Dietary Riboflavin Needs for Body Maintenance and Body Protein and Fat Accretion in Pigs

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Summary and Implications

The dietary bioavailable riboflavin needs for body maintenance and body protein and fat accretion were estimated in pigs. The riboflavin required to support body protein accretion was higher than that for body maintenance or fat accretion. Specifically, the riboflavin required to support protein accretion was six times higher than the riboflavin required to support fat accretion. Based on these data, both biological and environmental factors that alter body protein accretion in pigs will substantially alter riboflavin needs. In addition, the dietary bioavailable riboflavin required by high-lean, high-health pigs is greater than the current NRC (4) estimate.

Introduction

Traditionally, empirical experiments have been conducted to determine vitamin requirements based on the amount of each vitamin a pig requires to achieve maximum growth. Much of the research that these requirements are based upon, however, was conducted in the 1950s and 1960s. Since that time, pigs have become more efficient meat-producing animals with an ability to produce more proteinaceous tissue per killogram of body weight gain.

Results from empirical experiments can be used to effectively estimate vitamin needs of pigs, but these estimates are only appropriate for pigs of a specific age, gender, herd health status, climatic condition, and genetic strain used in the study. Stahly et al. (5) has shown that higher dietary concentrations of one or more of a group of five B vitamins (niacin, pantothenic acid, riboflavin, B_{12}, and folic acid) is needed to optimize performance of a high-lean-growth strain of pigs compared with a moderate-lean-growth strain of pigs. These results indicate the dietary vitamin needs of pigs may vary among pigs differing in their capacity for proteinaceous tissue growth.

A better approach to determine the vitamin requirements of pigs may be the factorial approach. Such an approach has been used to model both energy and amino acid needs by determining the amount of nutrients required for maintenance and body protein and fat accretion NRC (4).

Due to the important role riboflavin plays in carbohydrate, protein, and fat metabolism, determination of the amount of riboflavin required for specific biological processes (i.e. body protein and fat accretion) would be a valuable piece of information for estimating the riboflavin requirement of pigs. These data potentially could be used to estimate the riboflavin needs for pigs of differing genetic strains, body weights, genders, etc.

The objective of this experiment was to determine riboflavin needs for body maintenance and body protein and fat accretion in pigs.

Materials and Methods

Six experimental treatments were used in this study. The treatments consisted of two genetic strains (high versus moderate lean) of pigs and three dietary riboflavin concentrations. These supplemental riboflavin concentrations were 0, 3.7, 7.4 mg riboflavin/kg of diet. Pigs from each genetic strain were weaned at 8 to 12 days of age and transported to an isolated nursery unit at Iowa State University. Pigs were treated with Ceftiofur (Naxcel) on days 0, 1, and 2 after arrival (4.4 mg/kg of body weight) and Ivermectin on day 0. Pigs were fed a low riboflavin basal diet (Table 1) until the average weight of pigs in the litter reached 10 kg of body weight to minimize body riboflavin stores. All other vitamins were supplemented at 600% of NRC (3) estimated requirement for 5- to 10-kg pigs. Dietary amino acid concentrations were formulated to meet or exceed the ideal amino acid ratio relative to lysine. (1). Ten sets of three littermate high-lean barrows and six sets of 3 littermate moderate-lean barrows were utilized in this study. When the average weight of pigs in the litter reached 10 ± 1.5 kg, pigs were randomly allotted within litter to one of the three supplemental riboflavin concentrations.

Pig weights and feed consumptions were measured at 4-day intervals until the pigs reached 26 ± 1.5 kg of body weight. Additionally, pigs were injected with deuterium oxide at the beginning and end of the study and bled two hours post-injection via orbital sinus. The blood samples were sublimated to obtain the water-deuterium oxide mixture component in the blood. Sublimates were then analyzed by infrared spectroscopy to estimate changes in body water space over the duration of the study. Equations were then applied to body water space to determine protein and fat accretion. To quantify the level of immune system activation, pigs were bled via orbital sinus at 10 (initial) and 26 (final) kg of body weight to determine serum concentrations of the acute phase protein alpha-1 acid glycoprotein (AGP) and the presence of titers for four prevalent swine antigens. The erythrocyte glutathione reductase activity coefficient was evaluated on half the replications of pigs fed the basal diet in both the high- and moderate-lean strain at bodyweights of 10, 18, and 26 kg to evaluate the degree of riboflavin deficiency the pigs experienced.

Data were analyzed as a randomized complete block design with the pig considered as the experimental unit. Least square means are reported. Additionally, multiple regression was used to separate riboflavin needs for body maintenance and body protein and fat accretion.

