Effect of Ractopamine on the Optimum Dietary Phosphorus Regimen for Pigs

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Summary and Implications

Ten replications of individually penned gilts from a high-lean strain were used to determine the effect of ractopamine (RAC) on the optimum dietary available phosphorus (AP) regimen. At 70 kg body weight, pigs were randomly allotted to a corn-soybean meal basal diet (.08% AP) adequate in all nutrients except AP. The basal diet was supplemented with mono-dicalcium phosphate to create six AP concentrations (.08, .13, .18, .23, .28, .33%) and ractopamine HCl to create two RAC concentrations (0 and 20 ppm). A constant Ca/AP ratio of 2.5:1 was maintained in each diet. BW gain and feed intake were recorded weekly for 5 weeks, and total urine output was collected via urinary catheter the last 2 days of each 7-day period. After this 5-week collection period pigs remained on their diets until they achieved a body weight of 114 kg and were then slaughtered keeping the ham and loin for subsequent dissection and bone removal.

In pigs growing from 70 to 114 kg BW dietary AP additions resulted in improved ($P<.01$) daily BW gain, but did not alter carcass or ham-loin muscle content. Dietary AP additions also linearly improved ($P<.01$) bone integrity as observed by ham-loin bone content and femur and fifth vertebra weight and mineral content. RAC improved ($P<.01$) BW gain (+125 g), gain/feed ratio (+64 g/kg), and carcass and ham-loin muscle (+3.4%, +5.6%) content. RAC reduced ($P<.05$) the ham-loin bone content and femur and fifth vertebra weight and mineral content, but the amount of additional bone or bone mineral accrued per unit of added dietary AP was linear and independent of RAC. Because of their greater muscle accretion capacity, thus P demand, pigs fed RAC from 70 to 114 kg BW needed an additional .03% AP to maintain the same femur mineral content as the non-RAC pig.

Over the five periods, RAC lowered P content of BW gain (4.66 vs. 4.05 g/kg) and urinary P excretion (219 vs. 67 mg/d) independent of dietary AP. The magnitude of change in BW gain and P content of BW gain was reduced in later periods of growth. Dietary AP additions improved ($P<.01$) P accretion and P content of BW gain. To achieve maximum BW gain, the amount of AP needed was not altered by RAC. To achieve the same P content of BW gain, an indicator of the adequacy of the bone mineral content of gain, an additional .06% to .02% AP was needed in the RAC pigs depending on length of ractopamine feeding. Based on these data, RAC does not alter the amount of AP needed to optimize rate and efficiency of BW gain but does increase the AP needed to maintain P content of body growth equivalent to non-RAC pigs.

Introduction

The major phosphorus stores in the body are in bone and muscle. Factors that increase the accretion of one or more of these tissues increase the dietary phosphorus needs of the pig. Failure to provide sufficient phosphorus intake has been shown to result in a reduction in muscle as well as bone accretion (1). In the presence of marginal bone stores, a further reduction in bone accretion could result in loss of skeletal integrity.

Previously it has been reported that ractopamine feeding results in greater carcass muscle content but a lower bone mass (2,3). Therefore, it could be hypothesized that dietary phosphorus intake also must increase to allow the maximum amount of muscle growth to occur and minimize the reduction in bone mass that has been associated with ractopamine addition in the diet. If the dietary phosphorus intakes of the pigs before ractopamine feeding are sufficiently deficient, then it could be hypothesized that the pigs' mobilizable bone phosphorus stores would be insufficient to support maximum muscle growth in response to ractopamine feeding and that the incidence of compromised skeletal integrity would be increased.

Materials and Methods

The experimental treatments consisted of six concentrations of dietary available phosphorus (.08, .13, .18, .23, .28, and .33%) and two concentrations of ractopamine (0 and 20 ppm). The basal diet was comprised of corn, soybean meal, crystalline amino acids, minerals, and vitamins (Table 1). The supplemental phosphorus and calcium were provided by mono-dicalcium phosphate and calcium carbonate, respectively, and were included in the basal diet at the expense of cornstarch. A constant calcium to available phosphorus ratio of 2.5 to 1 was maintained. The dietary concentrations of the other nutrients were formulated to meet or exceed the nutrient needs of pigs expressing a high rate of lean tissue accretion. A single source of each ingredient was used throughout the study to minimize variation in nutrient content.

