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EFFECT OF VARIOUS LEVELS OF DIETARY CALCIUM AND PHOSPHORUS ON PERFORMANCE, BLOOD AND BONE PARAMETERS IN GROWING BOARS[1]

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Summary

Ninety-six 8-kg crossbred boars were initially allotted to three dietary levels of calcium (Ca) and phosphorus (P) – (A) .65% Ca; .50% P; (B) .975% Ca; .75% P and (C) 1.3% Ca; 1.0% P – to determine the effects of the different levels on average daily gain (ADG), average daily feed intake (ADFI), feed to gain (F:G) and certain blood and bone parameters. During the initial 8-week growth period, no differences in ADG (.55, .58, .55), ADFI (1.17, 1.23, 1.16) or F:G (2.08, 2.16, 2.10) were observed for treatments A, B and C, respectively. At the beginning of the 8-week final growth period (41.5 kg), 50% of the boars fed each of the primary dietary treatments (A, B and C) were assigned to the other two treatments, while the other 50% remained on their original assigned treatments. No differences in performance were observed for the total 16-week growth period when evaulated as nine treatments. Fresh femurs and third and fourth metatarsals were evaluated for physical measurements, bone strength and percentage ash. Peak force required to break the bones of the pigs on the final period treatments increased linearly (P<.025) as the dietary level of Ca and P increased. Final period stress and stress:strain parameters of the bones responded similarly to peak force (linear component, P<.01). Also, percentage ash increased (linearly, P<.05) as dietary Ca and P levels increased. No treatment differences in subjective soundness scores were observed for any of the dietary treatments. Serum Ca levels decreased linearly at the end of the initial period, but the response was quadratic at the end of the final period. Alkaline phosphatase decreased linearly (P<.05) across treatments, with the largest decrease occurring with treatment A during the final period. The feeding of dietary Ca and P at up to twice the levels suggested by NRC (1973) for growing swine did not adversely affect performance of boars fed .65% Ca and .50% P than with those fed higher levels.
(**Key Words**: Calcium, Phosphorus, Boars, Performance, Bone-Breaking Strength.)

Introduction

Years of research indicate that, in general, the optimum levels of dietary calcium (Ca) and phosphorus (P) required for growing swine to produce maximum weight gains and feed efficiency are lower than the requirements for nomal skeletal development. Boars have become the focus of much concern because they have a relatively high frequency of leg unsoundness, most notably when they are selected for high lean tissue production. Smith and Smith (1965) reported that approximately 35% of the boars they tested exhibited some form of leg abnormality. Little research is available to aid in the establishment of levels of dietary Ca and P that will produce optimum performance and maximum skeletal development in boars. Thus, the problem of estimating meaningful dietary Ca and P recommendations for boars is difficult, especially in view of the performance and skeletal development demand differences between boars and market animals. Numerous reports have identified performance and skeletal differences between boars and market animals (Kuhlers *et al.*, 1976; Kornegay *et al.* 1977). From these reports, it is apparent that early growth of the boar is critical. A

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sound Ca and P nutritional regime is necessary to ensure maximum bone and muscle tissue development because of rapid mineral deposition rates early in life.

Current research on Ca and P nutrition for boars (Tanksley 1974, Irlam *et al.*, 1974; Bayley *et al.*, 1975) has produced interesting results, but many aspects of total intensive growth phase studies and identification of ideal bone test parameters are yet to be uncovered.

The objective of this study was to evaluate the effects of various levels of dietary Ca and P during the initial, final and total growth periods on average daily gain and feed conversion by boars and on certain blood and bone parameters.

Experimental Procedure

Ninety-six 8-kg crossbred boars (19 to 21 days of age) were randomly allotted to three initial dietary levels of Ca and P, with four replications of the treatment (table 1). Treatment A consisted of .65% Ca and .50% P, levels which met NRC (1973) requirements for young growing pigs. Treatment B contained .975% Ca and .75% P, or NRC requirements plus 50%, and treatment C contained 1.3% Ca and 1.0% P, or NRC requirements plus 100%. The Ca:P ratio was maintained at 1.31:1 for all dietary treatments. Experimental diets were corn-soybean meal based (table 2) diets formulated to contain 17% crude protein; they were fed *ad libitum* in meal form. The appropriate levels of dietary Ca and P were attained by adjustment of the levels of dicalcium phosphate and calcium carbonate. Zinc was added to supply 200 ppm and vitamin D_3 was supplemented at 440 IU/kg. All boars were fed the three (A, B, C) initial treatments for 8 weeks to an average weight of 41.5 kilograms. At that time, 50% of the animals on each dietary treatment were randomly assigned to the other two treatments (that is, 50% of those on diet A were allotted to diets B and C, *etc.*), while the other 50% remained on their original treatments. Thus, the total growth period treatments were AA, AB, AC, BA, BB, BC, CA, CB and CC, (first letter indicates initial growth period treatment, second indicates final growth period treatment). All boars remained on the final period treatments for an additional 8 weeks. Thus, the total test period was 16 weeks. The boars were weighed biweekly, and average daily gain (ADG), average daily feed intake (ADFI) and feed conversion (F:G) were measured for each 2-week interval.

