THE EFFECT OF MINERAL FEEDS ON THE QUALITY AND COMPOSITION OF PORK CARCASSES

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By

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INTRODUCTION

Several years ago little emphasis was placed on feeds as affecting the composition and quality of pork carcasses. Since the ultimate goal of the hog is to produce meat for human consumption, more and more are we beginning to realize the close correlation existing between the feed and the finished product. Improvements in hog rations have been necessary in order that the producer may meet public demand for a better product and keep abreast of the fast pace that is being set in the production of meat animals.

Crippled hogs are a cause of one of the most serious losses suffered by hog raisers and shippers. Fractured leg bones and vertebrae and torn ligaments are quite common. Professor James R. Wiley (49)of the Indiana Agricultural Experiment Station found that cripples from the country's commercial hog crop cause an appalling loss of from three to three and one-half million dollars a year. The necessity of overcoming this unnecessary evil was soon recognized by the United States Department of Agriculture, Bureau of Animal Industry, Livestock Loss Prevention Board, and the many agricultural experiment stations throughout the country. Through many research projects they have found that calcium and phosphorus in the ration are greatly beneficial in producing strong bones, thus reducing the large number of cripples.

Since pork is a food product other factors to consider when attempting to make an improvement are tenderness, juiciness and firmness. Various methods have been developed in determining these characteristics of meat, which give quite accurate results.

Firmness is essential in good pork and is often an important grading factor in pork carcasses. Considerable work has been carried on at the various experiment stations, particularly with soy beans and peanuts as they affect the finished product.

To date a relatively small amount of work has been done on either tenderness or juiciness, but since palatability of meat is largely dependent on these factors more recognition of their importance is being made.

REVIEW OF LITERATURE

Size and Breaking Strength of Swine Bones

The bones are the main supporting organs in the animal body, and their strength and rigidity depend largely upon the minerals, principally calcium and phosphorus, which they contain. The hog supports a greater amount of weight on a smaller amount of bone than any other farm animal. Strong, dense, hard bones are very desirable in breeding and feeding swine. As Forbes (23) of Ohio State University has stated, "Big bone can be obtained by breeding for it, but dense bone only by feeding for it." Numerous feeding experiments have been conducted with this object in mind.

Howard (32), in 1931, worked on a mineral experiment with swine at the Oklahoma station. He fed a basal ration of shelled yellow corn, tankage, linseed oil meal, and alfalfa meal. Block salt was fed to all lots. Lot 1 received no mineral. Lot 2 received 2½ pounds of bone-meal with each 100 pounds of protein supplement. Lot 3 received 5 pounds of bone meal with each 100 pounds of protein supplement. Likewise, Lot 4 received 10 pounds of bone meal; Lot 5 received 20 pounds of bone meal, and Lot 6 received bone meal free choice.

An analysis of the bone size and breaking strength was made of the tibia of one hog in each lot. The data for bone measurements were obtained from a transverse section taken from the smallest part of the shaft. It was concluded that the addition of bone meal to the ration resulted in a slight increase in breaking strength and a slight decrease in circumference of the tibia as is indicated in Table I. The addition of mineral to a basal ration as was used should not be expected to produce wide differences. Bone having a high breaking strength owes its strength to its density rather than size.

Table I

Breaking Strength, Circumference, and Wall Thickness of the Tibia

Lot No.	Breaking Strength Pounds	Circumferences Centimeters	Average Wall Thickness Millimeters
1	565	6.35	3.20
2	895	6.70	3.80
3	630	6.25	2.80
4	550	6.10	3.12
5	690	6.40	3.41
6	680	5.80	3.82

In a review of literature on size and breaking strength of bone, Foreman (24) found that minerals increase the density, the thickness of wall, and the hardness and breaking strength of bones. The addition of bone meal to most rations resulted in a slight increase in breaking strength and a slight decrease in circumference of the tibia. 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.

Burnett, (6) at the Nebraska station in 1906, fed four lots of hogs as follows: Lot 1, corn; Lot 2, corn and shorts; Lot 3, corn and tankage; Lot 4, corn and ground bone. The tests showed a continually increasing average strength of bone in the lots in the order given. The addition of shorts to corn produced some beneficial results, while the addition of tankage to corn was still more satisfactory. Ground bone and corn produced the hardest, strongest bone of all, as is shown in Table II.

Table II

The Breaking Strength of Bones As Affected by the Ration

Lot	Ration	Femur	Tibia	Humerous	Radium and Ulna	All Bones
		Pounds	Pounds	Pounds	Pounds	Pounds
1	Corn	244	269	326	285	281
2	Corn and Shorts	264	274	381	326	311.75
3	Corn and Tankage	376	353	522	402	413.75
4	Corn and Gr. Bone	454	375	530	504	467.75

In 1907 five more lots of hogs were fed by Burnett (6) as follows: Lot 1, corn; Lot 2, corn and shorts; Lot 3, corn and skim milk; Lot 4, corn and tankage; and Lot 5, corn and ground bone. The average breaking strength of bones per 100 pounds live weight of hog was taken at the time of slaughter.

It was found that there was a gradual increase in the strength of these bones per hundred weight of hog from Lot 1 through Lot 5 and that the greater strength is not a matter simply of the more rapid growth and heavier weight of the pig resulting from these supplementary feeds. A marked difference was noted in the thickness of the walls of the bones. There is no apparent increase in the external measurements of the bones when mineral matter is added to the food nutrients, but these additional nutrients, so far as they are assimilated, have greatly added to the thickness of the bone walls by accretion on the inner surface of these walls, thereby reducing the marrow in the bones. The breaking strength of the bones increased about 50 percent in hogs fed bone meal over those fed only corn as shown in Table III. The extreme differences in the breaking strength of the bones of the different lots indicate that the skim milk, the tankage, and the ground bone each contained bone building substances lacking in corn, principally phosphates of lime in these particular supplements.

