EFFECTS OF PORCINE SOMATOTROPIN AND DIETARY PHOSPHORUS ON GROWTH AND BONE CRITERIA IN GILTS

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Summary

One hundred-eight gilts with an average initial wt of 129 lb were utilized to determine the effects of porcine somatotropin (pST) and dietary phosphorus on growth performance and bone mineralization and mechanical properties during the finishing phase (129 to 230 lb) and a 35 d post-finishing phase. Gilts were injected daily with placebo (control) or 4 mg pST and fed diets containing .4, .8, or 1.2% P during the finishing phase. Administration of pST improved F/G 18%, increased ADG 8%, and decreased daily feed intake 9%. There was a quadratic response to P, because gilts receiving the .8% P diet were more efficient than gilts fed either .4 or 1.2% P, regardless of whether they received pST or placebo. When pen wt reached 230 lb, half of the gilts were slaughtered and 1st rib, femur, and 3rd and 4th metacarpals were collected. First rib ash content increased linearly as the level of dietary P increased; however, pST administration had no effect on ash content. There was a pST × P interaction for rib bending moment, stress, and modulus of elasticity. Bone strength was maximized for control gilts at .8% P, whereas bone strength continued to increase as the level of dietary P was increased for pST-treated gilts. The remaining 54 gilts were individually fed 4 lb/d of a common diet for a 35 d post-finishing phase and then slaughtered. Gilts that received higher P levels in the finishing phase had higher rib ash content at the end of the post-finishing phase. There was a pST × P interaction for treatment combination received in the finishing phase on rib and femur bending moment post-finishing. Bone strength for pST-treated gilts receiving the .8 or 1.2% P diet in the finishing phased increased to levels exceeding those of control gilts by the end of the post-finishing phase, regardless of dietary P level control gilts were fed in the finishing phase. These data indicate that gilts administered pST in the finishing phase do not have higher Ca and P requirements than non-pST treated gilts to maximize growth performance. However, pST-treated gilts do have higher requirements for Ca and P than non-pST treated gilts to attain comparable bone strength in the finishing phase. Gilts receiving pST in the finishing phase demonstrate compensatory mineralization in the post-finishing phase, because bone strength increases to equal or exceed that of control gilts fed similar P levels.

(Key Words: Repartition, Performance, Gilts, Phosphorus, Bone.)

Introduction

Porcine somatotropin (pST) alters metabolism of carbohydrates, proteins, and lipids to significantly improve growth performance and carcass characteristics. These improvements have been well documented; however, the effect of pST on mineral metabolism and bone development is less defined. Because pST increases the lysine requirement for finishing pigs, Ca and P requirements also may be increased. Recent research has indicated some mobility problems in gilts administered pST. A possible reason for these may be that bones of pST-treated pigs are weaker than those of

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non-pST-treated pigs, as observed during slaughter at the end of the finishing period. This would seem to indicate that pST-treated gilts would have reduced durability and longevity in the sow herd. Conversely, pST-treated pigs have been shown to have increased growth of the collagen matrix, indicating that their bone is less mature and may have the potential for compensatory mineralization. Therefore, this study was conducted to evaluate the effects of pST administration and dietary P on growth performance and bone mineralization and mechanical properties in finishing gilts and to determine if compensatory bone mineralization would occur in pST-treated gilts during a 35 d post-finishing period.

Procedures

A total of 108 crossbred gilts (initial wt = 129 lb) were allotted on the basis of weight and ancestry in a 2 × 3 factorial arrangement to one of six experimental treatments. Experimental treatments consisted of daily injections of placebo or 4 mg pST in combination with a corn-soybean meal diet (Table 1) containing either .4, .8, or 1.2% phosphorus. This corresponds to 100, 200, and 300% of the NRC (1988) recommendations for P in finishing diets. Dietary P levels were attained by replacing corn with monocalcium P and limestone. All finishing diets were formulated to contain 1.2% lysine, and a constant Ca:P ratio of 1.25:1 was maintained throughout the experiment. All nutrients except Ca and P were formulated to be at least 200% of NRC (1988) recommendations for finishing pigs. There were three gilts per pen and six replicates per treatment. Gilts were housed in an open-front building with solid concrete floors in 4 × 15 ft pens. Feed and water were supplied ad libitum, and straw was used for bedding as needed. All gilts and feeders were weighed on d 14 and 28, then weekly thereafter until mean pen weight reached 230 lb. Gilts were injected daily in the extensor muscle of the neck until the pen mean weight reached 230 lb, at which time injections were terminated and 54 gilts were slaughtered (nine per treatment). The femur, 1st rib, and 3rd and 4th metacarpals were removed from the right side of the carcass, labeled, and frozen for later analyses.