At termination (19 weeks of age), the boars averaged 92 kilograms. Soundness scores were made by three independent judges at the start of the trial, after the initial 8-week growth period and at completion of the trial just before termination. Front and rear feet and legs were scored separately, with 10 points the maximum possible score for each. Freedom of movement was allotted up to five points, feet and leg structure up to three points and toes up to two points. Guidelines for evaluating movement were as follows: (1) Look for free and easy movement (2) Downgrade pigs with stiff, choppy, short strides. (3) Downgrade "goose-stepping" and kicking of back legs. (4) Severely downgrade buckled knees. Guidelines for evaluating front feet and leg structure were: (1) Evaluate the set of the shoulders, legs and

TABLE 1. EXPERIMENTAL DESIGN

	Treatment arrangement[ad]		
Initial period[b] (8 weeks)	A	B	C
Final period[c] (8 weeks)	A B C	A B C	A B C

[a]Dietary treatments: A = .65% Ca, .50% P; B = .975% Ca, .75% P; C = 1.3% Ca, 1.0% P.

[b]Initial period = 8-week period from 3 to 11 weeks of age; three treatments, four replications of each treatment.

[c]Final period = 8 week period from 11 to 19 weeks of age; four replications of each final period treatment: two from same initial period treatment, two (one each) from the other initial period treatments.

[d]Total period = nine dietary treatments for the total 16-week period. Treatments AA, BB, CC contained two replicates (16/treatment); AB, AC, BA, BC, CA, CB contained one replicate (eight/treatment).

TABLE 2. COMPOSITION OF DIETS

Ingredient, %	Internat'l Ref. No.	Diets A	B	C
Ground yellow corn	4-02-931	72.84	71.15	69.46
Soybean meal	5-04-612	23.74	24.07	24.42
Dicalcium phosphate	6-01-080	.81	2.20	3.51
Calcium carbonate	6-01-069	1.01	.98	1.01
Salt (iodized)	6-04-152	.50	.50	.50
Trace mineral premix[a]		.10	.10	.10
Vitamin and antibiotic premix[b]		1.00	1.00	1.00
		100.00	100.00	100.00

[a]Contributed the following in ppm of diet: Zn, 200; Fe, 100; Mn, 55; Cu, 10; Co, 1; I, 1.5

[b]Contributed the following per kilogram of diet: vitamin A, 3,300 IU; vitamin D_3, 440 IU; riboflavin, 4.4 mg; pantothenic acid, 26.4 mg; niacin, 35.2 mg; choline chloride, 220 mg; vitamin B_{12}, 44 μg; ethoxyquin, 8.8 mg; menadione sodium bisulfite, 4.4 mg; vitamin E, 44 IU. Antibiotic contined 4.4% chlortetracycline, 4.4% sulfamethazine, 2.2% procaine penicillin.

pasterns. (2) Downgrade "extra-straight" front legs as viewed from the side. (3) Downgrade pigs that are pigeon-toed, knock-kneed, splay-footed (unusually flattened or spread out), bow-legged or wing-shouldered. Guidelines for evaluating rear feet and leg structure were: (1) Look closely at hocks and pasterns and at sickle hocks that are likely to become excessively weak. (2) Downgrade swollen joints, tendons and ligaments of front and rear legs (adapted from Bereskin, 1977). To ensure standarized scoring, the three judges scored examples before evaluating the animals used in the experiment.

All boars were slaughtered 1 day after termination of the trial, with the left ham and foot excised for recovery of the femur and third and fourth metatarsals. Bones were broken on a fresh basis (wet). Bone test formulas, physical measurements, bone-breaking procedures and determination of ash methods are described in the preceding article (Nimmo *et al.*, 1980).

Blood samples were obtained from the brachial region in each boar four times during the trial. The initial bleeding (T1) was taken before the animals were placed on experimental diets; the second (T2) was made just before the animals were placed on the final growth period diets; the third (T3) 72 hr thereafter, and the fourth (T4) at the termination of the trial. Analysis of serum Ca, P and alkaline phosphatase was performed as described in the preceding article (Nimmo *et al.*, 1980).

Statistical analysis was conducted by an appropriate application of least-squares analysis of variance as designed and implemented by Barr and Goodnight (1972) and Steel and Torrie (1960).

Results and Discussion

A summary of ADG, ADFI and F:G for the initial period is presented in table 3. Increasing the dietary Ca and P levels from .65% Ca and .50% P in treatment A to .975% Ca and .75% P in treatment B and 1.3% Ca and 1.0% P in treatment C did not influence ADG (.55, .58,

TABLE 3. EFFECT OF VARIOUS LEVELS OF DIETARY CA AND P ON PERFORMANCE PARAMETERS DURING INTIAL PERIOD (3 WEEKS TO 11 WEEKS OF AGE)

Criterion[c]	Initial treatment[ab] A	B	C
Avg daily gain, kg	.55	.58	.55
Avg daily feed intake, kg	1.17	1.23	1.16
Feed to gain ratio	2.08	2.16	2.10

[a]All performance parameters were analyzed for initial period linear and quadratic responses and interactions.

[b]Treatment A = .65% Ca, .50% P; B = .975% Ca, .75% P; C = 1.3% Ca, 1.0% P.

[c]Standard error of treatment means: ADG = .03, ADFI = .08, F:G = .06.

