Director's Digest

FATS AND PROTEINS RESEARCH FOUNDATION, INC.

DR. GARY G. PEARL D.V.M.
Director Technical Services

16551 Old Colonial Road
Bloomington, Illinois 61704
Telephone: 309-829-7744 FAX: 309-829-5147
<www.fprf.org>

July, 1996 #281

IMPACT OF LEVEL OF IMMUNE SYSTEM ACTIVATION ON RESPONSE OF PIGS TO DIETARY ENERGY SOURCE

Tim S. Stahley, Ph.D.
Professor of Animal Science
Iowa State University, Ames, Iowa 50011

Co-Investigators: Douglas R. Cook, Assistant Research Scientist
Noel Williams, Ph.D.
Richard Ewan, Professor

Project Started: March 1995

Project Completed: March 1996

INDUSTRY SUMMARY

Introduction

Animal growth results from a myriad of biological processes that are regulated by various genetic and environmental (i.e., dietary regimen, health status) factors. Animals possess body defense systems (i.e., immune system) that function to contain, destroy, and eliminate foreign antigens (i.e., bacteria, viruses) from the body before they cause harm. Antigen exposure results in the release of compounds called cytokines. These cytokines serve a beneficial role of further stimulating the immune system. They also serve a potentially negative role in meat producing animals by inhibiting voluntary feed intake and tissue growth. In the U.S. swine industry, management practices are being developed and adapted that reduce the pigs level of chronic antigen exposure and thus immune system activation. These practices include segregated-early-weaning schemes and all-in-all-out production systems.

Dietary carbohydrates may be utilized preferentially over dietary fat as a fuel for metabolic and immunologic functions following antigen exposure whereas fat may be used more efficiently in animals with a low level of antigen exposure. Furthermore, the responses of animals to various fat sources may be dependent on the animal's immune status. Specifically, linoleic acid may stimulate indirectly the production of cytokines and thus may alter the animal's response to antigen exposure.

Objectives

To determine the impact of level of antigen exposure (thus immune system activation) on the response of pigs to dietary energy sources.

Industry Summary

The growth response and thus economic value of a calorie of metabolizable energy derived from fat is greater than a calorie derived from starch both in pigs experiencing a moderate or high level of antigen exposure. The growth responses of pigs to dietary fats containing a low or high linoleic acid content did not differ significantly in pigs experiencing a moderate or high level of antigen exposure.

ABSTRACT

Two experiments were conducted to determine if the growth response of pigs to dietary starch and fat calories are influenced by the level of antigen exposure thus immune system activation the animal experiences. In experiment one, moderate and high levels of chronic antigen exposure (AE) were achieved by rearing pigs via segregated-early-weaning and conventional rearing schemes, respectively. The segregated-early-weaning scheme is a management scheme used to minimize the level of antigen exposure that pigs experience.

Within each AE group, 9 sets of 3 littermate pigs were penned individually, and within a litter, pigs were self-fed one of three dietary energy regimens from 6 to 27 kg. In each energy regimen, 85% of the metabolizable energy (ME) was provided by a basal mixture of ingredients (20% corn, 44% SBM, 23% dried whey, 6% dried skim milk, and 7% vit-min, by weight) and 15% of the ME was provided by either corn starch (CS), choice white grease (CWG), or corn oil (CO). ME contents of the feedstuffs were based on NRC (1988) values except for CS (4.02 Mcal/kg). The analyzed unsaturated:saturated fatty acid ratios of the CS, CWG, and CO diets were 3.3, 1.5 and 5.8, respectively. Serum alpha-1 acid glycoprotein concentrations were similar in the moderate versus high AE pigs at 6 kg bodyweight (710 vs 714 mg/ml) but were lower ($P<.05$) in moderate AE pigs at 27 kg (452 vs 521 mg/ml). Pooled across dietary energy regimen, moderate AE pigs consumed more ME (2.79 vs 2.27 Mcal/d, $P<.01$) and grew faster (527 vs 434 g/d, $P<.01$), but gain:ME ratios were similar between AE groups (190 vs 192 g/Mcal, $P=.71$). Replacement of CS calories with fat calories (either CWG or CO) resulted in greater ($P<.01$) daily weight gains in both the moderate (514 vs 529 and 536 g/d) and high (413 vs 435 and 454 g/d) AE pigs. Similarly, replacement of CS calories with fat calories resulted in improved ($P<.01$) gain:ME ratios in both the moderate (179 vs 192 and 199 g/Mcal) and high (180 vs 190 and 206 g/Mcal) AE pigs. The magnitude of the growth responses to the two fat calorie sources were similar in both AE groups. No dietary energy regimen by AE level interaction was detected. Based on these data, a calorie of metabolizable energy from fat supports a greater rate and efficiency of growth than an equivalent ME calorie from starch in both moderate and high AE pigs.

