time.

In December 1924 these sows had a mineral mixture of ground limestone 10, steamed bone flour 25, common salt 10, iron oxide 25, and sulphur 2.5 parts by weight added to their ration at the rate of four pounds to every 100 pounds of basal ration. Under this system the sows averaged 10.4 pigs at farrowing time and raised 7.1 to weaning age. It was evident that while the sows were on the original diet there was an absence of a physiological balance of mineral matter, and the sows could not transmit a proper balance of minerals to the pigs through the milk.

Sinclair and Sackville[21] report the results of two trials with the feeding of minerals to hogs on pasture. The pigs in these experiments averaged from 45 to 55 pounds in weight at the beginning of

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[20] R. G. Baskett, The Effect of Minerals in Overcoming Breeding Difficulties in Certain Sows, Agricultural Progress, pp. 34-36, 1926.

[21] R. D. Sinclair and J. P. Sackville, Some Experiments in Mineral Feeding, Scientific Agriculture 6, No. 11, pp. 273-379, 1926.

the trial. All lots were run on rape pasture, and the grain consisted of oats, barley, and shorts.

In both trials the addition of a simple mineral mixture when tankage was not fed resulted in increased gains and lower feed requirements. Complex mineral mixtures were not as economical, either in rate of gain or feed required, as the simple mixtures.

The addition of a simple mineral mixture to tankage did not indicate tankage needed mineral supplements. In all tests the addition of the simple minerals mixtures to grain alone gave more rapid and economical gains than when tankage was added.

Palmer[22] says that to determine the mineral deficiencies in animals many things must be observed. Among these are:

Iodine deficiency in swine may be determined by the birth of dead, hairless pigs.

Calcium and phosphorus deficiency is not readily recognized until it is serious and of long standing. In time, however, the animals will exhibit a craving for bones. This may degenerate into a desire to eat dirt, chew fence posts, or devour any sort of rubbish.

"Pigs often exhibit a paralytic condition of the joints of either the fore legs or hind legs."

"Mineral elements are not to be regarded as medicine to be fed in doses, but as foods to be supplied daily."

"There is no conclusive evidence that Epsom salt, Galauber's salt, copperas, and sulfur, found in some proprietary mixtures, are of any feeding value."

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[22] L. S. Palmer, Minerals for Farm Animals, University of Minnesota, Special Bulletin No. 94, p. 4-8, September 1924.

Iodine should be fed as sodium or potassium iodide, preferably the former, or as a sea salt from which the iodine has not been removed by refining, or as commerically iodized common salt.

"When it is necessary or advisable to feed phosphorus as a mineral supplement, bonemeal, spent boneblack, or raw rock phosphorus floats, may be used."

When calcium and phosphorus are to be fed together, bonemeal, boneblack, or raw rock phosphate floats can be used. Fertilizer bonemeal is not recommended.

When animals suffering from a deficiency of calcium and phosphorus are offered bonemeal or similar mineral supplement, they will at first eat a large quantity but will later diminish the amount to meet the regular needs.

Wallace[23] suggests that swine raisers who are puzzled about mineral mixtures will find their questions answered in the following formulas which include the essential ingredients combined in the right proportions. A careful survey of experimental work with minerals suggests the following mixtures:

Four parts acid phosphate, or two parts rock phosphate, or one part bonemeal with four parts ground limestone, or six parts unleached wood ashes, or one part air-slacked or hydrated lime with one part salt.

Wallace also reports that the Illinois Experiment Station recommends giving mineral mixtures from a self feeder. They suggest a mixture of five parts of slack coal, one part of ground limestone, one part of rock phosphate and one part of salt. Or instead of using five

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[23] Wallace's Farmer, An Answer to Mineral Questions, Vol. 48, p. 158, February 2, 1923.

parts of slack coal, one-third of a part of tankage may be used in connection with the limestone, phosphate and salt.

Inasmuch as they have secured good results at the Iowa Station with salt and lime, it would seem that salt and ground limestone should serve as the essential basis of most hog mineral mixtures.

Grimes and Salmon,[24] using a basal ration of corn, two parts, and peanut meal, one part, supplemented with a mineral supplement consisting of one part charcoal, one part marble dust and one part salt, found that the lot receiving the mineral supplement made better gains, had better appetites and were much thriftier than the lot receiving no mineral supplement. The lot which received no minerals were restless, would root the feed out of the feeders, gnaw on the sides of the trough, indicating that there was something lacking that they needed in the ration.