.55), ADFI (1.17, 1.23, 1.16) or F:G (2.08, 2.16, 2.10) through the first 8 weeks of the trial. There appeared to be a trend for a quadratic response across all three of the Ca and P levels for all performance parameters, but it was not significant. The initial 8-week performance (from 3 weeks to 11 weeks of age) appeared to indicate that no adverse affect on performance results when Ca and P are fed to young growing boars at levels above the NRC (1973) suggested requirements for growing swine. This finding disagrees somewhat with that of Irlam *et al.* (1974), who reported that young growing boars fed 1.03% Ca and .86% P levels significantly lower gains and feed to gain ratios.

ADG, ADFI and F:G for the total growth period for all nine treatments are summarized in table 4. No significant differences in ADG, ADFI or F:G were observed between boars fed the different dietary levels of Ca, P or combinations of the two elements. The results contrast with those obtained by Kornegay *et al.* (1977), who reported superior gain and feed efficiency for boars fed levels of dietary Ca and P 25% higher than NRC-recommended levels. Tanksley (1974) obtained optimum gains and feed efficiency in boars with .50% Ca and .50% P, while gains were depressed with 1.2% Ca and 1.0% P. Bayley *et al.* (1975) reported that boars had a higher P requirements than gilts and that maximum growth rate occurred in boars fed Ca at .80% and P at .40% to .60%.

A summary of all bone parameters is presented in table 5. Peak force required to break the femur and metatarsals increased linearly ($P<.025$) for the final period treatments (figure 1). Bones from pigs fed treatments AA, BB and CC showed a linear ($P<.001$) increase in peak force (227, 254 and 259). In addition, a treatment × bone interaction ($P<.05$) was observed. The femur and both metatarsals increased dramatically in breaking strength when peak force for treatment AA was compared to that for treatment BB, but the metatarsals seemed to plateau when treatment BB peak force values were compared to those for treatment CC. The femur peak force values continued to increase across treatments. As expected, more peak force was required to break femurs than metatarsals ($P<.001$) because of physical differences between the bones. Peak forces required to break the third and the fourth metatarsal were also different ($P<.05$). These results are similar to those reported by Tanksley *et al.* (1974). Also, Kornegay *et al.* (1977) found that breaking strength of metacarpals was highest when Ca and P levels exceeded NRC requirements by 25%.

Since stress (kilograms/square centimeters) and stress:strain (kilograms/square centimeter/millimeter) parameters are partially derived from peak force (kilogram) values, similar results were expected. An initial period linear response (IL) ($P<.001$) and a final period linear response (FL) to the Ca and P treatment ($P<.01$) were observed for stress parameters. These results suggest that as the level of dietary Ca and P increased in the initial or final period, more stress was required to break the bones. The same IL response was observed for stress: strain ($P<.01$). Also, FL ($P<.01$), and final period quadratic (FQ) ($P<.05$) responses were ob-

TABLE 4. EFFECT OF VARIOUS LEVELS OF DIETARY Ca AND P ON PERFORMANCE PARAMETERS FOR TOTAL GROWTH PERIOD (3 WEEKS TO 19 WEEKS OF AGE)

	Diet schedule[a,b,c,d]								
Criterion[e]	AA	BB	CC	AB	AC	BA	BC	CA	CB
ADG, kg	.72	.74	.72	.72	.72	.72	.75	.73	.71
ADFI, kg	1.81	1.83	1.78	1.80	1.95	1.91	1.98	1.84	1.83
F:G	2.48	2.57	2.50	2.48	2.67	2.69	2.65	2.52	2.56

[a]All performance parameters were analyzed for linear and quadratic responses and interactions as nine treatments.

[b]First letter = diet fed from weeks 3 to 11; second letter = diet fed from 11 to 19 weeks of age.

[c]Diet A = .65% Ca, .50% P; diet B = .975% Ca, .75% P; diet C = 1.3% Ca. 1.0% P.

[d]ADG = average daily gain; ADFI = average daily feed intake; F:G = feed per gain.

[e]Standard error of treatment means: ADG = .04: ADFI = .30, F:G = .15.

TABLE 5. EFFECT OF VARIOUS LEVELS OF DIETARY Ca AND P ON BONE PARAMETERS[ab]