Table 1. Basal diet composition of high- and moderate-lean strains.

	High	Moderate
Ingredient	%	%
Corn	63.15	37.45
Soybean meal	17.89	32.14
Casein	7.00	5.00
Lactose	0.00	15.00
Choice white grease	5.00	5.00
Amino acids	0.99	0.35
Dicalcium phosphate	3.18	2.99
Limestone	0.48	0.43
Salt	0.40	0.40
Potassium sulfate	0.36	0.00
Sodium bicarbonate	0.31	0.00
Choline chloride	0.23	0.23
Trace mineral-vitamin premix[a]	0.31	0.31
Riboflavin carrier(starch)	0.20	0.20
Antimicrobial agent[b]	0.50	0.50

[a]Contributed the following per kg of diet: biotin, .3 mg; niacin, 90 mg; pantothenic acid, 60 mg; folic acid, 1.8 mg; pyridoxine, 9 mg; thiamin, 6 mg; vitamin B_{12}, 0.105mg; vitamin E, 96 IU; vitamin A, 13,200 IU; vitamin D3, 1320 IU; vitamin K, 3 mg; vitamin C, 100 mg; Fe, 280 mg; Zn, 240 mg; Mn, 96 mg; Cu, 28 mg; I, .32 mg; Se, .3 mg.
[b]Contributed the following per kg of diet: chlortetracycline, 110 mg; sulfathiazole, 110 mg; penicillin, 50 mg.

Results and Discussion

Pigs of both genetic strains were reared via a SEW scheme and expressed low levels of serum AGP (Table 2). As expected the high lean strain of pigs (Table 3) consumed less feed (931 vs. 1130 g/d), produced bodies that contained a higher proportion of body protein to fat (1.30 vs. 1.22), and gained more weight per unit of feed (.723 vs. .636 g/g) than the moderate lean strain.

For the riboflavin needs of different biological processes to be estimated, the pigs must receive diets containing inadequate concentrations of riboflavin. To achieve this status, pigs were fed a basal diet low in bioavailable riboflavin for about 20 days prior to the initiation of the study and by monitoring the presence of a riboflavin deficiency through the use of the erythrocyte glutathione reductase assay. Based on the erythrocyte glutathione reductase activity coefficient, both lean strains fed the basal diet were consuming deficient levels of riboflavin throughout the experiment (Table 4). As expected, pigs of the moderate lean strain fed the basal diet were less deficient because the analyzed riboflavin content of the basal diet was higher (Table 5). The higher than expected dietary riboflavin content was due to the inclusion of lactose.

Table 2. Serological titers for prevalent antigens and serum AGP levels.

	Pig	Lean Strain	
Criteria	Weight, kg	High	Moderate
Antibody titers[a]			
APP	26	-	-
MP		+	-
PRRS		-	-
SIV		+	+
AGP, µg/ml			
Initial	10	648	553
Final	26	414	403

[a]Actinobacillus pleuropneumoniae (APP), mycoplasma hyopneumonia (MP), porcine reproductive and respiratory syndrome (PRRS), and swine influenza virus (SIV).

Table 3. Growth and feed utilization of the high- and moderate-lean strains.

	Lean Strain	
Criteria	High	Moderate
Growth and feed utilization, g/day		
Feed	931	1130
Gain	672	719
Gain/Feed	.723	.636
Daily accretion of body protein to fat		
Protein/Fat	1.30	1.22

Table 4. Erythrocyte glutathione reductase activity coefficient.

Lean	Pig Weight, kg			Deficient
Strain	10	18	26	State
High	2.49	2.52	3.03	>1.30
Mod	1.59	1.41	1.45	>1.30

Red blood cells of five pigs from the high lean strain and three pigs from the moderate lean strain were analyzed at each stage of growth.

Table 5. Riboflavin content of diets.

	Lean	Added Riboflavin, mg/kg		
Criteria	Strain	0	3.7	7.4
Bioavailable riboflavin, mg/kg of diet[a]				
	High	1.4	5.1	8.9
	Mod	4.2	7.6	11.3
Bioavailable riboflavin % NRC (1998) requirement for 10 to 20 kg pigs				
	High	47	170	297
	Mod	140	253	377

[a]Bioavailable riboflavin concentration was determined by using analyzed values corrected for a riboflavin bioavailibility of 59% in corn and soybean meal (2).

As dietary riboflavin concentration increased, body protein accretion and efficiency of feed utilization increased linearly in the high- and moderate-lean strains. Body fat accretion was not altered by diet (Table 6).