Lot I		Lot II	
Corn, two pounds		Corn, two pounds	
Peanut meal, one pound		Peanut meal, one pound	
Minerals self fed		Self fed	
Daily gain	.93	Daily gain	.46
Daily feed per hog	3.83	Daily feed per hog	2.63
Feed for 100 pounds gain	414.90	Feed for 100 pounds gain	572.00

Because of the poor results of the first experiment, a second was made under the same conditions. Similar results were obtained. Two

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[24] J. C. Grimes and W. D. Salmon, A Simple Mineral Mixture for Fattening Pigs, Alabama Agricultural Experiment Bulletin 222, pp. 5-7, February 1924.

hogs from the non-mineral lot had to be removed during the experiment because of broken bones.

Daily gain for the non-mineral lot was .97 pounds with 437.2 pounds of feed being required for 100 pounds of gain. The lot receiving the minerals made a daily gain of 1.36 pounds with a feed requirement for 100 pounds of gain of 380.4 pounds.

Evvard[25] says:

> Our work last summer showed that high calcium limestone was much better than the particular air-slacked lime we used. Our results have indicated also that 20 percent salt with most mineral mixtures is about a fair allowance, although with some mineral combinations an even lesser proportion of salt is probably more correct.
>
> In our work with potassium iodide at Ames, we have found in three successive trials, one of which was conducted on pasture, that in spite of the fact that we have had no gross evidence of hairless pig malady or hairlessness in the new-born porkers, that its addition to the ration resulted in apparently a ten percent greater gain combined with a ten percent lesser feed requirement.

Minerals and vitamins greatly improve grain rations. Table 6 shows the effect of making good both mineral and vitamin deficiencies by adding two percent limestone and from one-half to one percent cod liver oil to a grain mixture of white corn, middlings, oilmeal and salt.

Table 6 also shows that, in the limestone-cod-liver-oil lot, not only was the grain and feed expenditure for 100 pounds gain fairly satisfactory, but the pigs escaped stiffness, sometimes referred to as rheumatism, and death.

Robison[26] says that minerals are essential in animal feeding. They

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[25] John M. Evvard, Better Mineral Rations for Hogs, Wallace's Farmer, Vol. 50, p. 458, March 27, 1925.

[26] W. L. Robison, Comparison of Minerals for Swine, Ohio Agricultural Experiment Station Bi-monthly Bulletin, Vol. 10, No. 8, pp. 146, September-October, 1925.

Table 6. Both Minerals and Vitamins Added to a Grain Ration Fed in Dry-Lot*

Average of Four Experiments, Using a Total of 56 Pigs

Ration	Average length of experiment	Average daily gain	Feed required for 100 lb. gain	Lameness: Stiffness: Paralysis	Strength thigh bones
				Number	
Grain mixture	161 days	0.41 lb.	688 lb.	3	201 lb.
Grain mixture, ground limestone, and cod liver oil	161 days	0.98 lb.	422 lb.	0	619 lb.

*Source: W. L. Robison, Comparison of Minerals for Swine, Ohio Agricultural Experiment Station Bi-monthly Bulletin, Vol. 10, No. 8, p. 146, September-October, 1925.

are needed in the formation of bone, as a part of the blood, and in the vital processes of the cells.

The elements most likely to be deficient in rations for swine are sodium, calcium, chlorine, and phosphorus. Hairless pigs can be prevented by the feeding of iodine and it is highly important where cases of hairlessness are concerned.

Possibly ashes would prove of value in either mixture, but apparently they added nothing beneficial to the combination of salt, limestone and bonemeal, which gave practically the same results without the ashes as it did with ashes included. Tankage supplied good proteins and minerals, as is shown by the data in Table 7.

Tankage in this case not only improved the protein of the mixture, but also added some much needed minerals, especially lime, through the bone which is contained. Tankage did not greatly improve the vitamin content, hence several of the pigs became slightly stiff near the end

Table 7. The Use of Tankage, An Animal Protein, in Balancing a Grain Mixture Fed in Dry-Lot*

Average of One Experiment, Seven Pigs Per Lot

Ration	Average length of experiment	Average daily gain	Feed required for 100 lbs. gain	Mortality	Lameness Stiffness Paralysis
				No.	No.
Grain mixture	154 days	0.49 lb.	526 lb.	3	2
Grain mixture and tankage	154 days	1.02 lb.	432 lb.	0	5

*Both rations have the same nutritive ratio.