Diet[cd]	Bone[v]	Peak force,[eprs]	Stress,[fghpqrs]	stress:strain,[gijpqs]	Deformation,[t]	% Ash,[klemu]	Weight,[ns]	Length,[os]
		(kg)	(kg/cm²)	(kg/cm²/mm)	(mm)	(%)	(g)	(cm)
AA	Femur	434.3	84.69	18.20	4.79	66.68	248.1	18.39
	Third meta	127.3	58.71	25.01	2.35	59.21	26.75	8.35
	Fourth meta	120.7	58.84	23.20	2.61	58.97	28.32	8.89
	Avg	227.4	67.41	22.14	3.25	61.67	101.0	11.87
BB	Femur	480.9	96.22	22.27	4.46	67.81	258.8	18.55
	Third meta	144.1	69.24	32.11	2.23	59.68	26.97	8.49
	Fourth meta	136.6	68.36	27.87	2.56	59.69	28.94	9.05
	Avg	253.9	77.94	27.42	3.08	62.39	104.9	12.03
CC	Femur	497.2	93.51	21.36	4.51	66.97	254.1	18.28
	Third meta	141.9	70.34	34.52	2.07	60.97	25.67	8.32
	Fourth meta	138.1	69.97	27.05	2.69	60.21	27.88	8.89
	Avg	259.1	77.94	27.65	3.09	62.66	102.6	11.83
AB	Femur	502.5	89.71	21.33	4.30	66.89	264.59	18.50
	Third meta	115.63	54.00	24.34	2.17	60.29	26.49	8.35
	Fourth meta	128.75	59.29	22.02	2.80	59.92	28.29	8.82
	Avg	248.9	69.29	23.54	3.09	62.37	106.5	11.89
AC	Femur	441.43	81.63	17.57	4.89	67.24	242.45	18.44
	Third meta	122.14	62.16	30.31	2.09	59.73	24.44	8.33
	Fourth meta	124.29	62.90	24.37	2.56	59.71	26.84	9.03
	Avg	229.3	68.90	24.08	3.18	62.35	97.91	11.93
BA	Femur	469.17	79.58	17.94	4.72	67.20	279.76	19.19
	Third meta	123.33	57.66	26.46	2.17	57.80	28.44	8.58
	Fourth meta	129.17	59.92	22.41	2.68	56.39	30.12	9.17
	Avg	240.6	65.72	22.27	3.19	60.70	112.8	12.31
BC	Femur	505.7	102.3	21.99	5.09	66.69	256.9	18.72
	Third meta	148.13	72.84	36.59	2.05	59.27	25.76	8.30
	Fourth meta	147.86	73.86	28.33	2.60	59.93	27.70	8.89
	Avg	261.8	82.54	29.32	3.19	62.21	99.91	11.81

BC	Femur	448.1	93.35	21.82	4.33	68.30	246.1	18.27
	Third meta	121.88	62.07	25.97	2.43	59.95	26.22	8.40
	Fourth meta	126.88	62.48	22.69	2.75	59.99	28.00	8.99
	Avg	232.3	72.63	23.49	3.17	62.87	100.1	11.88
CB	Femur	499.4	103.4	25.27	4.24	68.29	249.1	18.66
	Third meta	143.57	77.00	35.12	2.23	60.09	26.90	8.60
	Fourth meta	154.38	76.53	27.56	2.81	59.39	29.66	9.08
	Avg	271.1	86.03	29.06	3.13	62.98	105.1	12.27

[a]All bone parameters were analyzed by initial, final and total period treatment for linear and quadratic responses plus interactions as nine treatments. Replicated treatments AA, BB and CC were also analyzed separately in the same manner.

[b]Initial period linear response = IL; initial period quadratic = IQ; final period linear = FL; final period quadratic = FQ.

[c]First letter = diet fed from 3 to 11 weeks of age; second letter = diet fed from 11 to 19 weeks of age. *Standard error of treatment means*: peak force = 11.55; stress = 3.55; stress:strain = 1.46; deformation = .15; ash = .36; weight = 3.08; length = .13.

[d]Diet A = .65% Ca, .50% P; diet B = .975% Ca, .75% P; diet C = 1.3% Ca, 1.0% P.

[e]FL ($P<.025$).

[f]IL ($P<.001$).

[g]FL ($P<.01$).

[h]IQ × FL ($P<.05$).

[i]IL ($P<.01$).

[j]FQ ($P<.05$).

[k]IL ($P<.1$).

[l]IQ ($P<.01$).

[m]Treatment × bone interaction ($P<.025$).

[n]IQ ($P<.025$).

[o]IQ ($P<.05$).

[p]Linear response ($P<.001$).

[q]Quadratic response ($P<.05$).

[r]Treatment × bone interaction ($P<.05$).

[s]Meta 3 *versus* meta 4 ($P<.05$).

[t]Treatment × bone interaction ($P<.005$).

[u]Linear response ($P<.005$).

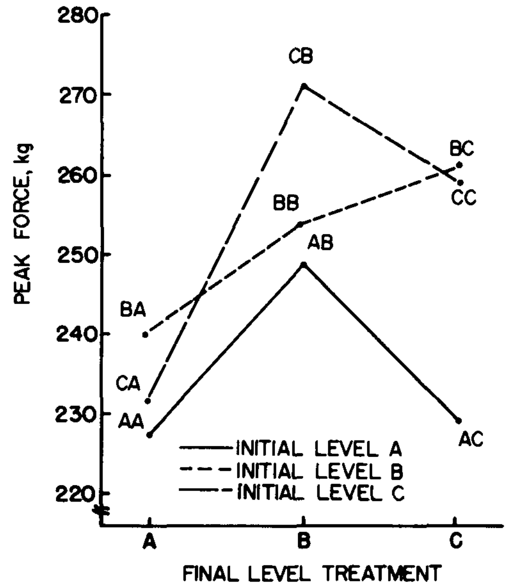

Figure 1. Effect of various levels of dietary Ca and P on peak force pooled across all bones. Final period linear response (P<.025).

served. Treatments AA, BB and CC produced linear (P<.001) and quadratic (P<.05) responses in the stress and stress:strain parameters of all bones as levels of dietary Ca and P increased. When only the replicated treatments AA, BB and CC are considered, it is apparent that the largest numerical differences in peak force, stress and stress:strain were those between treatments AA and BB, indicating that the largest added effect of increased stress, stress:strain and peak force parameters were achieved by increasing Ca and P to levels of .975% and .75%, respectively. When stress and stress:strain values are plotted graphically for the nine dietary treatments (figures 2 and 3), the plots of all treatments containing level A (.65% Ca and .50% P) occupy the lower section of the graph, regardless of the initial or final period level. These results, along with those for peak force, indicate that regardless of the increased dietary Ca and P levels (B or C) fed during the final growth period, no compensatory effect occurred in bone mineralization. In addition, when treatment A was fed during the final growth period, there were no apparent sustaining or carry-over effects from the feeding of diets B or C during the initial period. Bayley *et al.* (1975) reported that levels of P of at least .60% were required for maximum radius and femur development of the boar. However, Liptrap *et al.* (1970) reported decreased break-

