EFFECTS OF THE INTERRELATIONSHIP OF PORCINE SOMATOTROPIN ADMINISTRATION AND DIETARY PHOSPHORUS ON BONE PROPERTIES IN DEVELOPING GILTS[1]

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Summary

Seventy-two gilts (initial weight = 127 lb) were used to determine effects of the interrelationship of porcine somatotropin (pST) administration and dietary phosphorus (P) on bone mechanical properties and mineralization in finishing gilts (127 to 235 lb) and for a 35-d postfinishing phase following withdrawal of pST administration. Gilts were injected daily with placebo (control) or 4 mg pST and fed .4, .6, or .8% P in the finishing phase. When each block weight averaged 235 lb, half of the gilts were slaughtered and the first rib, femur, and third and fourth metacarpals were collected. Stress; modulus of elasticity; and ash content of rib, femur, and metacarpals were reduced and femur wall thickness was increased in pST-treated gilts. Increasing dietary P increased bending moment, stress, and ash content for all bones collected, with the exception of metacarpal stress, which was not affected. The remaining 36 gilts were individually fed 4 lb/d of a common diet to assure P intake of 22.8 g/d for the 35 d postfinishing phase. Gilts receiving higher levels of dietary P during the finishing phase had increased bending moment and ash content for the rib and femur; rib stress and femur wall thickness were also increased following the postfinishing phase. Gilts administered pST during the finishing phase exhibited a compensatory increase in mineralization as evidenced by equal stress values for rib, femur, and metacarpals compared to control gilts by the end of the postfinishing phase. Although bone strength and mineralization were lower in pST-treated gilts than controls at the end of the finishing phase, if pST-treated gilts were fed at least a .6% P diet (16.5 g/d P) during the finishing phase, then bone strength and mineralization similar to those of control gilts could be attained with a diet containing at least 18 g P and 22.5 g Ca daily during the postfinishing phase.

(Key Words: Somatotropin, Phosphorus, Gilts, Bone.)

Introduction

In the event that porcine somatotropin (pST) is approved for use and adapted by swine producers, gilts treated with pST may ultimately be kept in the breeding herd. This may alter how these gilts must be fed during the finishing phase and prior to breeding. Previous research at Kansas State University has established that pST-treated pigs have decreased bone strength at the end of the finishing phase. Therefore, the major question in using pST-treated gilts in the sow herd would be longevity. In a previous study, we confirmed that pST-treated gilts had decreased bone strength and mineralization at the end of the finishing phase and that even feeding 300% of NRC (1988) estimates for Ca and P could not maximize bone strength. However, gilts treated with pST had greater bone wall thickness and exhibited a compensatory increase in bone strength and mineralization during a 35-d postfinishing

[1]The authors would like to thank Pitman-Moore, Inc. for providing the pST used in this experiment.

period when fed at least .8% P during the finishing phase. Gilts fed .4% P during the finishing phase were unable to fully compensate and never attained bone strength values equal to the control gilts. Therefore, the objective of this experiment was to determine the minimum dietary P intake needed during the finishing phase, in order that compensatory mineralization would occur and pST-treated gilts would be able to attain similar bone stress and mineralization as control gilts by the end of the postfinishing phase.

Procedures

A total of 72 crossbred gilts (Hampshire × Chester White × Yorkshire × Duroc) with an initial average weight of 127 lb was used in a randomized complete block design with a 2 × 3 factorial arrangement. Gilts were blocked by weight, allotted by ancestry to pens, and randomly assigned to experimental treatments. There were two gilts per pen and six replications per treatment. Gilts were housed in 5 ft × 5 ft pens in an environmentally controlled building with total concrete slatted flooring. They were given ad libitum access to feed and water.

Experimental treatments consisted of daily injections of placebo or 4 mg pST and a corn-soybean meal diet (1.2% lysine; Table 1) containing either .4, .6, or .8% P. These correspond to 100, 150, and 200% of NRC (1988) estimates for P in finishing diets (110 to 240 lb). Dietary P levels were attained by replacing corn with monocalcium P and limestone. A constant Ca:P ratio of 1.25:1 was maintained throughout the entire experiment. All other nutrients were formulated to be at least 200% of NRC (1988) estimates for finishing pigs. Gilts were slaughtered at 235 lb (six per treatment, 36 total). The femur, first rib, and third and fourth metacarpals were removed from the right side of each carcass 24 h following slaughter.

Table 1. Composition of Diets

	Finishing phase[a]	Postfinishing[b]
Ingredient, %	.4% P	1.2% P
Corn	62.98	78.69
Soybean meal (48% CP)	29.77	14.53
Soybean oil	5.00	—
L-lysine HCl	.16	—
Monocalcium phosphate	.16	4.22
Limestone	.78	1.66
Salt	.30	.50
Vitamin premix	.50	.25
Trace mineral premix	.20	.10
Selenium premix[c]	.05	.05
Antibiotic[d]	.10	—
Total	100.00	100.00
Calculated analyses, %		
Lysine	1.20	.65
Ca	.50	1.50

[a]Monocalcium phosphate and limestone were added in place of corn to provide P levels of .6 and .8%. Finishing diets were fed from 127 to 235 lb.
[b]Postfinishing, fed for 35 d following the finishing phase.
[c]Provided 10 mg chlortetracycline per lb of complete diet.

