Impact of Level of Antigen Exposure on Response of Pigs to Dietary Energy Sources

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Summary and Implications

Two levels of chronic antigen exposure (moderate and high) were created by rearing pigs via a segregated-early-weaning and a conventional rearing scheme, respectively. In each antigen exposure group, three littermate pigs in each of nine litters were fed one of three energy sources from 13 to 60 pounds body weight. Fifteen percent of the metabolizable energy (ME) content of the diets was provided by corn starch (CS), choice white grease (CWG), or corn oil (CO). Moderate AE pigs consumed more ME per day and grew faster than high AE pigs. The dietary inclusion of fat calories (CWG, CO) for starch calories resulted in greater daily body weight gains and gain:ME ratios in both moderate and high AE pigs. The magnitude of growth responses to the two fat calorie sources was similar in both AE groups. Based on these data, dietary fat calories support greater growth rate and efficiency of dietary ME utilization than starch calories in pigs experiencing either moderate or high levels of antigen exposure.

Introduction

Animal growth is the result of a myriad of biological processes that are regulated by various genetic and environmental factors. These biological processes can be grouped into maintenance functions and growth processes. Maintenance functions include repair of body tissues, fuel for voluntary activity, generation of body heat, and support of body defense (i.e., immune) system. Growth processes include the synthesis of body tissues, organs, and fluids.

Dietary sources of carbohydrates (i.e., starch, lactose, glucose) are utilized efficiently when oxidized for support of either maintenance or growth functions. In contrast, fat calories are utilized less efficiently for maintenance function and most efficiently for fat tissue synthesis. Furthermore, animals (i.e., rats, chicks) with an activated immune system preferentially utilize glucose calories for metabolic processes as well as preferentially consume high starch versus high fat diets (Kelly et al. 1988, Kiser et al. 1973). Consequently, it is hypothesized that dietary fat calories may be utilized less efficiently in antigen challenged animals and more efficiently in animals with a low level of immune system activation and a high rate of tissue deposition.

The responses of pigs to specific fat sources also may be dependent on the animal's level of exposure to antigens and thus level of immune system activation. Feeding fats high in linoleic acid (i.e., vegetable oils - corn, soy) potentially results in greater cytokine production. Cytokine release has been shown to reduce feed intake and rate and efficiency of body growth as well as carcass muscle content in pigs. Linoleic acid is a direct precursor of prostaglandins such as PGE_3 which stimulates the production of cytokines. In contrast, fat sources low in linoleic acid (i.e., animal fats - lard, tallow, some fish oil) do not serve as precursors of prostaglandins and thus minimize cytokine release. Based on these relationships, dietary addition of animal fat low in linoleic acid may result in greater improvements in growth and efficiency of dietary energy utilization than isocaloric additions of vegetable oils in pigs experiencing a low level of antigen exposure and thus level of immune system activation.

The objective of this study was to evaluate the impact of level of antigen exposure (thus immune system activation) and dietary energy source (starch vs fat, high vs low linoleic acid fats) on the rate and efficiency of body growth in pigs fed from 14 to 60 pounds body weight.

Materials and Methods

Treatments

The experimental treatments consisted of two levels of chronic antigen exposure (AE) and three dietary energy sources. Pigs with a moderate and a high level of AE were created by rearing animals via a segregated-early-weaning (SEW) and a conventional weaning (CW) scheme, respectively. The SEW scheme consisted of administering Naxcel and Baytril to each pig on day 1, 3, 5, 8, and 11 of age to minimize the presence of pathogenic bacteria in the pigs. The pigs were weaned at 12 ± 2 days of age when their colostrally derived antibodies were still high and then placed in a sanitized nursery physically isolated from other pigs. Pigs were fed a milk pellet diet (day 14, Merrick Foods, Inc.) until they reached 19 days of age. The CW scheme consisted of not administering antibiotics to the neonatal pigs, weaning the pigs at 19 ± 4 days of age when their colostrally derived antibodies were largely depleted, and then placing them in a non-sanitized nursery concurrently occupied with older pigs from the herd of origin.

The diets consisted of a basal mixture supplemented with isocaloric amounts of a starch or fat source (Table 1). In each regimen, the basal mixture and supplemental energy source supplied 85 and 15%, respectively, of the

Table 1. Composition of experimental diets.