Table III

The Breaking Strength of Bones As Affected by the Ration

Lot	Ration	Femur	Tibia	Humerous	Radius and Ulna	All Bones
		Pounds	Pounds	Pounds	Pounds	Pounds
1	Corn	276	252	434	341	325
2	Corn and Shorts	343	309	555	376	396
3	Corn and Skim Milk	462	360	685	529	509
4	Corn and Tankage	559	409	740	611	580
5	Corn and Gr. Bone	646	465	898	715	681

John B. Rice (43) in 1934 studied minerals as they affected bone development in swine. One lot of pigs received wheat middlings, corn and oil meal with no mineral. Another lot was fed the same basal ration plus a mineral feed of ground limestone, rock phosphate, salt, and coal. The bones of the pigs receiving the mineral, while not greater in size, were considerably denser as indicated by a higher specific gravity.

Similar feeding work on pregnant and lactating sows were conducted by Rice. Two lots were fed a basal ration of corn, oil meal, middlings, and bluegrass pasture. One lot received mineral while the other did not. However, the analyses of bone from sows of both lots revealed no significant differences in size and composition.

E. B. Forbes (23) of the Ohio station fed a basal ration of corn, wheat middlings, linseed oil meal, and salt. The mineral supplements used were commercial precipitated calcium carbonate, special steamed bone flour, precipitated bone flour, and rock phosphate floats. Inspection of the data shows a general agreement as to the comparative breaking strength of the bone in the five lots receiving the mineral supplement. Lots 1 (calcium carbonate) and 2 (steamed bone flour) were always strongest followed in each case in the same order by Lots 3 (precipitated bone flour), 5 (basal ration), and 4 (rock phosphate). The striking fact manifested is that the bones of pigs receiving rock phosphate were in each case less strong than the bones of the pigs receiving no mineral supplement. However, they were somewhat more dense.

It was stated by Forbes that the breaking strength of bones as a basis of comparison is inaccurate from a logical point of view, but it has a usefulness in indicating roughly the resistance of bone to stress. Those conditions which render the data inaccurate are as follows: (1) The bones to be compared differ in shape in the transverse section. (2) Bones vary in ratio of diameter of the bone to thickness of wall. (3) The length of bone as related to diameter is likewise subject to variation. (4) The shape of the bones renders it impossible to support them at points so related to the length of the same that the breaking strength of one may be consistantly compared with that of another.

In 1908-1909 Burnett (7) continuing his mineral feeding studies fed the following rations to three lots of pigs: Lot 1, corn; Lot 2, corn and tankage; Lot 3, corn, alfalfa meal, and bone meal. Lot 3,

Table IV

The Effect of Mineral and Protein Supplement on the

Composition and Characteristics of Swine Bones

	Average Live Weight	Average Breaking Strength of Bone	Average Breaking Strength Per 100 lbs. Live Wt.	Average Length of Bone	Average Circumference of Bones
	Pounds	Pounds	Pounds	Millimeters	Millimeters
Lot I Corn	150	567	368	16.3	74
Lot II Corn and Tankage	218	824	387	17.1	77
Lot III Corn, Alfalfa Meal Bone Meal	187	888	479	16.7	82

	Average Weight of Bones	Average Volume of Bones	Average Wall Thickness of Bones	Average Specific Gravity	Percentage of Mineral Matter in Green Bones
	Grams	Cubic Centimeters	Millimeters		
Lot I Corn	595	426	3.4	1.22	33.96
Lot II Corn and Tankage	641	498	4.2	1.34	40.06
Lot III Corn, Alfalfa Meal Bone Meal	694	513	4.9	1.35	43.35

although not the largest pigs, had a considerably higher breaking strength of bone than did the pigs in the other lots. Bones from these pigs were greater in circumference, heavier in weight, and possessed greater volume and thicker walls as shown in Table IV. The specific gravity was greater, and there was a higher percentage of mineral matter in the green bones. It may be concluded that mineral feeds and feeds high in minerals exert no little influence on both construction and composition of bone in pork carcasses.

In 1921-1922 Carl P. Thompson (46) studied the effect of various rations on the bone of swine at the Oklahoma station. Five lots were fed as follows: Lot 1, kafir corn; Lot 2, kafir and mineral; Lot 3, kafir and shorts; Lot 4, kafir and tankage; and Lot 5, kafir, shorts and mineral. The tibia bone was used in making the tests.

The following conclusions were drawn; (1) The addition of mineral to a carbonaceous ration low in protein and the addition of mineral to a properly balanced ration low in mineral increased the breaking strength in bones. (2) The addition of mineral to a ration low in protein and to a protein balanced ration low in mineral increased the wall thickness of the bones. (3) The addition of wheat shorts to a ration of kafir increased the breaking strength of the bone very little over straight kafir, showing that protein rich feeds which are low in mineral do not produce strong bone. (4) The addition of shorts to a kafir ration did not increase the thickness of the bone wall over a straight kafir ration. (5) Mineral alone is not sufficient for bone building, but should be fed with protein to get best results. (6) Tankage of good quality in a ration with kafir is of equal value, if not superior, to mineral added to kafir-shorts ration.

It would appear from the above conclusions that where tankage containing a large percentage of mineral is available for hogs there would be no advantage whatever from the addition of mineral matter, but where a protein supplement low in mineral is used the addition of a small percentage of mineral will give a stronger bone with a much higher breaking strength, which is of considerable importance both to the hog feeder and hog breeder. Table V shows the thickness of walls and breaking strength of the bones of the hogs in the different lots.

Table V

The Effect of Protein and Mineral Supplements
on the Wall Thickness and Breaking Strength of Bones

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
Measures	Kafir	Kafir and Mineral	Kafir and Shorts	Kafir Shorts and Mineral	Kafir and Tankage
Wall Thickness In mm.	2.30	2.88	2.54	3.85	3.52
Breaking Strength In pounds	152	188	180	287	296

Ferrin, (21) after some study at the Minnesota station on mineral feeding, strongly advocates a mineral in the ration and is of the opinion that the feeding of mineral mixture to hogs is one good sign of a successful hog raiser. Palmer (42), also of Minnesota, advises feeding minerals not only to fattening pigs but to pregnant and nursing sows as well.

After conducting a mineral feeding project in 1924 Grimes and Salmon (25) concluded that a ration deficient in its mineral content apparently had some relation to a lowered resistance to disease and to the occurrence of a large number of fractured bones.