In the 35 d post-finishing phase, the remaining 54 gilts (nine per treatment) were individually fed 4 lb/d of a common diet (Table 1) to ensure daily intakes of 22.9 g P. This corresponds to 200% of the NRC (1988) recommended daily P intake for developing gilts. An additional 1 lb of corn for extra energy was offered to all gilts after consumption of the 4 lb was complete. At the end of the 35 d period, all gilts were slaughtered and bones were collected as described for the finishing phase.

Bones were manually cleaned of connective tissues and were constantly stored in plastic bags prior to mechanical determination on an Instron Universal Testing Machine (Instron Corp., Canton, MA) to prevent drying, with the exception of the few minutes when bones were cleaned. After testing, bones were cleaned of any remaining residue, extracted in petroleum ether for 48 h, and dried prior to ashing. All bones were ashed at 1,112°F for 12 h. Ash is the mineral content of the bone, expressed as a percentage of the dried, fat-free bone.

Mechanical properties of bones must be assessed through equations derived to evaluate the strength and elasticity of bones that differ in size and shape. These equations are similar to those used to evaluate strength and durability of building materials. 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 than bending moment. 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. High values for modulus of elasticity indicate a high degree of rigidity, whereas lower values indicate a more flexible bone. Strain is a measure of the amount of deformation that takes place in the bone while it is being tested.

Results and Discussion

Growth performance data are reported as interaction means in Table 2. However, main effects of pST and dietary P will be discussed, because no pST × P interactions ($P > .25$) occurred for growth performance. In a typical pST response, gilts administered pST had higher ($P < .01$) average daily gain (ADG), were more efficient ($P < .01$), and consumed approximately .6 lb/d less feed than placebo-treated gilts over the entire finishing period. From d 0 to 35 of the finishing phase, gilts receiving the .4% P diet had reduced (linear, $P < .05$) ADG compared to gilts fed the .8 and 1.2% P diets, regardless of whether they received pST or not. This can be explained by daily feed intakes below NRC (1988) estimates on all diets and subsequently reduced daily P intakes during this period for the gilts fed .4% P diet, which were 2 to 3 g below the NRC (1988) daily recommendation of 11.3 g. However, for the overall finishing phase (129 to 230 lb), ADG was unaffected by dietary P level. There was a P effect (quadratic, $P < .06$) on F/G, because gilts were most efficient when fed .8% dietary P from d 0 to 35 and for the entire finishing phase, whether pST was administered or not. This should not be interpreted as .8% P being the optimal dietary level to feed in order to maximize F/G, because the dietary levels (.4 to 1.2% P) cover a wide range. Consequently, daily P intakes ranged from slightly deficient on the .4% P diet, because of feed intakes below NRC (1988) estimates, to far in excess of current NRC (1988) recommended daily intakes of P in the 1.2% P diet.

For the finishing phase, a pST × dietary P interaction ($P < .05$) occurred for rib bending moment; placebo-treated gilts had highest rib strength at .8% P and then a slight decline at 1.2% P. In contrast, pST-treated gilts showed increased rib strength as the level of dietary P increased, although values for the 1.2% P diet were still below those the control gilts *attained* on the .8% P diet (Table 3). Rib stress followed a similar trend (pST × P interaction, $P < .12$), with highest strength attained by the control gilts on the .8% P diet and increasing rib strength for the pST-treated gilts as dietary P was increased. Rib strain was unaffected ($P > .19$) by either pST administration or dietary P level. Modulus of elasticity for the rib showed a pST × P interaction ($P < .05$), with control gilts having more rigid bones at all P levels, whereas pST-treated gilts had the highest degree of flexibility at the .4% P level. This would agree with previous research that showed increased collagen formation but decreased calcification of the bone protein matrix in pST-treated pigs. The femur bending moment increased (linear, $P < .04$) as the level of dietary P was increased. Although the pST × P interaction was not significant for femur bending moment, a similar trend occurred as in the rib with bending moment being highest for control gilts at .8% P and pST gilts at 1.2% P. However, femurs from pST-treated gilts fed 1.2% P diets had higher bending moments than those of any of the control gilts. Bending moment for the metacarpal increased (linear, $P < .01$ and quadratic, $P < .06$) as dietary P increased. Gilts administered pST had decreased ($P < .04$) bending moments compared to control gilts. The metacarpal bones were less responsive than rib or femur to dietary P levels. This would be expected, because the metacarpal bones were the furtherest skeletal extremities to be evaluated, and the skeletal extremities are less sensitive to demineralization. However, a similar trend in metacarpal bending moment was noted, with control gilts having the highest bending moment on .8% P and pST-treated gilts on 1.2% P.