Item	Dietary energy source		
	Starch	CWG	CO
Basal mixture			
Corn	17.96	19.08	19.00
Soybean meal	38.86	41.22	41.08
Whey, dried	20.00	21.22	21.14
Skim milk, dried	5.00	5.30	5.29
Dicalcium phosphate	3.31	3.51	3.50
Limestone	1.07	1.14	1.13
L-Lysine	.30	.31	.32
D,L-Methionine	.40	.42	.42
L-Threonine	.20	.20	.20
Salt	.35	.37	.37
Trace mineral-vitamin mix[a]	.58	.62	.61
Santoquin	.02	.02	.02
Supplemental calorie source			
Corn starch[b]	11.95	-	-
Choice white grease[c]	-	6.59	-
Corn Oil[d]			6.92
Total	100.00	100.00	100.00
Calculated composition			
ME, Mcal/lb	1.46	1.55	1.54
% from basal mix	85	85	85
% from suppl. cal. source	15	15	15
Fat, %	1.07	7.72	8.05
Protein, %	25.3	26.8	26.7
Lysine, %	1.80	1.91	1.90
Available P, %	.89	.94	.94

[a]Supplied the following per lb of diet (.61% inclusion rate): biotin, .04 mg; choline, 230 mg; folacin, .08 mg; niacin, 31.6 mg; pantothenic acid, 12.3 mg; riboflavin, 4.6 mg; pyridoxine, .40 mg; thiamin, .22 mg; vitamin B_{12}, 24.5 µg; vitamin E, 17.8 IU; vitamin A, 2119 IU; vitamin D, 530 IU; vitamin K, 2.2 mg; Cu, 8.4 mg; Fe, 84.0 mg; Mn 28.8 mg; Se, .15 mg; Zn, 72.5 mg; I, .10 mg.
[b]International Ingredients, Inc., St. Louis, Missouri.
[c]National By-Products, Inc., Des Moines, Iowa.
[d]Archer Daniel Midlands, Decatur, Illinois.

dietary metabolizable energy (ME) content. The basal mixture consisted of a corn, soybean meal, whey, skim milk, and amino acid mix fortified with minerals, vitamins, and an antioxidant. The three supplemental energy sources consisted of corn starch, choice white grease, and corn oil. The (ME) content of the ingredients was assumed to be that reported by NRC (1988) except for corn starch (4.02 Mcal/kg). A single source of each ingredient was used throughout the study. In each regimen, the source and amount of each nutrient per Mcal of dietary ME was maintained constant. The diets were formulated to meet or exceed the dietary lysine and phosphorous needs of the moderate AE pigs. Dietary concentrations of trace minerals and vitamins were provided at 300% of NRC (1988) estimated requirements for 11 to 22 pound pigs. The analyzed fatty acid composition of the three dietary energy sources is shown in Table 2.

Procedures

All pigs were from a single genetic strain and geographical site of origin. Based on previous studies at our station, the pigs' capacity for lean tissue growth from 40 to 240 pounds body weight was estimated to be .75 to .80 pounds per day. The herd of origin possessed serological titers for mycoplasma hyopneumonia (MP), actinobacillus pleuropneumoniae (APP), porcine respiratory and reproductive syndrome (PRRS), transmissible gastroenteritis (TGE), and swine influenza (SIV).

Within each level of antigen exposure, 10 sets of three littermate pigs were utilized. From birth until 19 days of age, pigs in both AE groups were offered a milk-based diet. When pigs reached 19 ± 2 days of age, three pigs in each litter were randomly allotted to one of three dietary energy sources. Pigs were penned individually on slotted floors in 2 ft x 4 ft pens in buildings maintained at 80-85° F. Pigs were allowed to consume feed and water ad libitum.

Table 2. Analyzed dietary fat compositions.[a]

Item	Dietary energy source		
	Starch	CWG	CO
Dietary fat, %	1.59	8.01	8.39
Dietary fatty acids, %			
C10:0	.021	.0303	.029
C12:0	.008	.014	.015
C14:0	.030	.114	.039
C14:1	.007	.014	.014
C16:0	.255	1.730	.945
C16:1	.006	.182	.013
C17:0	<.005	.030	.012
C17:1	<.005	.024	.012
C18:0	.073	.897	.197
C18:1	.329	3.010	2.018
C18:2	.779	1.502	4.692
C18:3	.080	.120	.144
C20:0	<.005	.018	.032
C20:1	<.005	.081	.025
C20:2	<.005	.043	.001
C20:3	<.005	.005	.011
C20:4	<.005	.006	.011
C22:0	.005	.006	.011
Dietary unsaturated-saturated fatty acids			
Unsaturated (U), %	1.19	5.20	7.08
Saturated (S), %	.40	2.81	1.28
U:S	2.96	1.85	5.53

[a]Analysis performed by Hazelton Laboratories, Madison, Wisconsin.

Pig weights and feed consumption were determined at four-day intervals until each animal reached a bodyweight of 60 pounds. Pigs were bled at 14 (initiation of study) and 60 pounds bodyweight (termination of the study) to estimate the level of immune system activation via quantification of the acute-phase protein, alpha-1 acid glycoprotein. Serological titers for the major antigens present in the herd of origin also were determined to evaluate the immune status of the pigs.

Data were analyzed by analysis of variance techniques using the General Linear Model procedure of SAS (1995). Data were analyzed as a split-plot design. Antigen exposure was considered the whole plot treatment. Dietary energy source was considered the subplot treatment. The experimental unit was the pig. Least square means are reported. Orthogonal contrasts were made to compare the responses of starch versus fat calories and of choice white grease versus corn oil calories. Responses of pigs at 4 pound increments of growth were analyzed as repeated measures.