Bohstedt (3) when working with minerals and vitamins for pigs found that the feeding of minerals had a marked effect on bone composition and breaking strength, particularly when the minerals were added to a mineral deficient ration. He attributed stiffness and posterior paralysis to mineral and vitamin deficiencies. Sunlight and the consumption of soil were found to be of benefit to the bone development of swine. Good bone growth was not necessarily synonymous with good growth and well being. In some cases a vigorous rapidly growing pig was found supported by a relatively weak skeletal system. Such cases, however, were the exception rather than the rule.

Blood analyses revealed a lower calcium and phosphorus content in the serum of blood taken from hogs on a mineral deficient ration.

Tenderness of Meat

Even though tenderness is one of the most important factors entering into the palatability of the meat we eat comparatively little work has been done to determine why some meats are less tender than others.

In 1932 K. F. Warner and Lucy M. Alexander (48) carried on a tenderness research project with lamb, using 1222 legs of lamb taken from an equal number of animals which had been selected at random. Two methods of testing were used: the mechanical method with a shear machine and the actual eating of the meat by four or five judges. A close correlation existed between the two methods. The palatability records of the 1222 legs were summarized to study the effect of ripening upon the tenderness of the meat. Comparisons were made to see whether the consumer would obtain a more desirable product from lamb that was freshly chilled or from lamb that had been ripened for a definite length of time.

The legs were roasted to an internal temperature of 76° Centigrade, sliced while hot, and tested. It was concluded that lamb which had been ripened was more tender up to a certain degree, after which, there was a decrease probably due to loss of moisture. From seven to ten days was found to be the most desirable ripening time.

The paired eating method of testing tenderness was developed at the Texas station (11) and was found to be quite satisfactory in judging tenderness. The samples were taken from the same animal from corresponding cuts in the two halves. The two cuts were cooked differently and then subjected to the judges' eating tests. It was concluded that beef roasted at low temperatures was more tender than beef roasted at high temperatures.

In 1933 H. H. Mitchell and T. S. Hamilton (39) studied the effect of exercise upon the composition of beef lean. They found that exercise tended to lower the fat, water, and creatine content of muscles, which would tend to decrease palatability, particularly tenderness, juiciness, and flavor.

Tenderness tests involving the meat from feeder calves, yearlings, and two-year-old steers were conducted at the Iowa station (41) in 1930. The meat from the calves was found to be less tender than that from the older animals which were considerably fatter and consequently displayed a proportionately smaller amount of connective tissue. Not only were the older animals more tender, but in addition they were more juicy than meat from the calves.

The Illinois station (40) in 1928 concluded from experiments conducted on toughness of meat that it is caused mostly by the presence of connective tissue in the meat. Two kinds of proteins, collagen and elastin, make up the connective tissue. Of the two, collagen is by far the more important. Age was not found to be much of a factor in the amount of connective tissue in a piece of meat. The rib eye of calves seems to have the lowest content of collagen of any other veal cuts. No correlation was found between grade and class of beef and the content of connective tissue in the rib eye.

A determination of relative tenderness of chilled and quick-frozen beef was made at the Birdseye Laboratories in 1932 (47). The data indicate that after quick-frozen meat has been stored for one week, it is approximately 20 percent more tender than before freezing. The tendering process continues slowly during the cold storage period.

Halliday, Klaas, and Noble (27) in 1934 conducted tenderness tests on cooked beef by means of a penetrometer. Very slight differences were detected in tenderness of corresponding left and right rib cuts from the same animal when treated in the same manner. However, the cuts heated to an internal temperature of 61° Centigrade were considerably more tender than a corresponding cut heated to 75° Centigrade. The meat cooked at 61° Centigrade was also much more juicy. The larger quantity of juice which came from the cut cooked at 75° Centigrade was found to be richer in solids and total nitrogen. In one case it was also richer in coagulable nitrogen.

The design of the mouse trap or shearing type of tenderness measuring machine has been studied and developed considerably at the Kansas station (4). The blade selected as most precise was .04 inches thick with an equilateral triangular hole one and one-half inches in altitude with cutting edges rounded to a radius of .02 inch. The machine is now identified as the Warner-Bratzler shearer.

The term "shear" is used to indicate the breaking strength in pounds of a cylinder of meat one inch in diameter as registered on the dynamometer of the Warner-Bratzler shear machine. Several tests were conducted at the Kansas station (4).

It was found that beef from mature steers is apparently less tender than that from yearling cattle as indicated by Table VI. A greater amount of collagen and connective tissue in the flesh of older animals seem to be the explanation.

Table VI

Tenderness Factors for Different Groups of Steer Carcasses

Description	Shear (pounds)	Palatability*
Mature Steers	43.4	5.4
Yearling Steers	25.67	5.76
Yearling Steers Full Fed, Dry Lot	24.22	6.12
Yearling Steers Full Fed on Pasture	26.93	5.87
Yearling Steers Pasture Only	28.82	4.95

* Palatability rated from 1 to 7, 7 being most palatable.

Mackintosh and co-workers (4) found very little difference in tenderness of the meat of two lots of steers, one of which had been full fed in dry lot on ground corn, cottonseed cake, and alfalfa hay;

the other lot had been full fed on ground corn, cottonseed cake, and bluestem grass pasture. Cattle with a similar amount of finish contained about an equal amount of collagen and elastin in the muscle tissue. The thinner cattle contained a higher proportion of connective tissue than fat cattle, and ripened meat had a lower content of collagen and elastin than did fresh meat. The amount of collagen and elastin in a meat sample was believed to be a criterion of tenderness, less tender meat usually being associated with a higher content of these two proteins.

The "shear" of the cooked meat was found to be considerably higher than that of the raw meat.

Juiciness of Meat

Juiciness adds much to the palatability of meat. Dry, cooked muscle tissue is inclined to be somewhat insipid and lacking in flavor, and naturally, it is to be discriminated against.

Alice M. Child and Mary Baldelli (8) have done considerable research on meat palatability with emphasis on juiciness. They have found that juiciness is dependent on the fluid content of muscles and that juiciness in meat is a readily expressible liquid. For convenience in their work grades of juiciness were set up as follows: very juicy, moderately juicy, slightly juicy, slightly dry, dry, very dry, and extremely dry.