Based on these data, the dietary need of pigs for bioavailable riboflavin is a minimum of 3 to 3.8 times greater than 1998 NRC estimates for 10 to 20 kg pigs. It was our objective, however, to go beyond just describing a requirement for a particular weight of pig by factorially estimating riboflavin needed for various biological processes. Riboflavin needs for specific biological processes were determined by using the fat and protein accretion data. The following equation was obtained:

$$R_i = -1.89 + .825E_m + 15.51E_{Pa} + 2.54E_{Fa}.$$

Where R_i stands for riboflavin intake and has the units $mg \cdot (BW, kg^{.75})^{-1} \cdot d^{-1}$, E_m is the energy (metabolizable) needed to maintain the body and was calculated as .442 $Mcal \cdot (protein\ mass, kg^{.78})^{-1} \cdot (BW, kg^{.75})^{-1} \cdot d^{-1}$, E_{Pa} is the energy required to support protein deposition and was calculated as $(10.5\ Mcal \cdot kg_{Pa}) \cdot (BW, kg^{.75})^{-1} \cdot d^{-1}$, and E_{Fa} is the energy required to support fat deposition, which was calculated as $(12.8\ Mcal \cdot kg_{Fa}) \cdot (BW, kg^{.75})^{-1} \cdot d^{-1}$. Each parameter estimate would be described as the milligrams of riboflavin required to support the expenditure of energy needed for each specific biological process per kilogram of metabolic weight per day and would have the following units:

$$mg\ riboflavin \cdot (Mcal\ ME\ for\ process)^{-1} \cdot (BW, kg^{.75})^{-1} \cdot d^{-1}.$$

The parameter estimates of riboflavin needs and associated probability values are shown in Table 7.

Table 7. Estimated riboflavin needs for each Mcal of ME expended for specific biological processes.

Biological Process	Estimate	Probability[a]	SEE[b]
Intercept	-1.89	.67	4.41
E_m	.825	.98	35.7
E_{Pa}	15.51	.002	4.59
E_{Fa}	2.54	.38	2.83

[a]R^2 for model is 0.32.
[b]Standard error of estimate.

This equation indicates that body protein accretion requires greater amounts of bioavailable riboflavin compared with fat accretion or body maintenance. In fact, riboflavin needs are six times higher for body protein accretion compared with body fat accretion. The negative intercept value calculated in modeling riboflavin needs, is assumed to represent the amount of riboflavin stored in body stores that is being mobilized in the deficient animal to help supplement that provided by the dietary sources.

If the values for a 35 kg pig with a lean gain rate of 370 g/d, whole-body protein accretion rate of 140 g/d, whole-body fat accretion rate of 252 g/d, and a protein mass of 5.88 kg, are substituted into the riboflavin needs equation the resulting estimated need is 5.2 mg/d of bioavailable riboflavin. In contrast, for a 35 kg pig with a lean gain rate of 473 g/d, whole-body protein accretion rate of 180 g/d, whole-body fat accretion rate of 219 g/d, and a protein mass of 5.88 kg the estimated bioavailable riboflavin need would be 10.8 mg/d.

These data indicate that the bioavailable riboflavin required to support body protein accretion is comparatively larger than the riboflavin needed to support the other biological functions in which riboflavin is involved. This indicates that biological and environmental factors that alter protein accretion rates also will alter riboflavin needs.

Table 6. Growth, feed utilization, and body nutrient accretion.

Item	LG Strain	Added Riboflavin, mg/kg 0	3.7	7.4	Prob[a]
Pig weight, kg					
Initial					
	High	10.3	10.3	10.3	NS
	Mod	10.1	9.8	9.9	NS
Final					
	High	27.7	27.2	27.8	NS
	Mod	26.1	26.5	26.8	NS
Growth and feed utilization, g/day					
Feed					
	High	925	920	938	NS
	Mod	1140	1160	1090	NS
Gain					
	High	645	677	696	L .05
	Mod	691	740	726	L .14
Gain/feed					
	High	.701	.735	.744	L .04
	Mod	.606	.638	.664	L .01
Body nutrient accretion, g/day					
Protein					
	High	110	115	118	L .05
	Mod	115	124	124	L .09
Fat					
	High	83	89	91	Q .18
	Mod	99	105	92	Q .16

[a]NS indicates nonsignificant differences between dietary riboflavin concentrations, L indicates a linear effect of dietary riboflavin concentration, and Q indicates quadratic effects of dietary riboflavin concentration.

References

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