Rib ash content increased (linear, $P < .01$ and quadratic, $P < .06$) as dietary P increased, whether gilts received pST or not (Table 3). In previous research, pST-treated pigs had decreased ash content as lysine level was increased. However, in this experiment, lysine levels were constant at 1.2%, and, consequently, daily lysine, Ca, and P intakes between control and pST-treated pigs were similar. Ash contents were lower across all treatments than typically measured for pigs fed lower lysine diets, because increasing protein levels results in increased collagen matrix formation and slight decreases in bone ash content. This agrees with previous research showing decreased ash content as protein level was increased.

In the post-finishing phase, pST × P interactions ($P<.03$) were observed for rib bending moment and strain (Table 4). At the end of the post-finishing phase, bending moment for rib and femur of pST-treated gilts on the .8% P diet was as high as bending moment for any of the control gilts. Additionally, pST-treated gilts fed 1.2% P in the finishing phase had bending moments at the end of the post-finishing phase that exceeded those of all control gilts. These results indicate that compensatory mineralization occurs in the post-finishing phase. Post-finishing rib stress was unaffected by treatment received in the finishing phase. However, a similar pattern of highest rib strength per unit area was found in control gilts fed .8% P in the finishing phase, whereas rib strength increased in pST-treated gilts as the dietary P level was increased. Post-finishing rib modulus of elasticity had no carryover effects from treatment received in the finishing phase, although pST-treated gilts tended to have less rigid bones. Metacarpal bending moments were unaffected by previous treatments received in the finishing phase, although bending moments increased substantially from the finishing phase. Rib ash was increased (linear, $P<.01$ and quadratic, $P<.10$) by increased P levels received in the finishing phase. Administration of pST had no effect on post-finishing ash content.

Our data indicate that commonly fed finisher diets containing .45 to .55% P should be adequate to maintain maximum growth performance in pST-treated gilts. Mobility was not a problem in this experiment, because no differences in mobility or structural soundness through live evaluation were found to be due to pST treatment or dietary P level.

Bone strength was maximized in the non-pST-treated gilts at .8% P, whereas dietary P levels at 300% of NRC (1988) recommendations did not maximize bone strength in pST-treated gilts during the finishing phase. This suggests that maximum bone strength of pST-treated gilts may not be attainable without using excessively high levels of P that may depress intake and, consequently, growth performance. In contrast, compensatory increases in bone strength of pST-treated gilts post-finishing potentially offers an alternative to increasing bone strength by feeding extremely high P levels in the finishing phase. Further research needs to be conducted to determine the P intake required to facilitate post-finishing compensatory mineralization and to determine the time needed for the compensatory effect. Extrapolation of our results suggests that with compensatory mineralization, longevity of pST-treated gilts in the breeding herd should not be decreased by reduced bone strength and mineralization.

In conclusion, pST-treated finishing gilts do not have higher requirements for Ca and P than non-pST treated gilts for maximizing gain and feed efficiency. Gilts treated with pST do have higher requirements for Ca and P to achieve similar levels of bone strength in the finishing phase. However, through compensatory mineralization post-finishing, gilts treated with pST appear to have the capability of increasing bone strength to levels equal to or above those of non-pST-treated gilts.

Table 1. Composition of Diets

	Finishing phase[a]			Post-finishing[b]
Ingredient, %	.4 P	.8 P	1.2 P	1.2 P
Corn	62.98	60.65	58.32	78.69
Soybean meal (48% CP)	29.77	29.77	29.77	14.53
Soybean oil	5.00	5.00	5.00	—
L-lysine HCl	.16	.16	.16	—
Monocalcium P (21% P)	.16	2.10	4.03	4.22
Limestone	.78	1.17	1.57	1.66
Salt	.30	.30	.30	.50
Vitamin premix	.50	.50	.50	.25
Trace mineral premix	.20	.20	.20	.10
Selenium premix	.05	.05	.05	.05
Antibiotic[c]	.10	.10	.10	--
Total	100.00	100.00	100.00	100.00
Calculated analyses, %				
Lysine	1.2	1.2	1.2	.65
Ca	.5	1.0	1.5	1.5

[a]Finishing phase, 129 to 230 lb.
[b]Post-finishing, 35 d following the finishing phase.
[c]Each lb of antibiotic contained 10 g chlortetracycline.