Miss Child developed the pressometer, a pressure instrument for testing the amount of fluid in meat. She used pieces of meat 1.27 centimeters in diameter and 1.87 centimeters thick. Each sample of meat was weighed and wrapped in unsized filter cloth and inserted in the pressometer for ten minutes at a pressure of 250 pounds. The samples were taken from a rump roast of beef and from psoas major and biceps femoris muscles.

Conclusions were drawn as follows: (1) The amount of fluid taken from samples of the adductor muscle in roast beef did not vary significantly when samples were under pressure for five and twenty minute periods. (2) The mean percentages of press fluid from the roasted psoas major and biceps femoris muscles did not vary significantly when the drams of press fluid per gram of dry matter were compared.

The press fluid of juice in meat was defined by Miss Child and Agnes J. Fogarty as the moisture plus soluble material plus the colloidal fraction expressed from muscle by use of the pressometer. Using the semitendinosus or eye muscle of the round of beef the following observations were made: (1) The ratio of press fluid to dry matter is greater in muscle heated to 58° Centigrade than in muscle heated to 75° Centigrade. (2) Approximately eleven percent more press fluid is found in the muscle heated to 58° Centigrade than that which was heated to 75° Centigrade. (3) The moisture content varies directly with the temperature inside the piece of meat. (4) An inverse relationship exists between the total nitrogen content of press fluid and the interior temperature, the raw meat having more nitrogen. Increased shrinkage appears to be accompanied by a decrease in tenderness, juiciness, and flavor of lean meat, and the loss of flavor may be attributed to loss of juices.

Workers at the Missouri station (10) found that high temperatures in cooking beef roasts materially decreased the juiciness of the meat. The higher temperatures tended to shrink the meat more, and the greater the shrinkage the less juicy and less palatable the meat was. It was also found that steaks were more juicy when broiled by gas than when broiled by electricity.

In working with the influence of soy beans on the quality and palatability of pork, Leveck (33) concluded that pork from soy bean fed hogs was more juicy, but that the cooking loss due to evaporation and drippings was greater with soy bean fed hogs than it was with corn fed hogs. In palatability tests the cooked hams from the bean fed hogs had a slight advantage in the flavor of lean, while the corn fed hogs had a slight advantage in the flavor of fat. The results of three years' work indicate that green soy bean pasture, either in the growing ration or throughout the entire feeding period, does not materially affect the quality or palatability of the pork produced.

Loeffel (36) found that wheat fed pork with tankage as a protein supplement was most desirable in flavor when compared to pork from pigs fed as follows: corn and tankage, ground rye and tankage, and corn and ground soy beans. A palatability committee ranked rye fed pork lowest, particularly in aroma and flavor. Little difference was noted in juiciness of pork produced on the above rations.

Cooking and palatability studies by Loeffel (37) showed no significant differences between wheat and corn fed pork.

Hardness of Fat

Soft pork is undoubtedly a problem of major importance in the field of meat. No one thing in meat is discriminated against more than the soft and oily flesh of swine. There are many factors which may tend to cause softness in pork, feed being, by far, the most important known factor. Sleeter Bull (5), working at the Illinois station, states that there are many factors involved in the production of soft pork which as yet are unknown. He emphasizes that an unfinished condition of the hog may cause pork to be soft.

Work at the Iowa station (12) in 1934 revealed that soy beans consistantly produce soft pork and are one of the most undesirable feeds in this respect.

Considerable research with soft and firm pork was conducted by F. R. Edwards (14) at the Georgia Experiment Station. He found that soft pork, although unattractive in appearance in the uncooked state, is not inferior to firm pork when cooked. In 1929 Edwards conducted a study in which one lot of hogs was fed corn, and another lot was fed peanuts. The differences in scores based on special score cards were significant between the two lots when the uncooked meat was graded. However, the scores on the cooked meat from hogs out of both lots were very similar. In fact, the flavor of soft peanut fed pork was preferred by most of the judges to that of firm corn fed pork. Freezing tends to overcome flabbiness in soft pork.

Ellis and Hankins (17) made a study on formation of fat in the pig on a ration moderately low in fat. It was concluded that in the case of young pigs the feed fat might be adequate to account for all the fat deposited, but in the older hogs the major portion of the fat must be synthesized from the carbohydrates and proteins. As the hogs take on weight and finish when on a hard fat feed, they become progressively harder. The changes in the fat constants indicate that a decrease in the degree of unsaturation of the fat accompanies the change in carcass grade from soft to hard.

It has been found by Ellis and Isbell (18) that the hog tends to deposit ingested fat in preference to synthesizing new fat. Consequently, the oils in the ration would materially influence the character of the body fat. Furthermore, a decrease of unsaturation of the fat results from a change in the ration from peanuts or soy beans which are softening feeds to corn and tankage, a ration which produces hard fat. However, after long periods on the latter ration the body fat was still less saturated than that of hogs grown upon corn and tankage. Cottonseed meal exerted some hardening effect upon the fat.

In feeding a low fat ration Ellis and Zeller (20) found that the animals synthesized and stored fat at a normal rate. Hard fat was formed even on young pigs on a ration containing only .5 percent of ether extract. This fat was formed principally from carbohydrates in the feed. The principal fatty acids found in the fat were oleic, palmitic, and stearic.

O. G. Hankins (28) states that the firmness of a hog carcass depends almost entirely on the amount and composition of the fat and that feed is the most important factor involved. Soy beans and peanuts are the feeds responsible for much of the soft pork. It is very difficult to harden peanut fed hogs. Initial weight and rate of gain appear to be two important factors affecting firmness. In fact there is quite a correlation. Higher final weights and degrees of finish accompany higher initial weights and rates of gain. The use of mineral supplements with soy beans increased rates of gain and to that extent the firmness of the resultant carcasses.

It was concluded by Hankins and N. R. Ellis (29) that the carcasses of soft hogs remain soft when chilled at temperatures for the length of time commonly employed in commercial practice, while those of hard hogs become satisfactorily firm under the same conditions. Oily hogs differ from soft hogs only in degree of softness. The firmness of the carcasses depends almost entirely upon the firmness of the fat. Variations in firmness are due to differences in the composition, soft fats containing a larger proportion of unsaturated fatty acids. The refractive index of the fat correlates closely with the physical grade of the carcass for firmness.