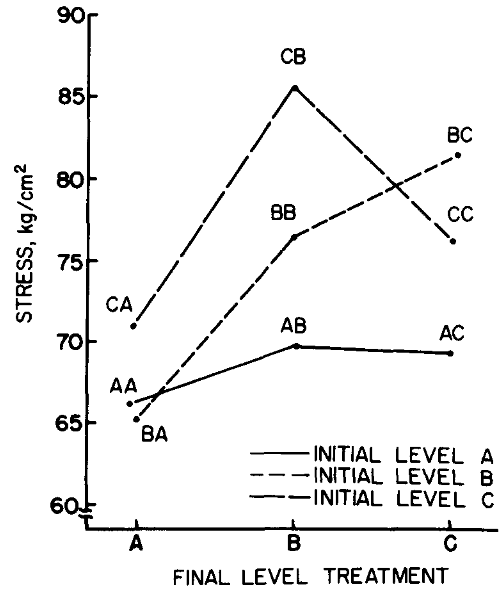

Figure 2. Effect of various levels of dietary Ca and P on stress pooled across all bones. Initial period linear response (P<.001), initial quadratic × final linear interaction (P<.05).

ing strength, bending moment and moment of inertia and maximal breaking stress of boar bones with increasing levels of dietary Ca up to

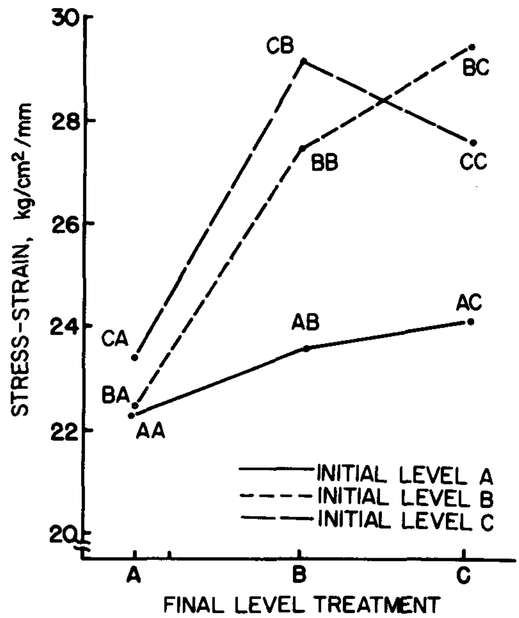

Figure 3. Effect of various levels of dietary Ca and P on stress:strain across all bones. Initial period linear response (P<.01), final period linear response (P<.01) final period quadratic response (P<.05).

1.2%. The limiting factor in their work appeared to be P, which was maintained at .50%. Several other studies do not support these results (Chapman *et al.*, 1962; Combs and Wallace, 1962; Miller *et al.*, 1962; Zimmerman *et al.*, 1963). However, the latter trials did not involve boars, and P was not a limiting factor.

Stress and stress:strain parameters responded in much the same way as peak force across the replicated treatments (AA, BB and CC) when individual bones were examined. Both stress (67.4, 77.9, 77.9) and stress:strain values (22.1, 27.4, 27.6) increased linearly (P<.001) and quadratically (P<.05) as the level of dietary Ca and P increased. As with peak force, the largest numerical differences were observed when treatment AA was compared to treatment BB. Third metatarsals withstood more (P<.001) stress and stress:strain than the fourth metatarsal.

No differences were observed in deformation when pooled across all treatments for either the femur or metatarsals. There was a tendency for Ca:P levels fed during the intial period to have a linear effect on percentage ash when averaged across all bones (P<.1). Initial quadratic (P<.01) and FL (P<.025) responses also occurred, and there was a treatment × bone interaction (P<.05) on percentage ash. Bone ash values are graphically represented in figure 4. The largest differences were observed in bones from boars fed treatment A during the final period. This finding suggests that some alteration in bone mineralization patterns may have occurred in boars fed treatment A during the final period, with the degree of severity more pronounced in boars fed treatments A and B during the initial period. When replicated treatments AA, BB and CC were fed throughout the trial, percentage bone ash increased in a linear manner (P<.005). In addition there was a treatment × bone interaction for percentage ash (P<.005). Tanksley (1974) reported that dietary Ca and P levels had no effect on femur and metacarpal ash content but that turbinate ash increased linearly with increasing levels of Ca and P. Bayley *et al.* (1975) found a tendency for ash content of the femur and radius to increase with increasing levels of dietary Ca and P, and they noted that the increases in ash content were associated with the increases in force required to break the femur.