Bones were manually cleaned of connective tissues, but otherwise were stored continually in plastic bags to prevent exposure to air. Bones were thawed for 36 h at 40°F prior to determination of mechanical properties by an Instron Universal Testing Machine (Instron Corp., Canton MA). Calculations were derived for bending moment, stress, strain, and modulus of elasticity. Bending moment refers to the actual force required to "break" or more appropriately bend a bone, adjusted for differences in the span over which the force is applied. Stress adjusts the force for the area and shape of the bone at the point where the force is applied. Stress actually gives a better estimate of the bones overall strength and mineralization than other measurements. Modulus of elasticity gives a measure of the ability of the bone to return to its original shape, which is an indicator of the stiffness or rigidity of the bone. Strain is a measure of the amount of deformation that takes place in the bone while it is being tested.

Bones were cleaned of remaining residues and marrow was removed prior to lipid extraction. Femur samples were extracted and used for determination of percentage ash. Ash is expressed as a percentage of dried, fat-free bone.

The remaining 36 gilts (six per treatment) were mixed and placed 18 per 150 ft × 100 ft pen in dirt lots. Gilts were individually fed 4 lb/d of a common diet (Table 1) to ensure daily intakes of 22.8 g of P. This corresponds to 200% of the NRC (1988) recommended daily intake for P in developing gilts. An additional 1.5 lb/d of corn was offered to all gilts that consumed the initial 4.0 lb feeding. Individual feed intake was determined by weighing back remaining feed daily for the entire 35 d postfinishing phase. On d 35, all gilts were slaughtered. Bones and carcass data were collected as described for the finishing phase.

Results and Discussion

A pST × P interaction ($P < .03$) was observed for femur modulus of elasticity (Table 2). Modulus of elasticity of control gilts was higher and increased more as dietary P was increased compared to pST gilts, indicating that femurs of control gilts were more rigid than those of pST-treated gilts. No pST × P interactions ($P > .10$) were observed for any of the other bone criteria measured. There was no effect ($P > .42$) of pST administration on rib bending moment; values were similar between control gilts and pST-treated gilts. Gilts receiving pST had decreased ($P < .06$) stress; modulus of elasticity; and ash content for rib, femur, and metacarpals and decreased bending moment for femur and metacarpals compared to control gilts. Administration of pST resulted in increased ($P < .03$) rib, femur, and metacarpal strain and increased ($P < .01$) femur wall thickness. As dietary P was increased from .4 to .8%, linear ($P < .05$) increases occurred in bending moment; stress; modulus of elasticity; and ash content of rib, femur, and metacarpals, with the exception of metacarpal stress ($P > .14$). Femur wall thickness was also increased (linear, $P < .02$) with increasing dietary P, whereas metacarpal wall thickness was not affected ($P > .38$) by dietary P.

A pST × P interaction ($P < .07$) was observed for rib bending moment in the postfinishing phase. Gilts that received pST and were fed .6 or .8% dietary P in the finishing phase exhibited a greater increase in bending moment to equal or exceed that of control gilts by the end of the postfinishing phase (Table 3). Gilts administered pST in the finishing phase still exhibited decreased ($P < .05$) femur modulus of elasticity and metacarpal bending moment following the postfinishing phase. However, gilts that received pST in the finishing phase had attained ($P > .16$) stress values and ash contents for rib, femur, and metacarpals similar to those of control gilts by the end of the postfinishing period. Gilts that were fed the higher P diets in the finishing phase continued to exhibit higher ($P < .01$) values for rib stress, rib and femur bending moment, and rib and femur ash following the postfinishing phase. Perhaps the pST-treated gilts have higher requirements for Ca and P early in the finishing phase because of the rapid increase in bone growth stimulated by pST administration.

Stress has been determined to be the most sensitive indicator of mineralization, because ash content requires a longer period of time to reflect changes in bone strength. Because bones of the axial skeleton are more responsive to demineralization than long bones of the extremities, rib bones would be expected to be more sensitive than the femur or metacarpals in determining treatment differences in stress. Rib bones were more responsive to our experimental treatments and, consequently, were used to determine Ca and P intakes required to maximize bone stress values.

It has been suggested that pST-treated gilts may have limited longevity in the breeding herd because of their decreased bone strength and mineralization at the end of the finishing phase. Recent research confirms that pST-treated pigs have decreased mineralization and bone strength, but have thicker bone walls, indicating a larger collagen matrix compared to controls at the end of the finishing phase. In a previous experiment, we determined that pST-treated gilts were able to exhibit a compensatory increase in bone strength and mineralization to values equaling those of control gilts during a 35-d postfinishing period. The present data substantiate that compensatory response and indicate that pST-treated gilts consuming at least 16.5 g of P per day in the finishing phase are able to increase bending moment and stress values for rib, femur, and metacarpals during a 35-d postfinishing phase to reach levels attained by control gilts. From this experiment, we are unable to determine the optimum daily intake of Ca and P required during the postfinishing phase for compensatory mineralization to occur, because only one level was fed during this period. However, the present data indicate that daily intakes of at least 18 g of P and 22.5 g of Ca during a 35 d postfinishing phase are effective in stimulating a compensatory increase in bone stress for gilts previously administered pST.