One hundred twenty gilts from a high lean genetic strain were evaluated. Pigs were penned individually on slatted floors in an environmentally regulated building. Pigs were allotted to treatment groups at 70 kg BW from outcome groups based on body weight. Pigs were allowed to consume feed and water ad libitum. Pigs were fed a basal diet with .08% available phosphorus 3 weeks before being placed on their experimental diets. This procedure was used to minimize phosphorus in bone stores and ensure a more sensitive animal for determining the role of phosphorus in optimizing the response to ractopamine.

Table 1. Basal diet composition.

Ingredient	%
Corn	66.50
Soybean meal	30.01
Starch	2.22
L-Lysine·HCl	.09
Mono-dicalcium phosphate	.05
Limestone	.17
Salt	.40
Vitamin premix[a]	.26
Trace mineral premix[b]	.13
Choline chloride, 60%	.17

[a]Provided per kg of diet: 7,800 IU Vit. A; 900 IU Vit. D_3; 66 IU Vit. E; 3 mg Vit. K; 42 mg niacin; 42 mg pantothenic acid; 12 mg riboflavin; .030 mg Vit. B_{12}; 1.8 mg folacin; .3 mg biotin; 6 mg pyridoxine; 6 mg thiamine.

[b] Provided per kg of diet: 158 mg Fe; 135 mg Zn; 54 mg Mn; 16 mg Cu; .18 mg I; .24mg Se.

A urinary catheter was placed in each gilt and 2-day urine output was collected for days 6–7, 13–14, 20–21, 27–28 and 34–35 of the study to determine urinary phosphorus excretion. Phosphorus retention was determined by using previously determined phosphorus fecal digestibility values for corn, soybean meal, and mono-dicalcium phosphate. Pig weights and feed consumption were determined at consecutive 5 days (between urine collection periods) and 2 days (start and end of 2-day urine collection period). As pigs individually reached a BW of 114 kg, they were transported to the ISU Meats Laboratory. Pigs were stunned, then killed by exsanguination, scalded, dehaired, eviscerated, and the carcass chilled for 24 hours at 2^{o}C. The hot carcass, visceral components and leaf fat weights were recorded. At 24-hours postmortem, standard carcass measurements of cold carcass weight, backfat thickness at midline first rib, last rib, last lumbar vertebrae and off-midline tenth rib, and longissimus muscle area at the 10th rib was collected. The ham and loin from the right side was separated, weighed and physically dissected into tissue components of muscle, fat, bone and skin. The fifth along with the femur was physically removed, isolated, and weighed. The bones were then ashed for determination of mineral content. Data were analyzed by analysis of variance technique using the general linear model of SAS. The pig will be considered the experimental unit.

Results and Discussion

Phosphorus

Dietary AP additions resulted in linear (P<.05) increases in body weight gain, feed intake and gain/feed ratios (Table 2). The amount of phosphorus that maximized daily body weight gain in pigs not fed ractopamine was .20% AP. Even though dietary AP additions elicited these improvements in body weight gain, the composition of this gain was not altered. Specifically, measurements of longissiumus muscle area, 10th rib backfat thickness, carcass fat-free lean percentage, and ham muscle and fat content were not altered by dietary AP regimen (Table 3).

As dietary AP concentration increased, the weight of the ham-loin bone, femur, and fifth vertebra increased (P<.01) linearly (Table 4). The ash concentration and total mineral content of the femur and fifth vertebra also increased (P<.01) linearly with increasing dietary AP concentration. Increasing the amount of AP fed to pigs, resulted in greater (P<.01) urinary P excretion and P retention both on a g/d and g/kg BWG/d basis (Table 5).

