Calcium and Phosphorus Studies with Young Pigs

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Story in Brief

Studies were made with 45 baby pigs using four calcium and phosphorus levels containing 0.27, 0.57, 0.95 and 1.25 percent calcium and 0.14, 0.44, 0.73 and 1.05 percent phosphorus, respectively. Growth was adequate on all diets except 0.27 percent Ca and 0.14 percent P with 0.95 percent Ca and 0.73 percent P exhibiting the most gain and lowest feed efficiency. Serum phosphorus was directly related to increases in calcium and phosphorus, while serum alkaline phosphatase was elevated only in pigs receiving 0.27 percent Ca and 0.14 percent P. Optimal skeletal development, as measured by bone weights, diameter, and ash content, occurred in pigs receiving 0.95 percent Ca and 0.73 percent P. Specific gravity was directly related to dietary increases in calcium and phosphorus. Under the conditions prevailing in this study, 0.95 percent Ca and 0.73 percent P were superior in total performance and skeletal development. Turbinate sections were grossly examined but showed no evidence of atrophic rhinitis.

Introduction

Calcium and phosphorus have long been recognized as essential elements in skeletal formation, growth and maintenance of physiological functions in swine. Calcium and phosphorus requirments for young pigs have recently been under investigation because of increased growth rates due to diet formulation, antibiotics and sanitation procedures. It was thought that specific-pathogen-free (SPF) pigs might have higher calcium and phosphorus requirements than conventionally reared pigs because of lowered disease levels, but this has not been shown.

In the establishment of standard requirements for calcium and phosphorus major emphasis has been placed almost consistently on growth and efficiency. The present studies were designed to study the effects of four calcium and phosphorus levels on baby pigs from three to nine weeks of age using growth, skeletal development, serum calcium, phosphorus and serum alkaline phosphate levels as criteria. Gross examinations were

made to determine if the pathological condition known as atrophic rhinitis can be initiated on a low calcium and phosphorus diet.

Procedure

A total of 40 purebred Yorkshire baby pigs and five purebred Hampshire baby pigs were used in this study. Pigs were maintained under relatively pathogen free conditions to minimize the confounding effects of certain environmental conditions on the response of the pigs to the dietary treatments.

The pigs were collected in sterile plastic bags as they emerged from the birth canal at term and placed in a pre-sterilized plastic isolator. They were transported to the Swine Nutrition Laboratory, given pasteurized sow colostrum by stomach tube, placed in individual cardboard rearing units and, thereafter, fed a fortified cows' milk diet. At two weeks of age, pigs were moved to individual, open-topped, solid-sided metal pens and assigned to one of four experimental semipurified diets. (Table 1) The four diets contained 0.27, 0.57, 0.95 and 1.25 percent calcium and 0.14, 0.44, 0.73 and 1.05 percent phosphorus, respectively. The period from 14 to 21 days of age was used to adjust the pigs to their respective diets, while the experimental period covered 42 days (21 to 63 days of age). Blood samples were obtained at 21, 42 and 63 days of age by anterior vena cava puncture. Serum calcium, phosphorus and alkaline phosphatase determinations were made.

Table 1. Composition of Diet

	Percent
Casein	25.58
Corn starch[1]	42.32-46.98
Glucose monohydrate	11.30
α—Cellulose	6.00
Corn oil	5.30
Mineral mixture[2]	3.00
Water soluble vitamins[3]	1.00
Fat soluble vitamins[4]	0.0041
Antioxidant	0.0125
Sulfamthazine-antibiotic	0.125

[1] Corn starch was varied inversely with dicalcium phosphate and calcium carbonate to mak 100 # diet.

[2] Mineral mixture contained 50.00% $NaHCO_3$, 23.37% K_2SO_4, 4.10% $MgCO_3$, 1.40% $FeSO_4 2H_2O$ 0.80% $ZnSO_4.H_2O$, 0.30% $MnSO_4.H_2O$, 0.20% $CuSO_4$, 0.20% $CoCO_3$, 0.004% KI and 19.63% cerelose. Courtesy Calcium Carbonate Company, Quincy, Illinois.

[3] Supplied 3 mg. thiamine, 6 mg. riboflavin, 40 mg. niacin, 30 mg. pantothenic acid, 2 mg pyridoxine, 13 mg. para-aminobenzoic acid, 80 mg. ascorbic acid, 130 mg. inositol, 1.3 gm choline, 260 mcg. folic acid, 50 mcg. biotin and 100 mcg. cyanocobalanin per kg. of ration Courtesy Hoffman-Taff, Inc., Springfield, Mo.

[4] Supplied 10 mg. alpha-tocopherol, 1.5 mg. vitamin A, 40 mcg. 2 methyl-1, 4-napthoquinone an 12.5 mcg. of vitamin D per kg. of ration.