Based on these data, pST-treated gilts should be able to attain satisfactory bone strength and mineralization through compensatory increases following withdrawal of pST injections, if they consume at least 16.5 g of P and 20.5 g of Ca per day (.6% P diet) in the finishing phase.

Table 2. Effect of Porcine Somatotropin and Dietary Phosphorus on Bone Mechanical Properties and Mineralization of Finishing Gilts[a]

	Placebo			4 mg pST			
Item	.4% P	.6% P	.8% P	.4% P	.6% P	.8% P	SE
Rib							
Bending moment, kg[b]	61.6	79.2	89.7	59.0	86.4	95.2	5.1
Stress, kg/cm^2[bc]	348	482	606	288	371	404	47.5
Strain[c]	.18	.15	.17	.21	.22	.24	.02
Modulus of elasticity, kg/cm^2[bc]	2,012	3,482	3,881	1,404	1,735	1,727	402
Ash, %[bc]	46.18	50.72	52.11	43.54	47.95	51.26	1.00
Femur							
Bending moment, kg[bc]	435	549	601	381	509	571	24.5
Stress, kg/cm^2[bc]	276	296	412	171	189	234	32.3
Strain[bc]	.22	.21	.17	.26	.28	.27	.02
Modulus of elasticity, kg/cm^2[bce]	1,333	1,386	2,497	691	751	908	190
Bonewall thickness, cm[bc]	.77	.80	.84	.83	1.04	1.04	.05
Ash, %[bcd]	68.41	68.84	69.21	65.73	68.16	68.38	.34
Metacarpal[f]							
Bending moment, kg[bc]	165	181	165	136	158	172	8.7
Stress, kg/cm^2[c]	933	867	955	637	775	799	75.1
Strain[c]	.34	.31	.30	.37	.36	.34	.02
Modulus of elasticity, kg/cm^2[bc]	2,645	2,962	3,170	1,744	2,175	2,243	291
Bonewall thickness, cm	.51	.52	.51	.49	.52	.54	.03
Ash, %[bc]	54.47	57.01	58.34	53.64	55.61	55.99	.83

[a]Values are least squares means and represent six observations per treatment.
[b]Effect of pST ($P < .05$).
[c]Effect of P (linear, $P < .05$).
[d]Effect of P (quadratic, $P < .10$).
[e]pST × P interaction ($P < .05$).
[f]Average values for 3rd and 4th metacarpals.

Table 3. Effect of Porcine Somatotropin Administration and Dietary Phosphorus Level during the Finishing Phase on Bone Mechanical Properties and Mineralization Following a 35-d Postfinishing Phase[a]

	Placebo			4 mg pST			
Item	.4% P	.6% P	.8% P	.4% P	.6% P	.8% P	SE
Rib							
Bending moment, kg[bcd]	88	105	121	90	117	144	4.4
Stress, kg/cm^{2}[c]	431	568	538	426	581	659	56
Strain[bc]	.19	.23	.22	.23	.24	.26	.02
Modulus of elasticity, kg/cm^2	2,429	2,633	2,430	1,938	2,563	2,626	344
Ash, %[cd]	49.91	48.47	51.66	45.86	50.33	51.41	1.2
Femur							
Bending moment, kg[c]	524	604	733	482	643	721	26
Stress, kg/cm^2	274	247	309	213	274	255	25
Strain[b]	.18	.16	.21	.22	.21	.25	.02
Modulus of elasticity, kg/cm^{2}[b]	1,660	1,681	1,579	999	1,366	1,190	253
Bonewall thickness, cm[c]	.88	1.01	.97	.86	.99	1.11	.05
Ash, %[c]	68.67	68.96	69.15	68.01	69.16	69.22	.42
Metacarpal[e]							
Bending moment, kg[b]	215	243	240	202	203	216	12.6
Stress, kg/cm^2	806	876	968	836	906	901	75
Strain	.41	.41	.41	.44	.38	.39	.03
Modulus of elasticity, kg/cm^2	2,099	2,124	2,249	1,888	2,213	2,309	233
Bonewall thickness, cm	.58	.62	.61	.58	.62	.64	.03
Ash, %	58.14	57.97	58.98	57.79	58.19	58.67	.7

[a]Values are least squares means and represent six observations per treatment.
[b]Effect of pST administration during the finishing phase ($P < .05$).
[c]Effect of dietary P fed during the finishing phase (linear, $P < .07$).
[d]pST × P interaction for finishing phase treatments ($P < .07$).
[e]Average of 3rd and 4th metacarpals.