Table 2. Effect of Porcine Somatotropin and Dietary Phosphorus on Growth Performance of Finishing Gilts[a]

	Placebo			4 mg pST			
Item	.4 P	.8 P	1.2 P	.4 P	.8 P	1.2 P	CV
0 to 35 d[b]							
ADG, lb[ceh]	1.79	2.01	1.94	1.90	2.07	2.06	7.9
Feed intake, lb/d[d]	5.37	5.53	5.59	4.77	4.90	4.97	9.0
F/G[de]	3.04	2.81	2.91	2.55	2.40	2.45	6.9
P intake, grams/d[df]	9.7	20.1	30.4	8.7	17.8	27.1	10.8
Finishing phase[g]							
ADG, lb[d]	1.78	1.99	1.87	2.02	2.05	2.07	8.4
Feed intake, lb/d[d]	5.64	6.09	6.14	5.36	5.26	5.48	5.9
F/G[de]	3.20	3.13	3.35	2.70	2.58	2.67	5.7
P intake, grams/d[df]	10.2	22.1	33.4	9.7	19.1	29.8	7.2

[a]A total of 108 gilts initially weighing 129 lb, 3 gilts/pen, 6 pens/treatment.
[b]Day 0 to 35 of the finishing phase.
[c]Effect of pST ($P < .08$).
[d]Effect of pST ($P < .01$).
[e]Effect of phosphorus (quadratic ($P < .06$).
[f]pST × phosphorus interaction ($P < .04$).
[g]The entire finishing phase, d 0 until pen wt averaged 230 lb.
[h]Effect of phosphorus (linear, $P < .05$).

Table 3. Effect of Porcine Somatotropin and Dietary Phosphorus on Bone Mechanical Properties and Mineralization (Finishing Phase)[a]

	Placebo			4 mg pST			
Item	.4 P	.8 P	1.2 P	.4 P	.8 P	1.2 P	CV
Rib							
Bending moment, kg[b]	86	125	119	54	104	120	19.4
Stress, kg/cm^{2}[cef]	602	624	609	298	576	609	40.5
Strain	.22	.29	.23	.24	.25	.26	29.6
Modulus of elasticity kg/cm^{2}[b]	2,974	3,022	2,816	1,260	2,174	2,828	55.6
Ash, %[de]	44.99	48.79	50.51	43.68	49.64	51.39	5.7
Femur							
Bending moment, kg[e]	484	603	598	394	569	664	22.5
Metacarpal							
Bending moment, kg[cde]	144	174	169	121	161	168	13.3

[a]Means represent 9 observations per treatment.
[b]pST × P interaction ($P < .05$).
[c]Effect of pST ($P < .06$).
[d]Effect of P (quadratic $P < .06$).
[e]Effect of P (linear $P < .04$).
[f]pST × P interaction ($P < .10$).

Table 4. Effect of Porcine Somatotropin and Dietary Phosphorus during the Finishing Phase on Bone Mechanical Properties and Mineralization during a 35-d Post-finishing Phase[a]

	Placebo			4 mg pST			
Item	.4 P	.8 P	1.2 P	.4 P	.8 P	1.2 P	CV
Rib							
Bending moment, kg[b]	119	109	131	104	131	144	16.7
Stress, kg/cm^2	571	774	613	534	560	647	37.3
Strain[b]	.28	.20	.25	.26	.32	.31	29.5
Modulus of elasticity kg/cm^2	2,402	3,243	2,500	2,493	2,233	2,345	68.7
Ash, %[cd]	44.52	49.46	48.09	44.59	47.80	48.78	8.9
Femur							
Bending moment, kg[def]	517	611	561	566	643	739	17.3
Metacarpal							
Bending moment, kg	217	226	230	216	218	224	14.1

[a]Means represent 9 observations per treatment.
[b]pST × P interaction ($P<.03$).
[c]Effect of P (quadratic, $P<.10$).
[d]Effect of P (linear, $P<.01$).
[e]Effect of pST ($P<.01$).
[f]pST × P interaction ($P<.12$).