In experiment two, two trials were conducted. In each trial, 12 sets of 3 littermate pigs were reared via a segregated-early-weaning scheme. Pigs were penned individually. Within each litter, pigs (19 days of age) were self-fed one of three dietary energy regimens for the duration of the 37-day study. The three dietary energy regimens consisted of a starchy, low-fat basal diet supplemented with 0% fat, 6% choice white grease or 6% corn oil. The basal diet consisted of wheat-soybean meal-whey-skim milk-amino acid-mineral and vitamin mix. The analyzed fat contents of the three diets were 1.7, 7.3, and 7.4%. The analyzed linoleic acid contents were .8, 1.4, and 4.2%. On days 21 and 29 of the study, 6 of the 12 sets of littermate pigs in each trial were administered subcutaneously 50 μg/kg bodyweight of the bacterial endotoxin, lipopolysaccharide (LPS), dissolved in saline. LPS administration results in a short-term, acute level of immune system activation. The magnitude and duration of the response to LPS differed among dietary regimens between trials. Thus, the results of the two trials are reported separately. Prior to LPS administration, dietary fat additions (CWG or CO) resulted in faster daily gains in Trial 1 and improved gain:ME ratios in Trials 1 and 2. The responses to the two

fat sources were similar in both trials. During the period of acute antigen exposure, (day 0 to 4 post-LPS), daily weight gain and gain:ME ratios were similar among the three dietary regimens in both AE groups. Following partial antigen clearances from the body (day 4 to 8 post-LPS), dietary fat (either CWC or CO) additions resulted in faster daily gains in Trial 1 and improved gain:ME ratios in Trial 2 in both AE groups.

Based on these data, dietary fat calories support greater growth rate and efficiency of dietary ME utilization than a starch calorie in 6 to 27 kg pigs experiencing both moderate and high levels of antigen exposure.

Key words: Pigs, energy, fat, choice white grease, corn oil.

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 most efficiently when oxidized for support of maintenance functions. 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 will 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 lean 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) apparently results in greater cytokine production. Cytokines have 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 thus level of immune system activation.

OBJECTIVE

To evaluate the impact of level of antigen exposure (thus immune system activation) and dietary energy source on the rate and efficiency of body growth in pigs.

EXPERIMENTAL PROCEDURES

Experiment One

Treatments: The experimental treatments consisted of two levels of chronic antigen exposure (AE) and three dietary energy regimens. Pigs with a moderate and high level of AE were created by rearing animals via a segregated-early-weaning (SEW) and conventional weaning (CW) scheme, respectively. The SEW scheme consisted of administering Naxcel and Baytril to each pig at 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. 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 dietary energy regimens 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 dietary metabolizable energy (ME) content. The basal mixture consisted of a corn-soybean meal-whey-skim milk-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). The analyzed fatty acid composition of the three dietary energy regimens is shown in Table 2. 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 low IS pigs. Dietary concentrations of trace minerals and vitamins were provided at 300% of NRC (1988) estimated requirements for 5 to 10 kg pigs.

Procedures: All pigs were from a single genetic strain and geographical site of origin. Based on previous studies at our station, the pigs' lean tissue growth capacity from 20 to 110 kg body weight was 340 to 360 g per day. The herd of origin possessed serological titers for mycoplasma hyopneumoniae (MP), actinobacillus pluropneumonia (APP), porcine respiratory and reproductive syndrome (PRRS), transmissible gastroenteritis (TGE), and swine influenza (SIV).

Within each level of antigen exposure, ten 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 regimens. Pigs were penned individually on slotted floors in 0.6 x 1.2 meter pens in buildings maintained at 80-85°F. Pigs were allowed to consume feed and water ad libitum.

