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The relationship between mineral levels in the diets of growing-finishing swine and the type of confinement system in which they are raised is not fully understood. In a previous report (A.S. Series 75-52), we reported the performance data of an experiment designed to provide more information in this area. Reported herein is the information on bone strength and bone development as related to floor type and calcium and phosphorus levels in the diet.

Experimental Procedure

Of the 280 pigs used in two trials, one-half were barrows from which bones were extracted for analysis. The pigs had been self-fed a basal diet that varied in calcium and phosphorus as follows:

Treatment 1 - .40% calcium, .40% phosphorus
Treatment 2 - .60% calcium, .40% phosphorus
Treatment 3 - .80% calcium, .40% phosphorus
Treatment 4 - .65% calcium, .55% phosphorus

These treatments formed calcium-phosphorus ratios of 1:1, 1.5:1 and 2:1 for the first three treatments, respectively, and the National Research Council's (N.R.C.) recommended levels and ratio (1.2:1) for treatment 4.

Each mineral treatment was represented across each of the five floor types. These floor types and the pen sizes were as follows:

	Pen Size	Slat Width	Floor Material
1.	7.5 x 9 ft.	8 in.	concrete
2.	7.5 x 9 ft.	5 in.	concrete
3.	7.5 x 9 ft.	3.5 in.	aluminum
4.	8 x 12 ft.	house	wood
	29 x 52 ft.	outside pen	dirt
5.	8 x 12 ft.	house	concrete
	12 x 16 ft.	outside pen	concrete

When the pigs reached approximately 210 lb., the barrows were removed from test, slaughtered at John Morrell and Company, Sioux Falls, and the front legs extracted and brought back to Brookings for analysis.

The inside and outside metatarsals were boned out, placed in hot water to denature the remaining tissue, scraped and the fat extracted from the bone marrow.

Bone circumference, diameter and length were recorded on the 560 bones. Dry weight, fat-free weight, percent ash, density and bone breaking stress were determined on the bones. Bone bending stress and shear stress were determined by mechanically applying force to the middle of the bone while in a horizontal position and compressive stress was obtained by applying force to the end of the bone while in a vertical position.

Formulas for determining the stress values when breaking the bones were as follows:

$$\text{Bending stress} = \frac{8}{\pi} \quad \frac{\text{load x length}}{\text{diameter}^3}$$

$$\text{Vertical shear stress} = 6.784 \text{ x } \frac{\text{load}}{\text{diameter}^2}$$

$$\text{Compressive stress} = \frac{4}{\pi} \text{ x } \frac{\text{load}}{\text{diameter}^2}$$

Results

The results of the effects on bone development of varying calcium and phosphorus levels in the diet are shown in table 1. Circumference of bone was greater from pigs receiving the N.R.C. recommended levels of calcium and phosphorus than those receiving the 1.5:1 ratio. Pigs receiving the 1:1 ratio had greater bone diameter than those receiving 1.5:1 or 2:1 ratios. Bone length was greater for both the 1:1 ratio and N.R.C. levels than either the 1.5:1 or 2:1 ratio-fed pigs. Most definitely, the ratio of calcium and phosphorus did affect bone dimension.

Bone weights followed the same pattern as did bone length. For bone ash, the N.R.C. recommended levels and 1.5:1 ratio diets produced pigs with more bone ash than did the diets which were 1:1 or 2:1 in calcium and phosphorus. No difference in density of bone was found due to calcium and phosphorus level.

Bending stress and shear stress were greater for bones from pigs which had received the 1.5:1 or N.R.C. level of calcium and phosphorus as compared to the group receiving minerals in the 1:1 or 2:1 ratio. No differences in compressive stress were found.

The results of the effect on bone development of different floor types is shown in table 2. For circumference, diameter and length of metacarpals, pigs grown on aluminum slats had lesser bone development. Pigs raised on aluminum slats had significantly less bone circumference than those on concrete or narrow concrete slats, less bone diameter than pigs raised on dirt or concrete and less bone length than pigs raised on any other floor type.