Ractopamine

Ractopamine additions improved (P<.01) daily body weight gain and efficiency of feed utilization in pigs growing from 70 to 114 kg BW (Table 2). The composition of this gain was also altered resulting in more lean and less fat tissue. Measures of this effect were an increased (P<.01) longissimus muscle area, carcass fat-free lean and ham muslce percentage along with a decrease (P<.01) in tenth rib backfat and ham fat percentage (Table 3).

The weights of the ham-loin bone, femur, and fifth vertebra were reduced in pigs fed ractopamine (Table 4). Total mineral content in the femur and fifth vertebra also was reduced in ractopamine fed pigs. Because of these differences, ractopamine fed pigs require additional dietary AP to achieve the same bone mineral content as pigs not fed ractopamine. This increased phosphorus need in ractopamine fed pigs is potentially due to the higher accretion rates of the high P demanding muscle tissue. For example, pigs fed ractopamine require an additional .03% AP to achieve a femur mineral content of 75 g when fed from 70 to 114 kg BW (Fig. 1). However, there was no interaction between dietary AP and ractopamine regimen for total femur or fifth vertebra mineral indicating the efficiency of phosphorus and other mineral deposition in bone is not altered by ractopamine feeding.

Urinary phosphorus excretion and phosphorus retained per kg of body weight gain was reduced in ractopamine fed pigs presumably due to the higher accretion rate of the high P demanding tissue muscle (Table 5). Again, ractopamine additions did not alter the efficiency of body phosphorus retention because the slope of the lines for body P retention were the same (.86 vs .85 g P/.05% dietary AP) in pigs either fed or not fed ractopamine (Fig. 2).

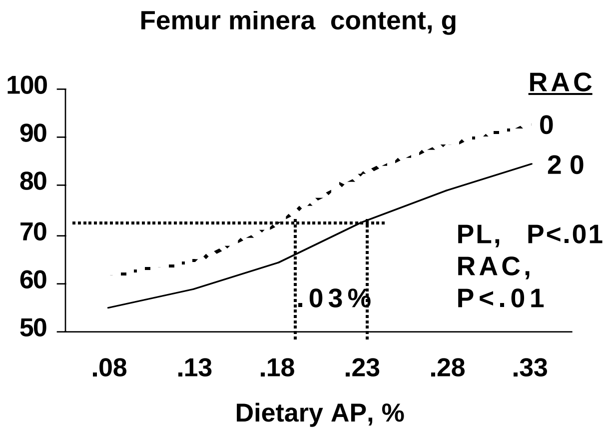

Figure 1. Effect of ractopamine and dietary AP regimen on femur mineral content.

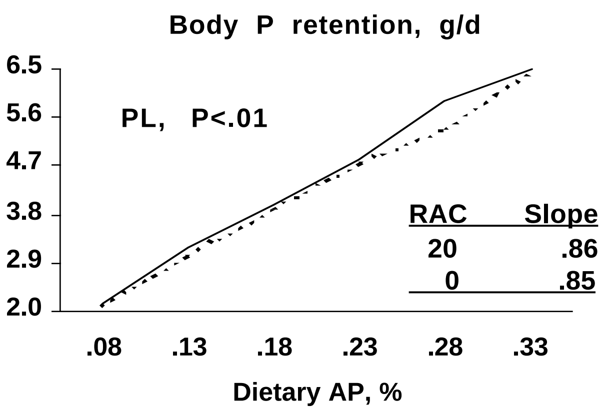

Figure 2. Effect of ractopamine and dietary AP regimen on rate and efficiency of P retention pooled across week.

Ractopamine feeding resulted in a large improvement in daily body weight gain during the early weeks of feeding but this degree of improvement declined as the length of feeding progressed (Fig. 3). These types of changes in body weight gain may result in different dietary AP needs, depending on the length of ractopamine feeding. In fact, to achieve the same P content of BWG, 5 g P/kg BWG in this example, ractopamine fed pigs required an additional .06% AP during the initial week of ractopamine feeding and this difference declined to only .02% AP by the end of the 5th week (Fig. 4).