Pig weights and feed consumption were determined at four-day intervals until each animal reached a bodyweight of 27 kg. Pigs were bled at 6 (initiation of study) and 27 kg 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. Dietary energy source was considered the subplot. 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 2 kg increments of growth were analyzed as a repeated measure.

Results and Discussion: 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 (7 to 16 kg 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 27 kg 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 IS 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 AE.

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.

The analyzed dietary fat concentration and fatty acid composition of the three dietary energy regimens 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 6 to 27 kg 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 exposure 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 IS 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 5.8, 7.8, 9.8, 11.8, 13.8, 15.8, 17.8, 19.8, 21.8, 23.8, and 25.8 kg were analyzed (Figures 1 to 6). The moderate AE group gained 36, 61, 20, 16 and 18% faster than the high AE group during the initial five, 2 kg increments of weight gain (4.8 to 14.8 kg

bodyweight) 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 (20 to 27 kg), 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 6 to 27 kg pigs experiencing either a moderate or high level of AE activation.

Experiment Two ...

Treatments: The experimental treatments consisted of two levels of acute immune system activation and three dietary energy regimens. The experimental animals were reared via an SEW scheme in order to create animals that initially possessed a low level of antigen exposure and thus immune system activation. The low and high level of acute immune system activation were created, respectively, by administering subcutaneously either 0 or 50 μg/kg of bodyweight of lipopolysaccharide (LPS), E. coli serotype K-235 phenol extracted, dissolved in .9% NaCl. LPS is a component of the outer membrane of gram-negative bacteria. LPS administration results in a short-term release of cytokines. In turn, cytokines stimulate an acute activation of the immune system and an acute inhibition of voluntary feed intake and proteinaceous tissue growth.

The dietary energy regimens consisted of a starchy, low-fat basal diet, supplemented with 0% fat, 6% choice white grease, or 6% corn oil (Table 6). The basal diet consisted of a wheat-soybean meal-whey-skim milk-amino acid mixture fortified with minerals, vitamins, and an antioxidant. The three diets were analyzed to contain 1.7, 7.3, and 7.4% fat and .8, 1.4, and 4.2% linoleic acid (Table 7). Wheat was used in the basal diet because of its low fat (1.8 vs 4.0%) and low linoleic acid (.6 vs 2.2%) contents relative to corn. The diets were formulated to meet or exceed the lysine, phosphorous, and essential fatty acid (linoleic acid) needs of the low IS pigs. Trace minerals and vitamins were provided at concentrations equivalent to 300% of NRC (1988) estimates for 5 to 10 kg pigs.

Procedures: All pigs were obtained from a single genetic strain and source of origin. Based on previous studies, the pigs' capacity for lean tissue growth from 20 to 110 kg bodyweight was 340 to 370 g per day. The herd of origin possessed serological titers for mycoplasma hyopneumoniae (MP), actinobacillus pleuropneumoniae (APP), porcine reproductive and respiratory syndrome (PRRS), transmissible gastroenteritis (TGE) and swine influenza virus (SIV). All pigs were reared via an SEW scheme to minimize the pigs' initial exposure to

antigens and thus level of immune system activation. Pigs were individually penned on slotted floors in 0.6 x 1.2 m pens in an environmentally regulated building maintained at 80-85°F. Pigs were allowed to consume feed and water ad libitum.

Two trials were conducted. In each trial, twelve set of three littermates were used. Within each littermate set, the three pigs were randomly allotted to one of three dietary energy regimens. On day 21 of the test, six of the twelve littermate sets were administered subcutaneously 50 μg LPS/kg of bodyweight to create an acute activation of the pigs' immune system. Each of the six littermate sets were administered a second dose of LPS eight days later. Each pig remained on its respective diet for 16 days following the initial LPS administration.

Pig weights and feed consumption were determined at 7-day intervals prior to LPS administration and at 4-day intervals for 16 days after LPS administration. Immune status of the pigs was estimated via quantification of the acute phase protein, alpha-1 acid glycoprotein, at 0, .25, 1, and 4 days after each LPS administration in Trial 2 (Table 10) but not Trial 1. Serological titers for prevalent antigens in the herd of origin also were determined at the initiation and completion of Trial 2. These pigs were found to be free of antibody titers for MP, APP, and PRRS but possessed antibody titers for SIV and TGE at the initiation and completion of the study.