Results and Discussion

Antigen Exposure Effects

The experimental animals were reared by procedures that have been previously used in our station to create animals with a low and high level of antigen exposure and thus chronic immune system activation. In the current study, some of the pigs in the SEW group exhibited mild diarrhea during days 12 to 24 (15 to 35 pounds bodyweight) of the trial. Evaluation of five affected pigs in the SEW group by the ISU Diagnostic Lab indicated the presence of rotavirus in three of the five animals; however, a specific diagnosis could not be confirmed. Based on serological titers for antigens, pigs in both the SEW and CW groups were negative for MP, APP, and PRRS at 60 pounds bodyweight, but possessed titers for TGE and SIV. The presence of TGE and SIV titers indicated that both groups were exposed to some level of these viruses and mounted immune responses to them.

Serum concentrations of alpha-1 acid glycoprotein, an acute phase protein produced by the liver in response to antigen challenge, were similar among the two AE groups prior to the initiation of the study (Table 3). However, the SEW group had lower circulating levels of the acute phase protein at the termination of the study, indicating a lower level of AE and thus immune system activation. Based on these data, the pigs in the two AE groups in the current study were estimated to experience a moderate and high level of antigen exposure.

As expected, pigs in the moderate AE group consumed more dietary ME and gained more weight daily than the high AE group (Table 4). However, body weight gain:ME ratios were similar among AE groups. The similarity in gain:ME ratios in the two AE groups may be due in part to the smaller than expected difference in level of AE activation between the groups.

Table 3. Serum alpha-1 acid glycoprotein (AGP) concentrations.

		Pig weight, lb	
Item	AE	13	60
Acute phase protein			
AGP, µg/ml[a]	Mod	710	452
	High	714	521

[a]AE effect, $P<.05$ at 60.1 lb.

Table 4. Pig growth and dietary energy utilization response.

		Dietary energy source		
Item	AE	Starch	CWG	CO
No. of pens[a]	Mod	9	9	9
	High	9	9	6
Pig weight, lb				
Initial	Mod	13.0	12.8	13.0
	High	13.9	14.3	15.2
Final	Mod	60.5	60.7	61.2
	High	59.0	59.6	60.3
Growth and energy utilization				
Daily ME, Mcal[bc]	Mod	2.87	2.72	2.69
	High	2.32	2.32	2.16
Daily gain, lb[bc]	Mod	1.13	1.17	1.18
	High	.91	.96	1.0
Gain:ME, g/Mcal[cd]	Mod	179	192	199
	High	180	190	206

[a]Pigs penned individually.
[b]AE effect, $P<.01$.
[c]Starch vs fat effect, $P<.05$.
[d]CWG vs CO effect, $P<.10$.

Energy source and AE x Energy Source Effects

The analyzed dietary fat concentration and fatty acid composition of the three diets are shown in Table 2. The starch, CWG, and CO diets contained 1.6, 8.0, and 8.4% fat with unsaturated:saturated (U:S) fatty acid ratios of 3.0, 1.9, and 5.5, respectively. True digestibilities of various fat sources are similar in diets in which the total U:S fatty acid ratio is greater than 1.5 (Stahly, 1984). Thus, the digestibility of the fat in the three experimental diets used in the current study should be similar.

In pigs fed from 14 to 60 pounds bodyweight, the inclusion of 15% dietary fat calories at the expense of starch calories resulted in faster bodyweight gains and improved gain:ME ratios in both the moderate and high AE groups (Table 4). The magnitude of the improvement in bodyweight gain in pigs fed supplemental fat calories was similar between the two fat sources (CWG vs CO) in both AE groups. The improvements in gain:ME ratios observed in the fat supplemented pigs tended ($P<.09$) to be less in pigs fed CWG versus CO. Based on these data, the dietary inclusion of fat calories at the expense of starch calories results in faster bodyweight gains and more efficient utilization of ME for growth in pigs experiencing a moderate or high level of chronic AE thus immune system activation.

Because the ability of the young pig to utilize fat calories may be dependent on the animal's stage of development, the growth responses of the pigs during 4-day periods in which their mean bodyweights were 13, 17, 22, 26, 30, 35, 39, 44, 48, 52, and 57 pounds were analyzed. The moderate AE group gained 36, 61, 20, 16 and 18% faster than the high AE group during the initial five, 4.4 pound increments of weight gain when the degree of AE and thus immune system activation between the two groups seemed greatest, whereas they gained only 0 to 10% faster at the later stages of the study when the differences in the level of AE and thus immune system activation among the two groups was less.

The substitution of dietary fat for starch calories improved daily weight gains in both AE groups independent of pig weight. The magnitude of improvement was numerically greater in heavier weight pigs (44 to 59.4 pounds), but the interaction between dietary calorie source and pig weight was not statistically significant. A similar pattern of response in gain:ME ratios was observed in the fat supplemented groups.

Based on these data, the biological and thus economic value of a calorie of metabolizable energy derived from fat is greater than that of a calorie of ME from starch in 14 to 60 pound pigs experiencing either a moderate or high level of AE activation.

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