Bone weight was less for pigs on aluminum slats and greater for pigs on concrete slats than for pigs on all other floor types. Pigs produced on wide slats, dirt lot and concrete lot had bones of higher percent ash than those produced on the narrow concrete slats or aluminum slats. Bones from pigs on all other floor types were more dense than those from pigs on aluminum slats. Also, pigs produced in concrete and dirt lots had bones denser than those from pigs in the concrete slat lots.

For both bending stress and shear stress, higher values were obtained from bones of pigs fed in dirt or concrete lots. No differences in compressive stress were found.

Summary

Two trials involving 280 pigs were conducted to evaluate the effect of calcium and phosphorus levels and the effect of different floor types on bone development. In general, bone size, weight and percent ash favored the 1:1 ratio or the N.R.C. recommended ratio of 1.2:1 over the 1.5:1 or 2:1 ratio of calcium and phosphorus. Breaking strength favored the 2:1 ratio or N.R.C. recommended levels.

Floor types affected these parameters with the least desirable bone development from pigs on aluminum slats and the most development from pigs on outside concrete or dirt lots. No interaction between calcium and phosphorus and floor types was observed.

Table 1. Differences in Bone Criteria Due to Mineral Diet

Calcium, %	.40	.60	.80	.65-.60
Phosphorus, %	.40	.40	.40	.55-.50
	Bone Measurements			
Circumference, cm*	4.82	4.77^{a}	4.81	4.84^{a}
Diameter, cm*	1.50^{ab}	1.48^{a}	1.49^{b}	1.50
Length, cm**	6.50^{ab}	6.38^{ac}	6.34^{bd}	6.47^{cd}
Dry weight, g**	15.65^{ac}	15.16^{cd}	14.95^{ab}	15.88^{bd}
Fat-free weight, g**	11.63^{a}	11.37^{b}	11.06^{ab}	12.22^{ab}
Percent ash**	57.3^{ab}	58.0^{ac}	56.7^{cd}	58.8^{bd}
Density	1.07	1.09	1.07	1.11
	Bone Strength			
Bending stress, g/cm^2**	162.6^{ab}	188.8^{bc}	164.4^{cd}	190.7^{ad}
Shear stress, g/cm^2**	171.8^{ab}	203.6^{bc}	178.5^{c}	201.1^{a}
Compressive strength, g/cm^2	48.4	54.8	52.7	51.3

* Means with common superscripts are significantly different ($P<.05$).
** Means with common superscripts are significantly different ($P<.01$).

Table 2. Differences in Bone Criteria Due to Floor Type

	Type of pen				
	8-inch slat concrete	5-inch slat concrete	3.5-inch slat aluminum	Concrete lot	Dirt lot
	Bone Measurements				
Circumference, cm**	4.80	4.83^{a}	4.76^{ab}	4.81	4.86^{b}
Diameter, cm*	1.49	1.49	1.47^{ab}	1.50^{a}	1.50^{b}
Length, cm**	6.44^{a}	6.43^{b}	6.36^{abcd}	6.43^{c}	6.47^{d}
Dry weight, g*	15.27^{a}	15.46^{b}	14.08^{ab}	15.84^{a}	16.41^{ab}
Fat-free weight, g**	11.02^{a}	11.34^{a}	11.13^{b}	12.35^{ab}	12.01^{ab}
Percent ash**	57.7^{ad}	57.0^{abc}	56.6^{def}	58.7^{be}	58.5^{cf}
Density**	1.08^{abc}	1.08^{def}	1.03^{cdgh}	1.11^{aeg}	1.13^{bfh}
	Bone Strength				
Bending stress, g/cm^2**	157.7^{ad}	165.6^{be}	161.5^{cf}	210.5^{abc}	187.9^{def}
Shear stress, g/cm^2**	167.8^{ad}	178.1^{b}	173.4^{ce}	224.7^{abc}	199.8^{de}
Compressive strength, g/cm^2	51.2	50.9	46.2	57.8	52.8

* Means with common superscripts are significantly different (P<.05).
** Means with common superscripts are significantly different (P<.01).