Data were analyzed by variance techniques using the General Linear Model procedure of SAS (1995). Data were analyzed as a split-plot design with IS status considered the whole plot and dietary energy regiment the subplot. The pig was considered the experimental unit. Orthogonal comparisons were made to determine the responses of pigs to low versus high dietary fat concentration (1.7 vs 7.3%) and dietary fat sources containing a low versus high dietary linoleic acid concentrations (1.4 vs 4.2%).

Results and Discussion: Pigs were self-fed their respective experimental diets for a 21-day period prior to immune challenge with LPS. This feeding period was required to allow the dietary fatty acids to be incorporated into the pig's membrane lipids. Upon immune challenge, these membrane lipids are mobilized and potentially contribute indirectly to cytokine production. Linoleic acid (N-6) in membranes can serve as a precursor for prostaglandin production, which stimulates cytokine release. Cytokine release further enhances greater immune system activity but also inhibits voluntary feed intake and tissue growth due to the inhibitory effect of cytokines on anabolic hormones such as IGF-I and somatotropin.

Prior to LPS administration (day 0 to 21 of study, 6 to 14 kg bodyweight), dietary inclusion of 6% fat (either CWC or CO) resulted in faster body weight gains in Trial 1 and greater gain:ME ratios in both Trials 1 and 2 (Table 8).

The response to LPS administration among the three dietary energy regimens differed between trials. Thus, the results of each trial were analyzed separately. LPS administration depressed daily gain and gain:ME ratios to a greater degree and for a longer duration in Trial 1 than that observed in Trial 2 (Figure 7). These data would indicate that pigs in Trial 1 experienced a more acute antigen exposure and thus immune system activation than in Trial 2. The failure of LPS to

depress ME intake in Trial 1 was unexpected. The authors do not have an explanation for this response.

Because LPS induces an acute, short-term (1 to 3 day) response followed by a rapid recovery, the trials were designed to analyze the response of pigs during the initial 4 day period immediately following LPS administration and the four day recovery period after LPS administration.

During the initial post-LPS periods (the initial 4-day periods after LPS administration) dietary additions of fat (either CWG or CO) did not alter daily ME intake, weight gain or gain:ME ratios in either IS group (Table 9). During the 4-day recovery period after LPS administration, during which the LPS should be largely cleared from the body and thus immune system activation minimized, dietary addition of fat (either CWC or CO) resulted in faster daily gains in Trial 1 and improved gain in ME ratios in both Trials 1 and 2.

Based on these data, dietary additions of fat to a low fat diet improves daily weight gain and gain:ME ratios in low IS activated pigs. The growth response of pigs experiencing acute AE and thus immune system activation was not altered by dietary fat additions of a low or high linoleic acid fat source.

CONCLUSION

The growth response and thus economic value of a calorie of metabolizable energy derived from fat is greater than a calorie derived from starch both in pigs experiencing a moderate or high level of antigen exposure. The growth responses of pigs to dietary fats containing a low or high linoleic acid content did not differ significantly in pigs experiencing a moderate or high level of antigen exposure.

Table 1. Composition of Experimental Diets

Item	Dietary Energy Regimen		
	Starch	CWC	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/kg	3.21	3.40	3.39
% from basal mixture	85	85	85
% from suppl. calorie 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 kg of diet (.61% inclusion rate): biotin, .03 mg; choline, 507 mg; folacin, .18 mg; niacin, 47.6 mg; pantothenic acid, 27.0 mg; riboflavin, 10.2 mg; pyridoxine, .87 mg; thiamin, .59 mg; vitamin B_{12}, 53.9 μg; vitamin E, 39.2 IU; vitamin A, 4661 IU; vitamin D, 1165 IU; vitamin K, 1.59 mg; Cu, 18.5 mg; Fe, 185.0 mg; Mn 63.4 mg; Se, .32 mg; Zn, 159.6 mg; I, .21 mg.

[b]International Ingredients, Inc., St. Louis, Missouri.

[c]National By-Products, Inc., Des Moines, Iowa. (Analyses in Appendix Table 1).

[d]Archer Daniel Midlands, Decatur, Illinois. (Analysis in Appendix Table 1).