An IQ response occurred (P<.025), indicating that maximum weight, when pooled across bones, occurred in the initial period with .975%

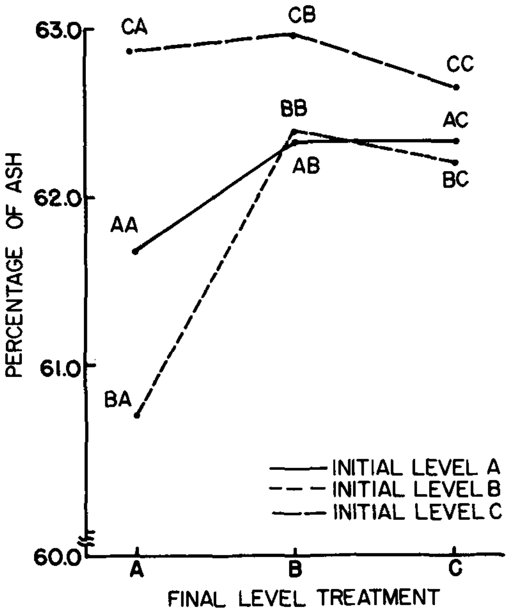

Figure 4. Effect of various levels of dietary Ca and P on percentage of ash pooled across bones. Initial period linear response (P<.1), initial period quadratic response (P<.01), final period linear response (P<.025).

Ca and .75% P. Liptrap *et al.* (1970) reported a linear decrease in bone weight as the level of Ca increased and P was held constant. Their results could have been due in part to the creation of an imbalance in the Ca:P ratio.

An IQ response occurred for bone length (P<.05). No differences existed in bone weight or length among pigs fed the Ca:P sequences AA, BB and CC.

Serum Ca, P and alkaline phosphatase for T1 and T2 are presented in table 6. Although some numerical differences were apparent, no significant responses were observed for T1 and T2, nor were there any differences in these response criteria between the two bleeding times. Brown *et al.* (1966) reported that alkaline phosphatase levels are inversely related to serum Ca. The findings reported herein correspond to that observation.

Comparisons of T2 *versus* T3 and T3 *versus* T4 analyzed as nine treatments are presented in tables 7 and 8. Within T2, there were no differences in blood parameters, but an IL × FL interaction (P<.05) for serum Ca and an IL × FQ interaction for serum P occurred. No specific trend was apparent for bleeding times T2 or T3, but serum Ca and P concentrations appeared to show an inverse relationship to the

TABLE 6. EFFECT OF VARIOUS LEVELS OF DIETARY Ca AND P ON BLOOD PARAMETERS[a]

Diet[cd]	T1[b] Ca	T1[b] P	T1[b] Alk. PO_4	T2[b] Ca	T2[b] P	T2[b] Alk. PO_4	Difference Ca	Difference P	Difference Alk. PO_4
	(mg/100 ml)		(IU/ml)	(mg/100 ml)		(IU/ml)	(mg/100 ml)		(IU/ml)
A	10.01	8.68	1.28	11.44	9.08	1.13	−1.43	−.40	.15
B	9.65	8.61	1.31	11.22	9.01	1.05	−1.57	−.41	.26
C	9.80	8.52	1.24	11.12	9.00	1.09	−1.32	−.48	.15

[a]All blood parameters in T1 *vs* 2 were analyzed by initial period treatments for linear and quadratic responses plus interactions as three treatments.

[b]Standard error of treatment means: T1, Ca = .16, P = .15, Alk PO_4 = .006; T2, Ca = .25, P = .09, Alk PO_4 = .004.

[c]All initial period diets were fed from 3 to 11 weeks of age, with 32 observations per treatment.

[d]Diet A = .65% Ca, .50% P; diet B = .975% Ca, .75% P; diet C = 1.3% Ca, 1.0% P.

change in dietary levels of Ca and P. The short period of time between T2 and T3 bleedings (72 hr) is probably an explanation for these results. Differences between T2 and T3 included a FL response for serum P and alkaline phosphatase (P<.05). Also, a FQ (P<.05) was noted

TABLE 7. EFFECT OF VARIOUS LEVELS OF DIETARY Ca AND P ON BLOOD PARAMETERS[ab]

Diet[cdl]	T2 Ca[e]	T2 P[f]	T2 Alk. PO_4	T3 Ca	T3 P	T3 Alk. PO_4	Difference Ca	Difference P[gh]	Difference Alk. PO_4[ijk]
	(mg/100 ml)		(IU/ml)	(mg/100 ml)		(IU/ml)	(mg/100 ml)		(IU/ml)
AA	11.84	8.92	.12	10.17	8.77	.13	1.67	.15	−.01
BB	11.73	9.06	.10	10.17	9.03	.11	1.56	.03	−.01
CC	11.32	8.84	.12	10.54	8.93	.10	.78	−.09	.02
AB	11.41	9.53	.11	10.08	9.40	.10	1.33	.13	.01
AC	10.47	8.86	.12	10.19	9.03	.11	.28	−.17	.01
BA	11.40	8.84	.09	10.19	9.03	.10	1.21	−.19	−.01
BC	11.41	8.87	.11	9.96	9.16	.10	1.45	−.29	.01
CA	10.97	9.52	.11	9.72	8.76	.10	1.25	.76	.01
CB	11.21	8.58	.10	10.08	9.20	.12	1.13	−.62	−.02

[a]All blood parameters in Time 2 *versus* Time 3 and Time 3 *versus* Time 4 were analyzed by total period treatments for linear and quadratic responses plus interactions as nine treatments.

[b]Initial period linear response = IL; initial period quadratic = IQ, final period linear = FL; final period quadratic = FQ.