In this experiment, both dietary AP and ractopamine improved daily body weight gain, but only ractopamine modified body composition resulting in more muscle and less fat. The amount of dietary AP required to support maximal rates of body weight gain was not altered by ractopamine feeding. However, to achieve similar P contents of body weight gain, ractopamine fed pigs required greater dietary concentrations of AP. This was not due to an inherent decline in the efficiency of P retention, but rather to

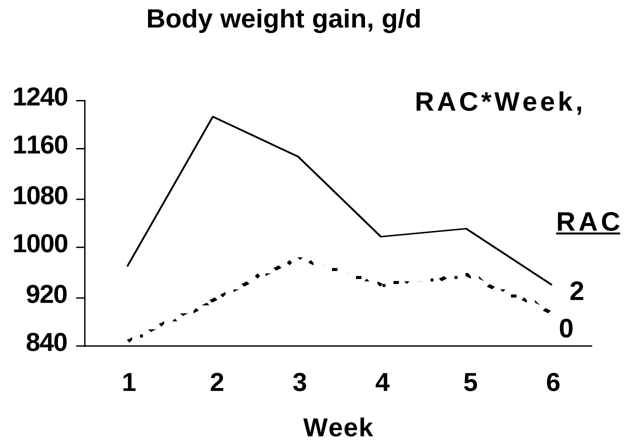

Figure 3. Effect of ractopamine on daily body weight gain during a 6-week period of ractopamine feeding.

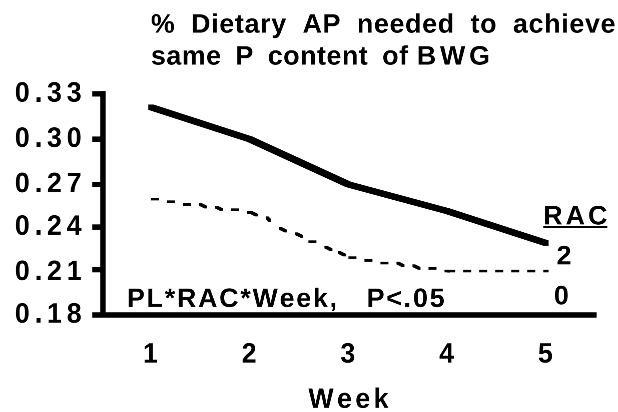

Figure 4. Percent dietary AP needed to achieve 5 g P/kg BWG in pigs fed 0 or 20 ppm ractopamine during each of the five weekly urine collection periods.

the higher accretion rates of the high P demanding muscle tissue. Ractopamine additions bring about the greatest changes in body growth during the early weeks of feeding and this is when the greatest AP needs were observed. Changes over the entire period of ractopamine and dietary AP feeding from 70 to 114 kg BW also indicated ractopamine fed pigs require a higher dietary AP concentration than pigs not fed ractopamine. Specifically, to achieve the same femur mineral content, ractopamine fed pigs required an additional .03% AP.

Table 2. Effect of ractopamine and phosphorus regimen on feed intake, body weight gain, and efficiency of feed utilization in pigs growing from 70 to 114 kg BW.

		Dietary AP, %							P=			
Criteria	RAC	.08	.13	.18	.23	.28	.33	SEM	RAC	PL	PQ	R*P
Daily feed, g												
	-	2415	2482	2611	2600	2543	2686	66	.11	.01	.43	.69
	+	2326	2479	2492	2426	2542	2549					
Daily gain, g												
	-	825	834	942	955	908	982	32	.01	.01	.16	.20
	+	946	1063	1043	1010	1062	1065					
Gain/feed, g/kg												
	-	344	335	361	368	358	365	9	.01	.04	.21	.30
	+	407	429	419	416	418	417					

Table 3. Effect of ractopamine and phosphorus regimen on carcass yield and lean percentage, and ham composition in pigs at 114 kg BW.