Table 8. Yellow Corn Compared with White Corn in a Grain Mixture Containing Ground Limestone Fed in Dry-Lot

Average of One Experiment, Five Pigs Per Lot

Ration	Average length of experiment	Average daily gain	Feed Required for 100 lbs. gain	State of thrift at end of trial
White corn in grain mixture	139 days	0.83 lb.	465 lb.	Fair
Yellow corn in grain mixture	139 days	1.12	418 lb.	Very good

of the trial. Fish meal had much the same effect as tankage.

Table 8 is given to show the difference in results between the feeding of yellow as compared with white corn in a grain mixture. It shows the record of two small groups of pigs, one on yellow corn and the other on white corn in the grain mixture fed in outdoor, brick-paved pens.

The equivalent of vitamin D was therefore supplied by sunlight, but more or less imperfectly on account of much cloudy and rainy weather during the fall and early winter. The rations were not ideal with respect to the proteins, minerals, and vitamins or vitamin equivalent, even for the yellow corn lot; nevertheless, the pigs grew surprisingly well.

Kelly,[27] in feeding pigs two to four months of age, found that the addition of potassium iodide to a cereal ration led to an increased assimilation and retention of nitrogen and phosphorus. There also seemed to be some evidence of an increase in the retention of calcium, although this seemed less definite. The amounts of iodide necessary varied with different individuals and was thought to depend on the type of diet fed previous to the experiment.

Bohstedt[28] has found that the addition of certain feeds rich in minerals and in vitamins and the addition of minerals to a grain ration increased the daily gain and decreased the amount of feed necessary to produce 100 pounds of gain.

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[27] Francis C. Kelly, The Influence of Small Quantities of Potassium Iodide on the Assimilation of Nitrogen, Phosphorus, and Calcium in the Growing Pig, Biochemical Journal, Vol. XIX.

[28] Gustav Bohstedt, et al., Ohio Agricultural Experiment Station Bimonthly Bulletin No. 3, May-June, 1927.

Gain in Weight and Cost of 100 Pounds

Gain in Weight of Swine

Howard[29] says that by chemical analysis and by work at other stations, it has been shown that tankage and linseed oilmeal are rich in phosphorus and that tankage and alfalfa are rich in calcium. Corn is known to be deficient in both of these minerals.

A ration consisting of yellow corn, tankage, linseed oilmeal, and alfalfa meal contain these two minerals, at least in moderate amounts. However, it was not known with certainty whether the addition of some mineral supplement supplying calcium and phosphorus would improve this ration by producing a bone with a greater breaking strength and whether larger daily gains are more economical gains to be obtained. Could too large quantities of a mineral supplement when fed in a ration of this kind prove harmful, was another question which needed answering.

Accordingly it was decided to self-feed pigs a ration consisting of these feeds in order to establish these points. The results are shown as follows:

Lot I, receiving the basal ration alone, made a daily gain of 1.72 pounds with 433,56 pounds of feed being required to produce 100 pounds of gain. The cost of 100 pounds of gain for lot I was $5.63.

Lots II, IV, and V made an average daily gain greater than that of Lot I. The remainder of the lots, all of which received the same basal ration but with the addition of the bonemeal, consumed less feed and the cost of 100 pounds of gain was lower.

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[29]Howard, op. cit., pp. 40-46.

Lot III, which received five pounds of bonemeal mixed with 100 pounds of the supplement, made the poorest showing of any of the lots, with the exception of lot I. However, the addition of this mineral saved 2.14 pounds of protein supplement.

Lot IV, receiving ten pounds of bonemeal to 100 pounds of the supplement, required more feed during the experiment than the other lots receiving the bonemeal. However, the protein supplement consumed was low. The cheapest gain made by any of the lots was made by lot V. This lot made an average daily gain of 1.78 pounds, with a feed requirement of 382.59 pounds for 100 pounds of gain. The amount of protein supplement consumed by this lot was the least consumed by any lot, the amount being 24.52 pounds.

Lot VI, which obtained its bonemeal free choice instead of having it mixed with the supplement, made an average daily gain of 1.70 pounds, which was less than that made by lot I, which received no mineral supplement. Lot VI required 23.97 pounds less feed to produce 100 pounds of gain than lot I. For each 100 pounds of gain the addition of 2.96 pounds of bonemeal saved 23.97 pounds of feed.

The addition of bonemeal to a ration as was fed here seems to have no effect upon the average daily gain, but the addition of bonemeal to the ration decreased the cost of 100 pounds of gain. Table 9 gives the data relative to the gains made and to the feed consumption.

Henry and Morrison[30] state that if pigs are fed well-balanced rations on such pastures as alfalfa, clover, or rape, good results will be secured without adding any mineral supplement except common

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[30] W. A. Henry and F. B. Morrison, Feeds and Feeding, Abridged Edition, p. 352, 1929.