The smaller the proportion of feed fat, which is softening in character, to carbohydrates and protein entering into fat deposition the firmer is the body fat stored. When feeds contain a small fat content fat is synthesized by the animal from carbohydrates and proteins. It is much harder than ingested fat from fatty feeds. Increasing the quantity of synthesized fat tends to produce firmer carcasses. Brewer's rice is an excellent hardening feed.

Hankins and Ellis with J. H. Zeller (30) continued their soft pork investigations in 1928. The back fat was found to be more representative of the body fat than the leaf fat. In brief, the character of the fat stored seems to be governed primarily by the amount and character of the fat fed, and secondarily by the amount of carbohydrates and protein, particularly the carbohydrates.

With normal growth and fattening the rate of fat deposition increases progressively. While a low fat feed may contain enough fat to meet the fat storage requirement of the young pig, it probably will not contain enough for the older pig fattening at a more rapid rate. The other nutrients, particularly the carbohydrates, will be called upon to an increasing extent resulting in increasing firmness as weight and finish are acquired.

Feeding a softening ration to a sow during gestation period at the Arkansas station (38) did not exert any appreciable softening effect upon the resultant pigs where the pigs were fed a hardening ration after weaning.

Little correlation was shown between the chilled carcass grades and the smoked ham and bacon grades at the Purdue station (45). The general trend was for the cured hams to grade firmer than the carcass, while no definite conclusions could be drawn concerning the cured bacons.

Edwards and Massey (15) at the Georgia station found that sweet potatoes had a stronger tendency to produce firm pork than corn, which is generally considered a good hardening feed.

N. R. Ellis (16), in 1933, found that the addition of hard fat formed from the non-fatty constituents of a hardening ration, such as corn, to the oily fat already formed during the peanut feeding period produced a gradual hardening of the body fat as a whole.

Fat samples taken by Ellis and Isbell (19) in 1926 contained oleic, linoleic, arachidonic, myristic, palmitic, and stearic acids. The feeding of soy beans had a tendency to cause deposition of small quantities of linolenic acid, while the feeding of peanuts led to the deposition of arachidic acid. The oils in these two feeds have a pronounced effect upon the composition of the lard. A greater likeness was noted between peanut oil and "peanut lard" than was noticed between soy bean oil and "soy bean lard." Fat formed on a ration of brewer's rice and tankage was very hard, as practically all of it was synthesized.

It was found by Ferrin (22) that the pork from pigs fed corn and rye ranked above the pork produced by pigs fed rye alone in firmness, aroma, and palatability. In all cases rye fed pork was considered objectionable in aroma and palatability.

In working with grain sorghums at the Texas station Fred Hale (26) states that the nutritive value of milo, kafir, and hegari for fattening hogs is practically equal to that of corn and that the hogs fed on these feeds kill out firm, white carcasses.

Hostetler, Halverson and Sherwood (31) at the North Carolina station studied the effect on the firmness of the carcass of a ration of corn with cottonseed meal fed as a hardening ration following a ration of peanuts. They found the chief factors determining the firmness of a carcass in order to be: (1) the total oil intake on the softening ration, (2) live weight at which the change from softening to hardening ration is made, (3) total starch intake on the hardening ration, (4) proportion of gain on the softening and hardening rations, (5) length of time the respective rations have been fed, and (6) initial and final weights of pigs. The greater the average daily gain the firmer is the resulting carcass when initial weight, oil and starch intake, and either total gain or length of the feeding period remain constant. A cottonseed meal content of thirteen percent in the ration will produce just as high a degree of firmness as greater quantities.

A considerable number of hog feeding tests have been conducted at the Nebraska station (35). In comparing corn, wheat, and barley fed pork, the pork from the barley lot was noticeably leaner; that is, it lacked the finish shown by the carcasses of the pigs which had been fed either corn or wheat. The wheat fed pigs showed consistently more finish than pigs which were fed corn and particularly more than those pigs which had been fed barley.

Wheat fed hogs all graded hard. However, cooking and palatability studies showed no significant difference between wheat and corn fed pork.

In 1931 Loeffel (36) studied the effect of certain feeds upon the quality and palatability of pork. It was concluded that pork from wheat fed hogs was firmer and fully equal in palatability to that produced with corn, as is indicated in Table VII. When one-fifth ground soy beans was combined with tankage and fed with corn, some softening of the fat was observed.

Table VII

The Effect of the Ration on Firmness and Palatability of Pork

Ration	Lot I Corn and Tankage	Lot II Gr. Wheat and Tankage	Lot III Gr. Rye and Tankage	Lot IV Corn and Gr. Soy Beans
Firmness Grade	1 H, 4 MH, 1 MS	5 H, 1 MH	5 H, 1 MH	3 MS, 3 S
Av. Refr. Index of Back Fat	1.4591	1.4578	1.4581	1.4607

Oats fed with yeast had a tendency to produce a medium hard fat, whereas corn with tankage and corn with molasses produced a hard fat. (34)

Experiments conducted at the Iowa station (1) in 1935 indicated that consumption of large quantities of soy beans by swine impaired the keeping qualities of the lard. Swine fed on corn produced much firmer fat, and the lard exhibited better keeping qualities. The greatest deterioration occurred in lard from swine eating the largest amount of soy beans.

Corn fed hogs yielded firmer carcasses with a trifle thicker back fat than the soy bean fed hogs as was brought out in a study at the Mississippi Agricultural Experiment Station (2).

It was found by Leveck (33) that the use of green soy bean pastures had no significant effect on the quality of pork produced therefrom.