		Dietary AP, %							P=			
Criteria	RAC	.08	.13	.18	.23	.28	.33	SEM	RAC	PL	PQ	R*P
Hot carcass weight, kg												
	-	81.58	83.38	83.60	82.98	83.32	83.38	1.20	.01	.12	.57	.98
	+	85.91	86.59	87.48	86.51	86.73	88.12					
Carcass yield, %[a]												
	-	72.76	74.42	73.83	73.29	73.81	73.80	.36	.01	.35	.34	.14
	+	75.48	75.35	75.62	75.63	75.38	75.64					
Tenth rib backfat, cm[a]												
	-	1.70	1.87	1.59	1.41	1.57	1.77	.11	.01	.66	.04	.38
	+	1.19	1.14	1.24	1.15	1.20	1.42					
Longissimus muscle area, cm^2[a]												
	-	44.69	46.18	45.52	46.93	46.74	46.18	1.35	.01	.72	.50	.20
	+	52.36	51.47	52.43	52.95	47.93	51.05					
Estimated fat free lean, % of hot carcass[a]												
	-	54.38	53.98	55.08	56.18	55.45	54.35	.73	.01	.71	.10	.59
	+	58.66	58.70	58.50	59.05	57.63	57.44					
Ham separable tissue at 114 kg BW, %[a]												
Muscle	-	71.08	69.89	69.99	70.38	70.01	70.18	.72	.01	.12	.27	.78
	+	76.43	75.79	74.11	75.07	75.68	74.29					
Fat	-	17.16	18.22	18.00	17.26	17.41	17.45	.86	.01	.47	.41	.76
	+	12.69	12.94	14.53	13.61	13.26	14.29					
Skin	-	3.89	3.63	3.61	3.76	3.83	3.77	.20	.01	.80	.70	.01
	+	3.36	3.57	3.60	3.48	3.24	3.49					
Bone	-	7.97	8.28	8.47	8.70	8.83	8.85	.34	.01	.01	.32	.74
	+	7.39	7.61	7.63	7.67	7.88	7.89					

[a]Adjusted for hot carcass weight.

Table 4. Effect of ractopamine and phosphorus regimen on bone weight, ash percentage, and total mineral content in pigs at 114 kg BW.

		Dietary AP, %							P=			
Criteria	RAC	.08	.13	.18	.23	.28	.33	SEM	RAC	PL	PQ	R*P
Ham-loin bone weight, g												
	-	2,243	2,283	2,443	2,527	2,507	2,540	71	.01	.01	.28	.55
	+	2,177	2,118	2,238	2,308	2,403	2,358					
Fifth vertebra												
Weight, g	-	31.2	31.6	38.8	38.7	39.5	39.1	3.3	.03	.01	.09	.70
	+	31.3	24.7	38.9	36.0	33.5	32.7					
Ash, %	-	11.7	14.5	15.5	15.8	16. 0	18.0	.7	.17	.01	.10	.01
	+	11.3	10.7	14.8	16.8	16.2	18.0					
Mineral, g	-	3.56	4.58	5.94	6.14	6.35	6.98	.55	.05	.01	.04	.49
	+	3.50	2.80	5.66	6.01	5.52	5.88					
Femur												
Weight, g	-	358	358	375	389	396	398	11	.01	.01	.84	.52
	+	337	348	346	350	374	366					
Ash, %	-	17.3	18.3	19.4	21.4	22.5	23.3	.6	.03	.01	.69	.79
	+	16.5	17.2	18.7	20.8	21.4	23.4					
Mineral, g	-	62.2	65.2	72.6	82.7	89.0	92.9	2.0	.01	.01	.59	.90
	+	55.1	59.1	64.3	72.6	79.5	84.7					

Table 5. Effect of ractopamine and phosphorus regimen on urinary P excretion and body P retention pooled across week.

		Dietary AP, %							P=			
Criteria	RAC	.08	.13	.18	.23	.28	.33	SEM	RAC	PL	PQ	R*P
Daily urinary P excretion, mg												
	-	124	172	210	214	245	323	45	.01	.01	.19	.82
	+	44	40	60	40	47	177					
Daily P retained, g												
	-	2.14	3.06	3.94	4.79	5.40	6.48	.13	.18	.01	.55	.33
	+	2.19	3.19	3.96	4.81	5.86	6.50					
Daily P retained, g/kg BWG												
	-	2.43	3.49	3.99	5.00	6.06	6.78	.12	.01	.01	.55	.12
	+	2.13	2.80	3.61	4.46	5.17	6.01					

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