Table 2. Analyzed Dietary Fat Compositions[a]

Item	Dietary Energy Regimen		
	Starch	CWC	CO
Dietary fat, %	1.59	8.01	8.39
Dietary fatty acids, %			
C10:0	.021	.030	.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	.011
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.

Table 3. Serum Alpha-1 Acid Glycoprotein (AGP) Concentrations

Item	AE	Pig Weight 6.1	Pig Weight 27.3
Acute phase protein			
AGP, μg/ml[a]	Mod	710	452
	High	714	521

[a]AE effect, $P < .05$ at 27.3 kg.

Table 4. Pig Growth and Dietary Energy Utilization Response

Item	AE	Dietary Energy Regimen: Starch	CWC	CO
No. of pens[a]	Mod	9	9	9
	High	9	9	6
Pig weight, kg				
Initial	Mod	5.9	5.8	5.9
	High	6.3	6.5	6.9
Final	Mod	27.5	27.6	27.8
	High	26.8	27.1	27.4
Growth and energy utilization				
Daily ME, Mcal[bc]	Mod	2.87	2.72	2.69
	High	2.32	2.32	2.16
Daily gain, g[bc]	Mod	514	529	536
	High	413	435	454
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]CWC vs CO effect, $P<.10$.

Table 5. Analysis of Variance (Probabilities) of Response of Pigs to Antigen Exposure (AE), Dietary Starch vs Fat Calories (DC1), Dietary CWC vs CO (DC2), and Pig Weight (PW) (Refer to Figures 1-6)

	Source of Variation					
Item	PW	AE x PW	DC1 x PW	DC2 x PW	AE x DC1 x PW	AE x DC2 x PW
Daily ME, Mcal	.01	.14	.20	.75	.72	.78
Daily gain, g	.01	.59	.98	.24	.83	.16
Gain:ME, g/Mcal	.01	.14	.89	.12	.69	.55

Table 6. Composition of Experimental Diets

Item	Dietary Energy Regimen		
	Basal	CWG	CO
Wheat	29.27	22.71	22.71
Choice white grease[a]	-	6.00	-
Corn oil[b]	-	-	6.00
Soybean meal, dehulled	42.69	43.20	43.20
Whey, dried	20.00	20.00	20.00
Skim milk, dried	5.00	5.00	5.00
Dicalcium phosphate	1.27	1.38	1.38
Limestone	.69	.63	.63
D,L-methionine	.18	.18	.18
Salt	.25	.25	.25
Trace mineral-vitamin mix[c]	.55	.55	.55
Santoquin	.10	.10	.10
Total	100.00	100.00	100.00
Calculated composition			
ME, Mcal/kg	3.21	3.47	3.46
Fat, %	1.07	6.97	6.97
Protein, %	28.30	27.80	27.80
Lysine, %	1.70	1.70	1.70
Available P, %	.52	.53	.53

[a]National By-Products, Inc., Des Moines, Iowa (Analyses in Appendix Table 1).
[b]Archer Daniel Midlands, Decatur, Illinois (Analyses in Appendix Table 1).
[c]Supplied the following per kg of diet: biotin, .03 mg; choline, 480.0 mg; folacin, .17 mg; niacin, 45.1 mg; pantothenic acid, 25.6 mg; riboflavin, 9.6 mg; pyridoxine, .82 mg; thiamin, .56 mg; vitamin B_{12}, 110 μg; vitamin E, 37.1 IU; vitamin A, 4409 IU; vitamin K, 1.5 mg; Cu, 13.1 mg; Fe, 131.3 mg; Mn 45 mg; Se, .24 mg; Zn, 112.5 mg.

Table 7. Analyzed Dietary Fat Composition[a]

Item	Dietary Energy Regimen		
	Starch	CWC	CO
Dietary fat, %	1.68	7.33	7.38
Dietary fatty acids, %			
C10:0	.022	.027	.027
C12:0	.008	.014	.014
C14:0	.035	.111	.041
C14:1	.006	.006	.006
C16:0	.297	1.665	.885
C16:1	.006	.174	.012
C17:0	.005	.029	.006
C17:1	<.005	.018	.006
C18:0	.071	.817	.108
C18:1	.288	2.797	1.771
C18:2	.815	1.408	4.240
C18:3	.107	.124	.154
C20:0	<.005	.017	.024
C20:1	<.008	.080	.026
C20:2	<.005	.041	.011
C20:3	<.005	.006	.011
C20:4	<.005	.023	.011
C22:0	.007	.007	.013
Dietary unsaturated-saturated fatty acids			
Unsaturated (U), %	1.23	4.64	6.26
Saturated (S), %	.45	2.69	1.12
U:S	2.73	1.73	5.61