[c]First letters = diet fed from 3 to 11 weeks of age; second letter = diet fed from 11 to 19 weeks of age.

[d]Diet A = .65% Ca, .50% P; diet B = .975% Ca, .75% P; diet C = 1.3% Ca, 1.0% P.

[e]IL × FL (P<.05).

[f]IL × FQ (P<.05).

[g]FL (P<.01).

[h]IL × FQ (P<.005).

[i]FL (P<.05).

[j]FQ (P<.05).

[k]IL × FQ (P<.01).

[l]Standard error of treatment means: T2, Ca = .32, P = .19, Alk PO_4 = .007; T3, Ca = .18, P = .15, Alk PO_4 =.008.

TABLE 8. EFFECT OF VARIOUS LEVELS OF DIETARY Ca AND P ON BLOOD PARAMETERS[ab]

Diet[cdn]	T3			T4			Difference		
	Ca	P	Alk. PO_4	Ca[efg]	P	Alk. PO_4[h]	Ca[ijkl]	P	Alk. PO_4[m]
	(mg/100 ml)		(IU/ml)	(mg/100 ml)		(IU/ml)	(mg/100 ml)		(IU/ml)
AA	10.17	8.77	.13	10.88	8.32	.09	− .71	.45	.04
BB	10.17	9.03	.11	10.02	8.50	.08	.15	.53	.03
CC	10.54	8.93	.10	10.52	8.32	.09	.02	.61	.01
AB	10.08	9.40	.10	9.57	8.72	.09	.51	.68	.01
AC	10.19	9.03	.11	11.45	8.40	.10	−1.26	.63	.01
BA	10.19	9.03	.10	9.28	8.40	.07	.91	.63	.03
BC	9.96	9.16	.10	10.08	8.45	.08	− .12	.71	.02
CA	9.72	8.76	.10	10.71	8.71	.08	− .99	.05	.02
CB	10.08	9.20	.12	10.00	8.45	.08	.08	.75	.04

[a]All blood parameters in Time 2 *versus* Time 3 and Time 3 *versus* Time 4 were analyzed by total period treatments for linear and quadratic responses plus interactions as nine treatments.

[b]Initial period linear response = IL; initial period quadratic = IQ, final period linear = FL; final period quadratic = FQ.

[c]First letters = diet fed from 3 to 11 weeks of age; second letter = diet fed from 11 to 19 weeks of age.

[d]Diet A = .65% Ca, .50% P; diet B = .975% Ca, .75% P; diet C = 1.3% Ca, 1.0% P.

[e]IQ ($P<.005$).

[f]FQ ($P<.005$).

[g]IQ × FQ ($P<.005$).

[h]IQ ($P<.01$).

[i]IQ ($P<.05$).

[j]FQ ($P<.05$).

[k]IL × FL ($P<.05$).

[l]IQ × FQ ($P<.05$).

[m]FL ($P<.05$).

[n]Standard error of Treatment means: T3, Ca = .18, P = .15, Alk PO_4 = .008; T4, Ca = .23, P = .16, Alk PO_4 = .006.

for alkaline phosphatase. The increasing concentrations of serum P with increasing concentrations of dietary P are similar to findings of Miller *et al.* (1964) and Bayley *et al.* (1975). Serum P concentrations generally respond in a positive linear fashion with increasing levels of dietary P. A typical pattern for serum phosphorus is one in which levels appear to peak at approximately 1 to 2 weeks of age, then fall steadily to approximately 7.0 mg/100 ml at 5 months and remain constant thereafter (Ullrey *et al.*, 1967). That typical pattern was not apparent in the present study.

Within replicated treatments, alkaline phosphatase levels were higher in boars fed diet AA than in those fed diet CC. Hurwitz and Griminger (1961) reported that plasma alkaline phosphatase, when reflecting the bone phosphatase level, is associated with decalcification or insufficient calcification. Thus, maximum calcification occurs with minimum plasma alkaline phosphatase. Hurwitz and Griminger also stated that consideration should be given to the use of plasma alkaline phosphatase levels as a possible measure of Ca adequacy. Thus, the data indicate that insufficient calcification of bones may have occurred during the final growth period of boars fed treatment A (.65% Ca; .50% P) during the final period.

As reported, no differences in any of the parameters were observed within the T3 bleeding, but T4 resulted in an IQ and FQ response ($P<.05$), with a resulting IQ × FQ interaction ($P<.005$). No differences were noted in serum P within T4, but alkaline phosphatase did show an IQ response ($P<.05$). Analysis of differences

TABLE 9. EFFECT OF VARIOUS LEVELS OF DIETARY Ca AND P ON FEET AND LEG SOUNDNESS[ab]

	Initial growth period diets			Total growth period diets								
	A	B	C	AA	BB	CC	AB	AC	BA	BC	CA	CB
Period 1[de]												
Front	7.67	7.70	7.81									
Rear	8.23	8.17	8.21									
Period 2[de]												
Front	8.03	8.43	8.49									
Rear	7.66	7.89	7.72									
Period 3[e]												
Front				7.91	7.87	8.23	8.33	7.88	7.91	7.88	7.66	8.33
Rear				7.85	7.78	7.92	8.17	8.12	7.67	8.12	7.88	8.17

[a]Soundness scores for front and rear legs were analyzed by contrasts A *vs* BC and B *vs* C in periods 1 and 2, with a total of 96 observations (32/treatment). Period 3 was analyzed as nine total period treatments for linear and quadratic responses and all interactions.