At the conclusion of the experiment, four pigs (two males and two females) from each treatment were selected at random and sacrificed by exsanguination.

The right humerus, femur, ulna-radius and eighth rib were dissected free of muscles, ligaments and periosteum, weighed and the maximum length was measured by means of a vernier scale slide-calipers. Diameter or width of each bone was recorded and the specific gravity determined.

Bones were extracted with 95 percent ethanol for 16 hours, followed by petroleum ether extraction for an additional three hours. The fat-free bones were ashed at 550°C. for 16 hours, with the ash being dissolved in 4 N HCl. Bone calcium and phosphorus were analyzed in duplicate.

Results and Discussion

Growth rate was depressed only in those pigs receiving Ration A (0.27 percent Ca and 0.14 percent P; Table 2). Pigs on Ration C (0.95 percent Ca and 0.73 percent P) had the greatest gain and most desirable feed conversion ratio. Pigs on Ration D (1.25 percent Ca and 1.05) percent P) had the greatest feed intake, which indicates the high calcium and phosphorus levels did not decrease feed intake. The levels of 0.95 percent calcium and 0.73 percent phosphorus are much greater than those recommended by Dudley *et al.* (1961) who indicated maximum rate and efficiency of gain was obtained on calcium levels no higher than 0.20 percent of the diet. Miller *et al.* (1960) indicated that 0.60 perecnt calcium was needed for maximum growth and feed efficiency. Combs *et al.* (1966) reported that average daily gain and efficiency were significantly decreased when the level of calcium was increased from 0.48 to 0.88 and

Table 2. Weight Gain, Feed Consumption and Feed Efficiency of Pigs Fed Different Levels of Calcium and Phosphorus

Ration	A	B	C	D		
No. of pigs	11	11	11	12		
Dietary Ca, %	0.27	0.57	0.95	1.25		
Dietary P, %	0.14	0.44	0.73	1.05	SE[1]	SD[2]
Lb. gain	28.07	34.99	38.62	37.08	2.22	*4.7
Lb. feed	53.16	61.68	64.76	72.05	3.74	*5
Feed efficiency[3]	2.03	1.80	1.67	1.97	0.08	*6

[1] Standard error of treatment means.
[2] Significant differences, * ($P < 0.05$).
[3] Lb. of feed solids per Lb. of body weight gain.
*4.7 Significant linear effect ($P < .005$).
*5 Significant quadratic effect ($P < .10$).
*6 Significant linear effect ($P < .01$).
Significant quadratic effect ($P < .005$).

then to 1.32 percent in the diet of young pigs.

Mean serum calcium levels (Table 3) ranged from 11.03 to 12.54 mg. per 100 ml. There were no significant differences although pigs on Ration C had the highest serum calcium values after six weeks.

Significant differences (Table 3) were noted in serum inorganic phosphorus values at initial, three and six weeks. Initial values could be due to some depletion during the adjustment period. Values at six weeks increased linearly from lowest (0.14 percent) to highest phosphorus diet (1.05 percent). This is in close agreement with Miller *et al.* (1964) who reported that serum inorganic phosphorus concentrations are related to dietary phosphorus intakes.

Serum alkaline phosphatase (Table 3) was elevated only in pigs on Ration A (low calcium and phosphorus). This shows the same trend as reported by Miller *et al.* (1964) where serum alkaline phosphatase activity became elevated only in the severely phosphorus-deficient pigs.

Fresh weights of right humerus, femur, ulna-radius and eighth rib (Table 4), from which all soft tissues and periosteum had been removed, differed significantly with those from Ration C being the largest. Absolute bone diameter was positively related to fresh bone weight. Specific gravity of these bones showed significant differences and was positively related to calcium and phosphorus levels in the diet.

Mean values for ash, calcium and phosphorus content (Table 5) exhibited the same pattern as bone weights. Ash, calcium and phosphorus

Table 3. Serum Calcium, Phosphorus and Alkaline Phosphatase Level of Pigs Fed Different Levels of Calcium and Phosphorus

Ration	A	B	C	D		
No. of pigs	11	11	11	12		
Dietary Ca, %	0.27	0.57	0.95	1.25		
Dietary P, %	0.14	0.44	0.73	1.05	SE[1]	SD[2]
Serum Calcium, mg/100 ml						
Initial	11.23	11.20	11.57	11.28	0.33	NS[3]
3 weeks	11.57	12.54	12.27	11.48	0.33	NS
6 weeks	11.03	11.44	11.63	11.61	0.27	NS
Serum Inorganic Phosphorus, mg/100 ml						
Initial	6.29	7.10	8.19	7.62	0.28	*
3 weeks	7.34	8.85	9.19	12.03	0.48	*
6 weeks	7.99	8.67	9.17	12.64	0.50	*
Serum Alkaline Phosphatase, Klein-Babson-Read Units						
Initial	32.94	30.19	26.38	27.69	1.76	NS
3 weeks	33.63	19.22	14.21	18.75	1.88	*
6 weeks	21.79	11.80	9.79	12.35	1.81	*

[1] Standard error of treatment means.
[2] Significant differences, * ($P < 0.05$).
[3] NS = non-significant ($P > .05$).