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

Table 8. Pig Growth and Dietary Energy Utilization -- Pre-LPS Administration

	LPS, μg/kg	Dietary Energy Regimen					
		Trial 1			Trial 2		
		Basal	CWC	CO	Basal	CWC	CO
No. of Pens[a]	0	6	6	6	5	6	6
	50	5	6	6	6	6	6
Pig weight, kg							
Initial	0	6.36	6.34	6.27	6.25	6.13	5.81
	50	6.26	6.36	6.17	5.35	5.63	5.73
Day 21	0	14.21	14.93	13.99	13.84	13.36	13.20
	50	12.69	15.13	14.34	12.87	13.39	14.27
Pre-LPS, d 0 to 21							
Daily ME, Mcal	0	1.95	1.93	1.88	1.60	1.45	1.46
	50	1.97	1.96	1.90	1.68	1.57	1.65
Daily gain, g[b]	0	374	409	368	361	344	352
	50	319	418	389	358	370	407
Gain:ME, g/Mcal[c]	0	197	214	199	225	237	241
	50	166	216	208	219	240	248

[a]Pigs penned individually.
[b]Basal vs CWC and CO effect, P<.07 in Trial 1.
[c]Basal vs CWC and CO effect, P<.05 in Trials 1 and 2.

Table 9. Pig Growth and Dietary Energy Utilization -- Post-LPS Administration

	LPS, μg/kg	Dietary Energy Regimen					
		Trial 1			Trial 2		
		Basal	CWC	CO	Basal	CWC	CO
Pig weight, kg							
Day 0	0	14.21	14.93	13.99	13.84	13.36	13.20
	50	12.69	15.13	14.34	12.87	13.39	14.27
Day 16	0	25.21	26.73	25.56	26.27	24.65	24.60
	50	18.75	22.35	21.50	23.01	23.53	24.44
Post-LPS, d 0 to 4 after the two LPS administrations							
Daily ME, Mcal[a]	0	3.02	3.32	3.06	3.27	3.15	3.33
	50	2.94	3.44	2.98	2.81	2.79	2.51
Daily gain, g[b]	0	680	708	689	638	633	680
	50	287	365	287	521	457	495
Gain:ME, g/Mcal[c]	0	228	214	228	197	203	206
	50	101	107	97	188	165	209
Post-LPS, d 4 to 8 after the two LPS administrations							
Daily ME, Mcal	0	3.87	4.07	3.71	4.28	3.92	3.96
	50	3.88	4.09	3.59	3.98	3.81	3.78
Daily gain, g[cd]	0	694	767	757	763	779	745
	50	427	537	607	746	810	777
Gain:ME, g/Mcal[cef]	0	185	188	207	182	201	190
	50	110	133	169	188	213	208

[a]LPS effect, P<.02 in Trial 2.
[b]LPS effect, P<.01 in Trials 1 and 2.
[c]LPS effect, P<.01 in Trial 1.
[d]Basal vs CWC and CO effect, P<.01 in Trial 1.
[e]Basal vs CWC and CO effect, P<.01 in Trials 1 and 2.
[f]CWC vs CO effect, P<.01 in Trial 1.

Table 10. Serum Alpha-1 Acid Glycoprotein Concentrations (Trial 2 only)

	LPS, μg/kg	Dietary Energy Regimen		
		Basal	CWC	CO
Post-LPS, days after the two LPS administrations				
0	0	610	618	563
.25		570	542	495
1		650	578	564
4		593	575	502
0	50	645	568	580
.25		674	503	496
1		692	534	546
4		664	496	547