Table 9. Rations Fed, Gain in Weight, and Cost of 100 Pounds of Gain in Swine*

		Lot I	Lot II	Lot III	Lot IV	Lot V	Lot VI
		Basal Ration					
Ration			2 1/2 lbs.	5 lbs.	10 lbs.	20 lbs.	
		No min-	mineral	mineral	mineral	mineral	Mineral
Self-fed		eral	to 100 lbs.	to 100 lbs.	to 100 lbs.	to 100 lbs.	free
			supplement	supplement	supplement	supplement	choice
Number hogs to lot		10	10	10	8**	10	10
Number days fed		75	75	75	75	75	75
Total initial weight		1143	1158	1184	927	1154	1076
Total final weight		2435	2462	2428	1992	2499	2354
Total gain in weight		1292	1304	1244	1065	1445	1278
Average initial weight		114	115	118	115	115	107
Average final weight		243	246	242	249	249	234
Average gain		129	130	124	133	134	128
Average daily gain		1.72	1.73	1.65	1.77	1.79	1.70
Average total feed consumed	Corn	516	498.8	498.9	514.25	478.7	482.5
	Protein Supplement	43.3	30.713	37.335	30.55	27.2	38.0
	Mineral	0.0	.787	1.965	3.35	6.8	3.8
	Total	560.1	530.300	537.300	547.76	512.7	524.3
Average	Corn	6.89	6.65	6.64	6.84	6.38	6.43
	Protein Supplement	.57	.48	.49	.40	.36	.50
	Mineral	0.00	.01	.02	.04	.09	.05
	Total	7.46	7.06	7.15	7.27	6.83	6.98

- Continued -

Table 9. Continued.

		Lot I	Lot II	Lot III	Lot IV	Lot V	Lot VI
				Basal Ration			
Ration			2 1/2 lbs.	5 lbs.	10 lbs.	20 lbs.	
Self-fed		No mineral	mineral to 100 lbs. supplement	mineral to 100 lbs. supplement	mineral to 100 lbs. supplement	mineral to 100 lbs. supplement	Mineral free choice
Feed required for 100 pounds gain	Corn	400	383.6	401.6	386.6	357.2	376.9
	Protein Supplement	33.5	23.6	30.1	22.6	20.2	29.6
	Mineral	0.0	.6	1.5	2.5	5.0	2.9
	Total	433.5	407.8	433.2	411.7	382.4	409.4
Cost of 100 pounds gain***		$5.63	$5.16	$5.59	$5.20	$4.87	$5.32

*Source: Maurice B. Howard, The Effect of Mineral on the Size and Breaking Strength of Bone in Fattening Swine, Oklahoma Agricultural and Mechanical College, Master's Thesis, pp. 40-46, 1931

**This lot originally contained 10 hogs, but due to sickness two were removed. The feed that they ate was computed and subtracted from the total amount consumed by the lot.

***Feed prices used in figuring cost of gain are as follows: corn 65¢ per bushel; tankage $70 per ton; linseed oilmeal $60 per ton; alfalfa meal $36 per ton; and bonemeal $50 per ton.

salt. If there is plenty of skim milk, buttermilk, tankage, or fish meal fed to balance the ration, there may be no advantage whatsoever in adding a mineral supplement to furnish additional calcium or phosphorus where swine are on pasture.

When there is any danger of a lack of calcium or phosphorus in the ration, a mineral supplement should be fed. Calcium may be furnished by finely ground limestone, wood ashes, chalk, steamed bonemeal, or ground rock phosphate. The last two supplements also furnish phosphorus. One-half to one pound of one of these mineral supplements may be mixed with each 100 pounds of concentrates, if one is feeding ground concentrates. When shelled corn or ear corn is fed, such a mineral mixture as one of the following should be fed separately in a box or self-feeder.

1. Equal parts by weight of ground limestone and salt or equal parts wood ashes and salt.

2. Equal parts of ground limestone, salt, and either bonemeal or boneblack.

3. Equal parts of either bonemeal or boneblack and one part tankage for flavoring.

SUMMARY

Breaking Strength of Swine Bones

Minerals markedly increase the density, the thickness of wall, the hardness and breaking strength of bones.

The addition of bonemeal to the ration resulted in a slight increase in breaking strength and a slight decrease in circumference of the tibia.

Where a ration composed of yellow corn, tankage, linseed oilmeal and alfalfa meal, the addition of bonemeal caused little effect on the circumferences and breaking strength of the bone.