Robison (44) working with soy beans and soy bean oil meal at the Ohio station had made some interesting conclusions: (1) Soy bean oil when present in the ration, either naturally contained or as added oil, has a softening effect on the body fat which increases with an increase in the oil content of the ration. (2) Soy beans, due to their high oil content, when fed to pigs from weaning time until they are ready for market, in sufficient quantities to supply the protein needed to balance corn or other grains are likely to cause soft pork. (3) Rapidity of growth is an important factor in producing firm carcasses when what might be termed border-line rations or those containing a medium amount of softening oils are fed. Hogs making slow gains on such rations produce less satisfactory carcasses than those making rapid gains. (4) Other factors influencing the firmness of the carcasses when softening feeds are used are the weight of the pigs at the beginning of the feeding period, the length of time such feeds are fed, and the proportion of hardening to the softening feeds used in the ration. (5) Pigs fed raw soy beans and pigs fed cooked soy beans have quite similar degrees of firmness at the same finished weights. (6) Soy bean oil meal cannot be fed without danger of producing soft pork; consequently, the most satisfactory solution so far in the soy bean problem is first to press out the oil and then feed the remaining meal.

Fourteen percent soy beans in a ration is regarded as adequate to supply the necessary protein. Where more than fourteen percent is used it must be considered as a corn or feed substitute rather than as a protein supplement. If feeding with corn a 10:1 or 12:1 ratio would be more satisfactory, according to Zeller and Hankins(51); and there would be less danger of producing soft pork.

Rather definite indications were secured by Wilfred (50) that distillery slop produces soft pork where it comprises any considerable portion of the ration.

The effect of calcium and phosphorus on firmness of fat has not been studied extensively, if at all. However, it is entirely possible that these minerals may have some effect on the composition and hardness of body fat.

EXPERIMENTAL

Object of the Experiment

It has long been recognized that the feeding of minerals, particularly calcium and phosphorus, has a definite place in the nutrition of farm animals. However, it has been only in the last few years that their full importance has been realized and the proper emphasis accorded to their presence in the ration. There are two reasons why livestock men have had to give more consideration to mineral feeding. Years ago before the soils suffered from depletion due to erosion and constant cropping the feeds grown thereon were richer in mineral matter. As the fertility decreased, the nutritive value of the feeds grown on these soils decreased as well. Time has also played a large part in changing the type of livestock to meet market demand. An earlier maturing, faster growing animal with a greater weight at a younger age has found great favor with the livestock producer, packer, and consumer. Naturally such a rapid rate of production as has been established requires a maximum output on the part of the meat producing animal, particularly the hog which is expected to carry nearly 200 pounds of weight to market on a six month old skeletal framework. This has resulted in a large loss from crippled and dead animals due to broken and fractured bones, paralysis, and other ills which may be attributed to mineral deficiencies in the ration. It is becoming increasingly necessary to overcome these deficiencies, and the feeding of calcium and phosphorus has been found to be beneficial. Work has been carried on to determine the effect that the feeding of these minerals may have upon the composition and characteristics of the physical make up of farm animals. Much light has been shed on the subject, but there are still many questions to be answered.

It is the object of this investigation to determine the effect of feeding calcium and phosphorus to swine fattened on a ration of kafir, shorts, tankage, and carotene, with particular emphasis being placed on bone size and breaking strength, on the effect of calcium and phosphorus on the tenderness and juiciness of the lean and the hardness of fat, and on the changes affected in the calcium and phosphorus content of the blood. The purpose of these investigations was to gain some information whereby more scientific feeding methods can be developed for producing a higher quality and more desirable product.

Method of Procedure

Eight pigs of like breeding were put on feed at an average weight of 63 pounds. They were divided into two lots of four each, the allotment being made on a basis of weight for age and apparent thrift.

Lot I - Self-fed Ration:		Lot II - Self-fed Ration:	
Kafir	46.5%	Kafir	47.5%
Shorts	46.5%	Shorts	47.5%
Limestone	1.0%	Tankage *	5.0%
Bonemeal	1.0%	Carotene *	10 c.c. per pig
Tankage *	5.0%		
Carotene *	10 c.c. per pig		

Both lots had free access to salt and water.

At the end of the experiment the hogs were weighed and killed in pairs, one hog from each lot, care being taken to pair the hogs according to their weight rank in their respective lots.

The pairs and weights were as follows:

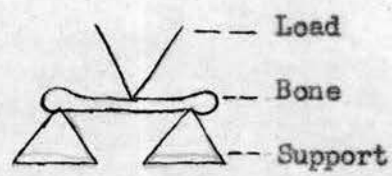
Pair	Mineral or Non-mineral Ration	No. of Pig	Initial Weight Pounds	Final Weight Pounds
1	M.	1	50	190
	N. M.	2	70	205
2	M.	3	65	185
	N. M.	4	68	190
3	M.	5	75	180
	N. M.	6	64	167
4	M.	7	57	150
	N. M.	8	57	154
Av.	M.		62	176
	N. M.		65	179

* Tankage and carotene were added to the ration after the pigs had been on feed one month.

They were slaughtered at the Oklahoma A. and M. College abattoir in the regular manner and blood samples were taken from the sticking cut. All carcasses were chilled 48 hours at 33° Fahrenheit and cut according to the standard method.

Procedure in Breaking Strength Study

The tibia was removed from the ham of each hog and used in the breaking strength tests, which were conducted in cooperation with the Civil Engineering Department of Oklahoma A. and M. College. The bones were broken under pressure with a Riehle Universal testing machine with a capacity of 100,000 pounds. The load was applied to the smallest part of the shaft of the bone, and the two supports were placed 3.16 inches apart. Pressure was applied until the bone broke under the weight. The reading in pounds was taken from the machine and recorded.



Method of Testing Breaking Strength of Bone

Cross sections were taken from the smallest part of the tibia of each hog, and measured for wall thickness, measurements being made of the thinnest portions of the three walls. The three measurements were then averaged to obtain the final thickness.

Procedure in Juiciness Study

Juiciness, which is dependent upon the fluid content of muscle, is an important factor in palatability of meat and may be described as the readily expressible liquid in a piece of meat. In running the juiciness tests measured sections of the longissimus dorsi muscle from the right side of the carcass in the vicinity of the 9th, 10th, and 11th ribs were seared twenty minutes at a temperature of 480° Fahrenheit. The meat was then transferred to an oven at 300° Fahrenheit and the cooking was continued until the meat thermometer registered 185° Fahrenheit. The tests were made immediately upon the meat as it was removed from the oven.