Table 4. Weight, Specific Gravity and Diameter of Bones Taken from Pigs Fed Different Levels of Calcium and Phosphorus

Ration	A	B	C	D		
No. of pigs	4	4	4	4		
Dietary Ca, %	0.27	0.57	0.95	1.25		
Dietary P, %	0.14	0.44	0.73	1.05	SE[1]	SD[2]
			Weight, gm			
Eighth rib	3.9	7.7	11.2	8.8	1.5	*3,5
Humerus	47.9	68.4	87.2	76.6	7.6	*4,5
Femur	55.8	84.3	102.0	89.4	8.9	*3
Ulna-radius	38.6	51.1	65.8	60.9	6.0	*3
			Specific Gravity			
Eighth rib	1.11	1.19	1.22	1.28	0.02	*6
Humerus	1.13	1.16	1.20	1.23	0.01	*6
Femur	1.12	1.16	1.20	1.23	0 01	*6
Ulna-radius	1.14	1.18	1.21	1.25	0.01	*6
			Diameter, mm			
Eighth rib	4.3	5.6	6 3	5.4	0.4	*7,5
Humerus	10.7	13.0	13.9	13.2	0.7	*4,5
Femur	12.7	16.3	17.1	12.4	1.4	*
Ulna-radius	22.1	24.6	26.8	26.4	0.9	*6

[1] Standard error of treatment means.
[2] Significant differences, *($P < 0.05$).
[3] Significant linear effect ($P < .025$).
[4] Significant linear effect ($P < .05$).
[5] Significant quadratic effect ($P < .10$).
[6] Significant linear effect ($P < .005$).
[7] Significant linear effect ($P < .10$).

content were greatest in bones from Ration C (0.95 percent Ca and 0.73 percent P) and lowest in Ration A (0.27 percent Ca and 0.14 P). These data are in agreement with results obtained by several workers who found that baby pig rations low in calcium and phosphorus tend to produce bones with low ash values. Ration C produced the highest values of calcium and phosphorus in bone ash; this would be expected since this ration produced the largest bones and ash values. These data indicate that greatest gain, feed efficiency and skeletal development occurred in pigs obtaining 0.95 percent calcium and 0.73 percent phosphorus.

Nasal turbinates were grossly examined but showed no evidence of atrophic rhinitis.

Table 5. Ash, Calcium and Phosphorus Content of Bones Taken from Pigs Fed Different Levels of Calcium and Phosphorus

Ration	A	B	C	D		
No. of pigs	4	4	4	4		
Dietary Ca, %	0.27	0.57	0.95	1.25		
Dietary P, %	0.14	0.44	0.73	1.05	SE[1]	SD[2]
Eighth Rib Ash						
Ash, %	44.98	54.23	56.85	56.23	1.35	*4,5
Ca, %	17.80	21.88	23.21	22.66	0.46	*4
P, %	8.15	9.08	10.87	10.41	0.32	*4
Ca/P	2.17	2.42	2.13	2.17	0.07	*
Humeral Ash						
Ash, %	60.49	64.43	67.37	68.44	2.62	NS[7]
Ca, %	24.77	26.50	26.71	25.73	0.51	NS
P, %	10.36	11.89	12.32	12.23	0.15	*4,5
Ca/P	2.38	2.22	2.16	2.09	0.04	*
Femur Ash						
Ash, %	58.37	62.45	67.10	65.36	1.68	*6
Ca, %	23.63	25.60	26.73	26.05	0.59	*6
P, %	11.15	11.80	13.20	13.15	0.35	*4
Ca/P	2.12	2.17	2.02	1.97	0.04	*
Ulna-radius Ash						
Ash, %	52.79	54.68	60.22	59.22	1.64	*6
Ca, %	21.67	22.52	24.75	23.39	0.92	NS[4]
P, %	9.07	9.84	11.30	10.77	0.33	*4
Ca/P	2.39	2.28	2.19	2.17	0.09	NS

[1] Standard error of treatment means.
[2] Significant differences, * ($P < 0.05$).
[3] Expressed on a dry, fat-free basis.
[4] Significant linear effect ($P < .005$).
[5] Significant quadratic effect ($P < .005$).
[6] Significant linear effect ($P < .01$).
[7] NS = Non-significant ($P > 0.05$).

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