While the addition of mineral supplements to a ration of corn, linseed oilmeal, middlings, and blue-grass pasture, has no great or certain effect on the rate or economy of the gains secured, it does distinctly produce denser and probably stronger bones.

Pigs bathed in sunlight in the open made better gains and grew denser and stronger bones than pigs fed the same rations but kept indoors.

Stiffness in Swine

The evidence furnished by chemical and pathological studies showed that stiffness in pigs sometimes was a result of inadequate minerals in the ration.

Pigs are apt to incur stunted growth, stiffness, posterior paralysis and death where proper minerals are not fed.

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Ground limestone added to a grain mixture of white corn, wheat middlings, linseed meal, and salt, stimulated growth and prevented posterior paralysis.

Mineral Problems in Swine Feeding

Pasture proved the one best practical corrective of a grain ration. Pasture furnished abundant vitamins, easily assimilated minerals, and favorable proteins.

A grain ration for pigs in the winter, or in dry lot feeding is unsatisfactory because they lack the proper amounts or the right kinds of minerals, vitamins, and proteins.

If mineral mixtures are self-fed, the free offering of coal also may be expected to reduce the consumption of minerals.

During the period of growth from the time pigs are 18 weeks old until they are 40 to 43 weeks old, the percentage of total phosphorus in the skeleton is increased about one-half, and that in the entire body is increased about three-twentieths.

Animals require for their proper growth and development twelve or fifteen or possibly more mineral elements.

About 85 percent of the ash of bones is calcium phosphate.

One to two percent mineral in a swine ration is sufficient.

A supply of minerals should be kept before swine at all times, as minerals and vitamins greatly improve the grain ration.

Minerals are necessary for the maintenance of neutrality of the blood and the lympth, this being essential for the normal action of the body cells.

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Iodine is necessary for the proper growth of the body, and its addition to some rations will cause an increase in gain, but it is a matter of geographical importance.

Coarse and gritty mineral substances are more palatable to pigs than finely ground substances.

Cereals fed alone, and especially corn, do not provide enough calcium to permit any considerable retention of this element for the bone and tissue growth.

Gain in Weight and Cost of 100 Pounds Gain in Weight of Swine

The addition of salt to a ration will pay greater dividends than the addition of any other mineral.

The greater part of the cost of producing pork lies in the feed consumed. The quantity of feed required for a unit of gain in weight varies greatly under different conditions, and it is materially lessened where one has healthy, thrifty pigs, uses good pastures, gives access to minerals and has sufficient protein feed to balance the ration properly.

The addition of bonemeal to a ration decreased the amount of feed consumed, especially the protein supplement, and lowered the cost of producing 100 pounds of gain.

Corn alone is a high-priced feed. Protein and minerals must be added to make an economical ration.

CONCLUSIONS

The soils of Oklahoma are fast becoming depleted in plant food elements such as calcium, phosphorus, and other plant foods.

Small grains, cereals and other plants fed swine are also becoming more deficient in these elements as the soils are depleted of their mineral plant foods.

Today one of the most serious losses suffered by hog raisers and shippers is caused by hogs becoming crippled, leg bones fractured, vertebrae fractured, or ligaments torn, directly due to a lack of minerals in the rations to produce strong boned hogs. These losses are annually costing hog raisers and shippers over three and a half million dollars, as shown by the slaughter records.

The most urgent need for mineral matter by farm animals is for calcium and phosphorus. Over 80 percent of the mineral matter retained in the bodies of growing animals is calcium and phosphorus.

Minerals should be added to a sow's ration to produce strong pigs. Not only will mineral increase the size and strength of pigs farrowed, but it increases and strengthens the bones of the pigs farrowed.

Today we breed our sows for two litters a year, a spring and fall litter. Then these pigs are crowded to reach the market at about six months of age, weighing from 200 to 250 pounds in this short period. This forced growth requires strong bone framework to carry the weight to market. With this forcing condition and depleting of our soils of calcium and phosphorus we can expect continued difficulties from bone weaknesses.

Mineral matter is required for maintenance of vital body functions and growth of strong bone. A deficiency in minerals leads to unthriftiness, poor development, and diseases such as rickets, depleted appetite, and paralysis.

The corrective for these conditions need not be an expensive mineral mixture. Bone flour added to a basal ration of ground corn, flour wheat middlings, linseed meal bonemeal and salt increases the breaking strength of the femur over 50 percent.

Skim milk is high in minerals and one-half gallon a day per pig will supply all the mineral necessary.

Calcium may be supplied in the form of bonemeal or calcium carbonate. Two percent of either of the above added to the ration is sufficient mineral per pig daily.

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