For sampling a slice 1.87 centimeters thick was cut from the center of the roast by means of a sharp thin-bladed knife, using a mechanical gage for determining the thickness of the slice. Three adjacent samples were cut from the center of the slice with a round borer 1.27 centimeters in diameter. Each sample was transferred to a numbered, previously weighed aluminum dish containing a piece of dry, weighed, unsized, shrunken filter cloth that had been boiled ten minutes in distilled water, dried and cut in the shape of a cross. The dish with cloth and muscle sample was then weighed. The sample was carefully wrapped and placed in a brass tray which was inserted in the pressometer and allowed to remain for ten minutes at a pressure of 250 pounds. The muscle sample and the cloth were then removed from the tray and placed in separate, dried aluminum dishes and weighed. Rapid work was necessary from the time the sample was cut to the last weighing so as to avoid evaporation losses. Forceps were used for all handling.

The percentage of press fluid in the muscle was found by dividing the weight of the press fluid by the weight of the muscle sample before pressing. The weight of the press fluid was found by subtracting the weight of the press muscle sample from the weight of the unpressed sample.

Procedure in Tenderness Study

In conducting the tenderness and juiciness tests identical cuts and cooking methods were used with the exception that the samples for the tenderness study were taken from the longissimus dorsi on the left side of the carcass. All samples were taken by a cork borer type of samplerone inch in diameter and tested immediately upon removal from the oven. Three different samples were taken from the longissimus dorsi muscle and were termed as lateral, center and medial samples. An average of the three shear readings was used as the true tenderness figure.

The Warner-Bratzler mousetrap or shear machine was developed at the Kansas Agricultural Experiment Station and was used in making the test. Thin blades with a thickness of .04 inch and a triangular opening were found to be most satisfactory.

Procedure in Blood Analysis for Calcium and Phosphorus

Blood analyses for total calcium and phosphorus were run by the Agricultural Chemistry Department at Oklahoma A. and M. College.

Procedure in Hardness of Fat Study

Fat samples were taken from the back fat, and hardness of fat studies were made by the Agricultural Chemistry Department. The iodine number was used in making the tests.

RESULTS

Breaking Strength and Wall Thickness of the Tibia

A highly significant difference in the breaking strength and wall thickness of the tibia was found between the hogs fed calcium and phosphorus and those not receiving these minerals in their rations. The average breaking strength of the tibia for the hogs receiving calcium and phosphorus was 1190 pounds as compared with 972 pounds for the hogs receiving no calcium and phosphorus. Within each of the four pairs, which were set up on a basis of weight for the analyses, a noticeable difference was found in the breaking strength which was higher in all cases for the mineral fed hogs. (See Table VIII) Snedecor's "F" test, analysis of variance, was amployed in obtaining the highly significant difference found.

Table VIII

The Effect of Calcium and Phosphorus on the Breaking Strength and Wall Thickness of Swine Bones

Pair	No. of Pig	Mineral or Non-Mineral Ration	Initial Weight Pounds	Final Weight Pounds	Breaking Strength of Tibia - Pounds	Wall Thickness of Tibia Millimeters
1	1	M.	50	190	1110	4.06
	2	N. M.	70	205	1095	3.50
2	3	M.	65	185	1240	3.86
	4	N. M.	68	190	1065	2.80
3	5	M.	75	180	1080	3.03
	6	N. M.	64	167	1005	3.03
4	7	M.	57	150	1330	3.76
	8	N. M.	57	154	730	2.83
Av.		M.	62	176	1190	3.68
		N. M.	65	179	972	3.04

Similar results were found when the bones were compared for wall thickness. With the exception of pair No. 3, the bones from the hogs receiving calcium and phosphorus had thicker walls, averaging 3.68 mm. as compared to an average wall thickness of 3.04 mm. in the bones from the non-mineral fed hogs. In pair No. 3, even though the measurements for thickness of walls were the same, the hog receiving calcium and phosphorus had the higher breaking strength of the two, indicating that these minerals had a beneficial effect, and also that breaking strength may be more dependent on density of bone than on the thickness of the walls. This fact may be further illustrated, for while there is a high correlation between breaking strength and wall thickness within pairs, this is not necessarily the case when each hog is considered as an individual. It can be seen in Table VIII that the bones showing the greatest thickness of walls do not always show the greatest breaking strength. For example, pig No. 7, even though showing the greatest breaking strength of any individual is surpassed by both No. 1 and No. 3 in wall thickness. A difference in the sizes and weights of the individuals must be taken into consideration in a comparison of this kind as well as difference in density of the bones. Due to the irregular shape of the tibia there is also a possibility of some experimental error in the process of obtaining the wall thickness and breaking strength of this bone. However, within the pairs, where the weights and conditions for analysis are approximately the same, there is a correlation existing between breaking strength and thickness of walls.

The presence of calcium and phosphorus in the ration did not increase the gains of the mineral fed hogs over the non-mineral fed animals. The average final weight of the lot receiving limestone and bonemeal as calcium and phosphorus supplement was 176 pounds as compared to 179 pounds for the lot receiving no mineral supplement, which was a three pound advantage. However, the non-mineral fed hogs had a three pound advantage in the average initial weights, weighing 65 pounds to 62 pounds for the hogs fed mineral supplements.

Although no measurements were made of the circumference of the tibia, it was quite apparent that the hogs receiving no phosphorus and calcium had a slightly larger bone with a greater circumference than mineral fed hogs.

Results of Tenderness Tests

With the exception of pair 2, there was little or no difference in the tenderness of meat between hogs receiving calcium and phosphorus in their rations and hogs not receiving these minerals. In each pair in which there was a difference in pounds of shear (the criterion for tenderness) the mineral fed hogs showed a lighter shear or more tender meat. However, the difference was minor when all pairs of hogs are considered. In a test of this kind, where a noticeable difference was found to exist in only one of the four pairs of hogs, as indicated in Table IX, there was insufficient evidence to form any definite conclusions as to the effect of calcium and phosphorus on the tenderness of meat.