[b]Initial period diets were fed from 3 to 11 weeks of age. Total period diets include the intitial and final periods of 16 weeks.

[c]Period 1 = 3 weeks of age. Period 2 = 11 weeks of age, just prior to diet change. Period 3 = 19 weeks of age at termination of trial. Front = front feet and leg score; Rear = rear feet and leg score.

[d]Front *versus* Rear ($P<.001$).

[e]Standard error of period means across treatments: period 1 = .28, period 2 = .25, period 3 = .20.

between T3 and T4 showed an IQ and FQ response (P<.05), with resulting IL × FL and IQ × FQ interactions (P<.05). Alkaline phosphatase differences between T3 and T4 were expected. A FL response (P<.05) was observed, with boars fed treatment A during the final phase exhibiting the largest decrease in alkaline phosphatase. In contrast, the smallest decrease occurred in those fed treatment C during the final period.

A summary of front and rear feet and leg soundness scores is presented in table 9. No differences were observed between soundness scores for periods 1 and 2 when analyzed by initial period treatments, but the rear feet and legs pooled by treatments did have higher scores (P<.0001) than the front feet and legs. Results for period 3 revealed no treatment or pooled treatment leg differences when analyzed as nine total period treatments.

Literature Cited

Barr, A. J. and J. H. Goodnight. 1972. A user's guide to the statistical analysis system (SAS). North Carolina State Univ., Raleigh.

Bayley, H. S., D. Arthur, G. H. Bowman, J. Pos and R. G. Thomson. 1975. Influence of dietary phosphorus level on growth and bone development in boars and gilts. J. Anim. Sci. 40:864.

Bereskin, B. 1977. Some genetic aspects of feet and leg soundness in swine. Duroc News 51(3):86.

Brown, W. R., L. Krook and W. G. Pond. 1966. Atrophic rhinitis in swine. Etiology, pathogenesis and prophylaxis. Cornell Vet. (Suppl. 1) 66:1.

Chapman, H. L., Jr., J. Kastelic. G. C. Ashton, P. C. Homeyer, C. Y. Roberts, D. V. Catron, V. W. Hays and V. C. Speer. 1962. Calcium and phosphorus requirements of growing-finishing swine. J. Anim. Sci. 21:112.

Combs, G. E. and H. D. Wallace. 1962. Growth and digestibility studies with young pigs fed various levels and sources of calcium. J. Anim. Sci. 21:734.

Hurwitz, S. and P. Griminger. 1961. The response of plasma alkaline phosphatase, parathyroids and blood and bone minerals to calcium intake in the fowl. J. Nutr. 73:177.

Irlam, D. E., H. H. Hodson, Jr. and R. A. Snyder. 1974. Calcium and phosphorus levels for boars. J. Anim. Sci. 39:977 (Abstr.).

Kornegay, E. T., H. R. Thomas and S. L. Crews. 1977. Phosphorus levels for growing boars and gilts. Livestock Research Rep. 17, Virginia Polytech. Inst., Blacksburg. p. 136.

Kuhlers, D. L., L. L. Christian and H. L. Tsou. 1976. How boar and barrow performance compare. Hog Digest 1(4):92.

Liptrap, D. O., E. R. Miller, D. E. Ullery, K. K. Keahey and J. A. Hoefer. 1970. Calcium level for developing boars and gilts. J. Anim. Sci. 31:540.

Miller, E. R., D. E. Ullrey, C. L. Zataut, B. V. Baltzer, D. A. Schmidt, J. A. Hoefer and R. W. Luecke. 1962. Calcium requirements of the baby pig. J. Nutr. 77:7.

Miller, E. R., D. E. Ullrey, C. A. Zataut, J. A. Hoefer and R. W. Luecke. 1964. Mineral balance studies with the baby pig. Effect of dietary phosphorus level upon calcium and phosphorus balance. J. Nutr. 82:111.

Nimmo, R. D., E. R. Peo, Jr., B. D. Moser, P. J. Cunningham, T. D. Crenshaw and D. G. Olson. 1980. Response of different genetic lines of boars to various levels of dietary calcium and phosphorus. J. Anim. Sci. 51:112.

NRC. 1973. Nutrient Requirements of Domestic Animals, No. 2. Nutritional Requirements of Swine. National Academy of Sciences – National Research Council, Washington, DC.

Smith, R.G.D. and C. Smith. 1965. Report on boar performance testing at Sterling. Anim. Prod. 7:284.

Steel, R.D.G. and J. H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co., New York.

Tanksley, T. D. 1974. Evaluation of the dietary calcium and phosphorus requirements of developing boars. Proc. Swine Short Course, Texas Agr. Exp. Sta., College Station, p. 68.

Ullrey, D. E., E. R. Miller, B. E. Brent, B. L. Bradley and J. A. Hoefer. 1967. Swine hematology from birth to maturity. IV. Serum calcium, magnesium, sodium, potassium, copper, zinc and inorganic phosphorus. J. Anim. Sci. 26:1024.

Zimmerman, D. R., V. C. Speer, V. W. Hays and D. V. Catron. 1963. Effect of calcium and phosphorus levels on baby pig performance. J. Anim. Sci. 22:658.