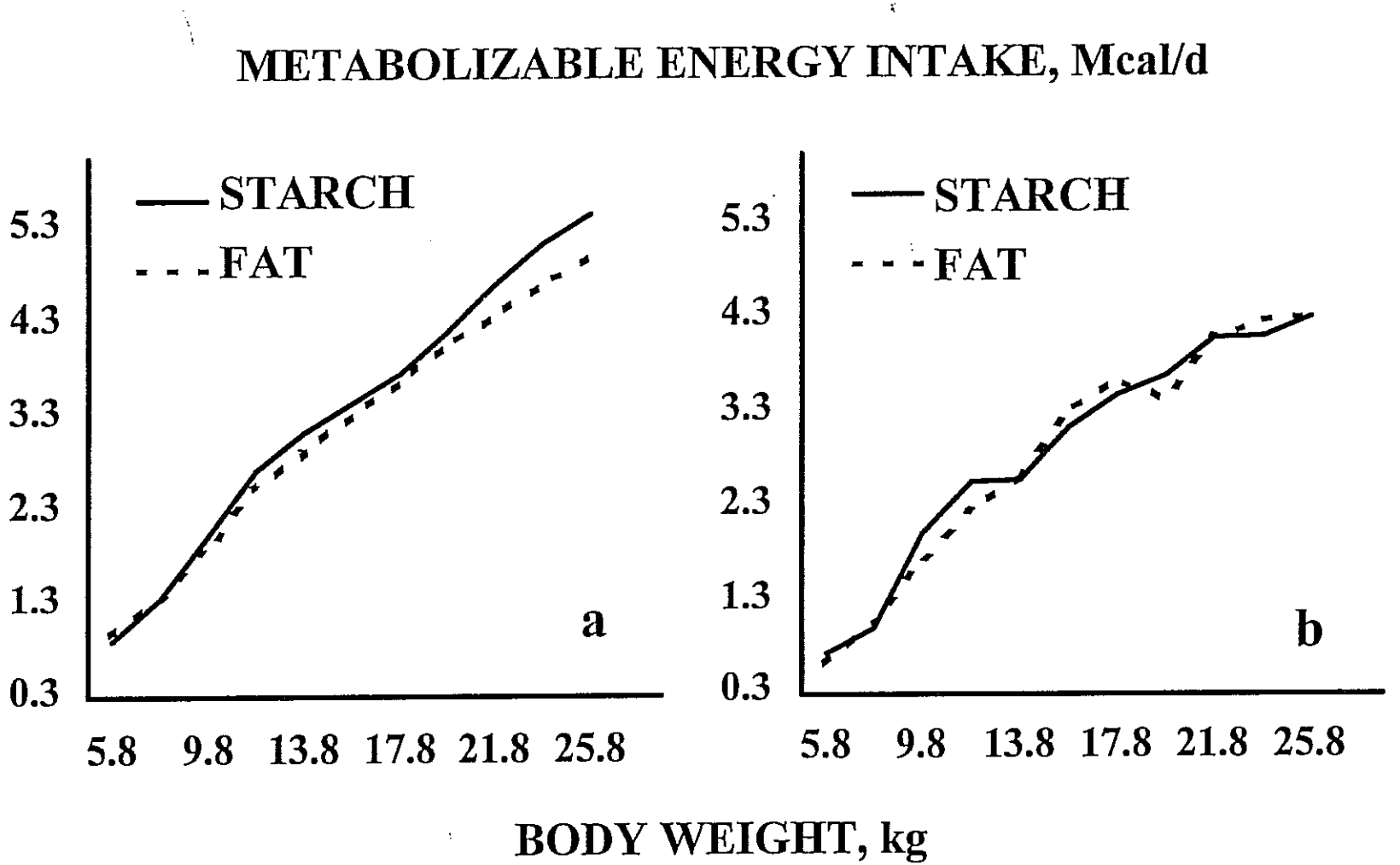

Figure 1. Metabolizable energy (ME) intake in (a) moderate and (b) high antigen-exposed (AE) pigs. Moderate and high AE pigs were reared via SEW or conventional schemes, respectively, and allowed ad libitum access to one of three dietary energy regimens from 6 to 27 kg BW. Within each energy regimen, 85% of ME was provided by a basal mixture of ingredients and 15% of ME was provided by supplemental starch, choice white grease or corn oil. AE effect ($P < .01$); Starch vs fat effect ($P < .03$); Pig weight effect ($P < .01$).