Table IX

The Effect of Calcium and Phosphorus

On the Tenderness and Juiciness of Pork

Pair	No. of Pig	Mineral or Non-Mineral Ration	Final Weight Pounds	Tenderness Pounds of Shear	Juiciness Percent
1	1	M.	190	15	42.0
	2	N. M.	205	16	40.8
2	3	M.	185	14	40.5
	4	N. M.	190	20	50.0
3	5	M.	180	16	31.8
	6	N. M.	167	17	38.8
4	7	M.	150	19	44.0
	8	N. M.	154	19	32.6

Results of Juiciness Tests

The presence of calcium and phosphorus in the ration did not produce any significant differences in juiciness of the meat. In pairs one and four the meat from the hogs receiving calcium and phosphorus was more juicy than the meat from the non-mineral fed hogs. In pairs two and three, the meat from the hogs receiving no calcium and phosphorus was the more juicy. (See Table IX) No correlation existed between the juiciness of the meat and the presence or absence of calcium and phosphorus in the rations.

A correlation might be expected between the juiciness and tenderness of a piece of meat. This was not the case, however, as is shown in Table IX.

Calcium and Phosphorus Content of the Blood

The presence of limestone and bonemeal as a source of calcium and phosphorus in a ration did not affect the amount of blood calcium and phosphorus. In several cases (see Table X) the hogs which had been on a non-mineral ration were found to have a higher content of calcium and phosphorus in the blood than hogs that had been receiving these minerals in their feed. Some of the mineral fed hogs, as might be expected, had a higher content of blood calcium and phosphorus, but there was no definite trend established when all four pairs of hogs are considered. From the data presented in Table X, it would appear that calcium and phosphorus in the ration did not affect the amount of these minerals in the blood.

Table X

The Effect of Calcium and Phosphorus in the Ration on the Calcium and Phosphorus Content of the Blood

Pair	No. of Pig	Mineral or Non-Mineral Ration	Final Weight Pounds	Calcium Mgs. per 100 Ml. Serum	Phosphorus Mgs. per 100 Ml. Blood
1	1	M.	190	14.3	75.9
	2	N. M.	205	14.7	79.1
2	3	M.	185	14.7	82.9
	4	N. M.	190	14.1	69.7
3	5	M.	180	14.7	69.9
	6	N. M.	167	15.1	76.9
4	7	M.	150	13.6	29.6 *
	8	N. M.	154	13.6	73.1

* This blood sample clotted making an accurate analysis impossible.

Results of Fat Tests

The iodine number of the fat was found to be somewhat higher for the mineral fed pigs in three of the four pairs of pigs used in the test. In one of the pairs the iodine number of the fat was higher for the pig receiving no calcium and phosphorus. Within the pairs the differences were not considered to be large. There was insufficient evidence from the results of this test to conclude that calcium and phosphorus affect the chemical composition and physical properties of fat. From the data presented in Table XI, it appears that calcium and phosphorus in the ration do not affect the fat, particularly the iodine number or unsaturation.

Table XI

The Effect of Calcium and Phosphorus in the Ration on the

Iodine Numbers of Moisture Free Hog Fats

Pair	No. of Pig	Mineral or Non-Mineral Ration	Final Weight Pounds	Iodine Number
1	1	M.	190	74.70
	2	N. M.	205	71.43
2	3	M.	185	78.23
	4	N. M.	190	71.52
3	5	M.	180	74.10
	6	N. M.	167	77.85
4	7	M.	150	78.35
	8	N. M.	154	71.90

DISCUSSION

The value of calcium and phosphorus in a ration has been recognized by livestock breeders and feeders for quite some time. Extensive research in the past has resulted in conclusive evidence that these minerals are very essential in the proper growth and development of swine. The livestock man is interested in developing and producing stronger bone in the pigs he raises and sends to market in order to eliminate large losses from crippled and dead animals which have been on mineral deficient rations prior to the time of marketing. The feeding of calcium and phosphorus partially solves this problem and to a great extent eliminates much of the losses formerly suffered by the hog breeder and feeder. Stronger, denser, harder bones are developed that are more able to withstand the strains and stresses to which they are subjected on the way to the packing plant. The walls of the bones are thicker indicating greater strength, and the circumference is often slightly smaller which indicates that the greater strength in the bones of mineral fed pigs is not due to larger bone, but rather, it is because of the thicker bone walls and greater density. Calcium and phosphorus have been proved by research workers in the past as well as in this experiment to be beneficial in the proper development of strong bones.

Calcium and phosphorus, while being of great importance in bone building are not nearly so important in the other tissues of the animal body. The meat from pigs receiving these minerals was no more tender or juicy as found in the experiment than meat from hogs on a non-mineral ration. The fact that calcium and phosphorus are present in the muscle tissues in very small amounts as compared to the bone tissues probably accounts partially for their lack of influence on tenderness or juiciness of meat. In past studies of tenderness and juiciness the effect of mineral has not been taken into consideration. Emphasis has been placed on the various cooking methods, different ages of meat animals, and varying degrees of finish as they affect the tenderness and juiciness of the meat.

It might be expected that blood calcium and phosphorus would be higher in pigs on a mineral ration of limestone and bonemeal than it would be for pigs not receiving these minerals. However, blood samples from each pig on the experiment were analyzed, and no significant differences were found.

The iodine number revealed no significant differences in hardness between fat samples from pigs receiving calcium and phosphorus and pigs not receiving these minerals. Fat, which is composed of carbon, hydrogen, and oxygen is not known to contain any minerals, and the presence of minerals in the ration would not be expected to have any effect. As far as is known, no previous experiments have been conducted in which a study of minerals as they affect hardness of fat has been made. Conclusive evidence has been produced by various workers that soy beans and peanuts cause soft pork if fed in large enough quantities.

SUMMARY

This study attempts to evaluate the importance of calcium and phosphorus in swine rations with particular emphasis attached to their function in regard to bone strength and structure, tenderness, and juiciness of meat, composition and characteristics of fat, and blood content of calcium and phosphorus.

The presence of calcium and phosphorus in the swine ration was found to produce the following results:

1. A stronger bone with thicker walls and a greater breaking strength was developed.
2. No significant differences were found in tenderness or juiciness of the meat from mineral and non-mineral fed pigs.
3. The presence of calcium and phosphorus in the ration had no significant effect on the amount of blood calcium and phosphorus.
4. The composition and quality of fat are not affected by calcium and phosphorus.

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Typist:

Fern Fredrica Petree