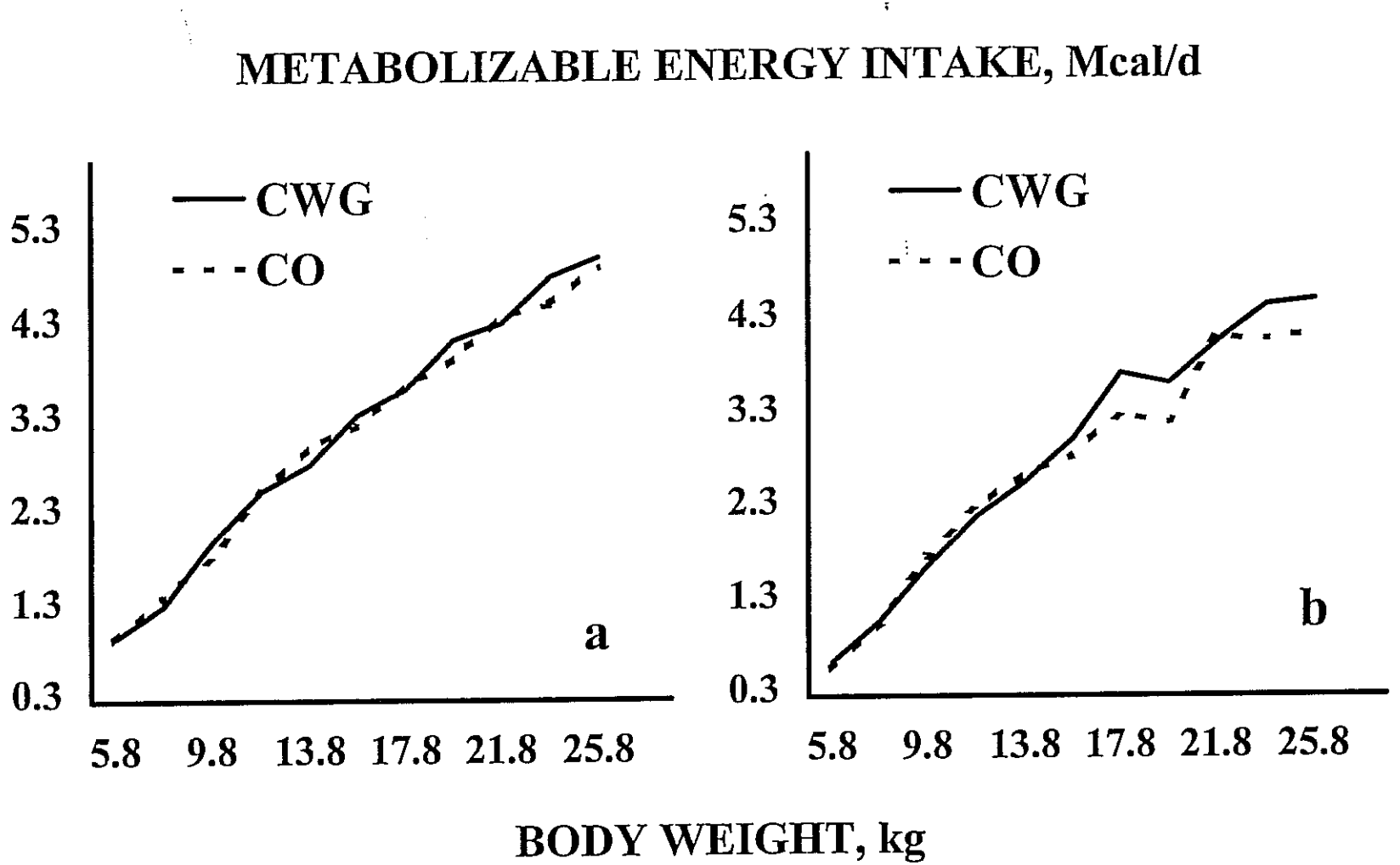

Figure 2. Metabolizable energy (ME) intake in (a) moderate and (b) high antigen-exposed (AE) pigs. Moderate and high AE pigs were reared via SEW or conventional schemes, respectively, and allowed ad libitum access to one of three dietary energy regimens from 6 to 27 kg BW. Within each energy regimen, 85% of ME was provided by a basal mixture of ingredients and 15% of ME was provided by supplemental starch, choice white grease or corn oil. AE effect ($P < .01$); Pig weight effect ($P < .01$).

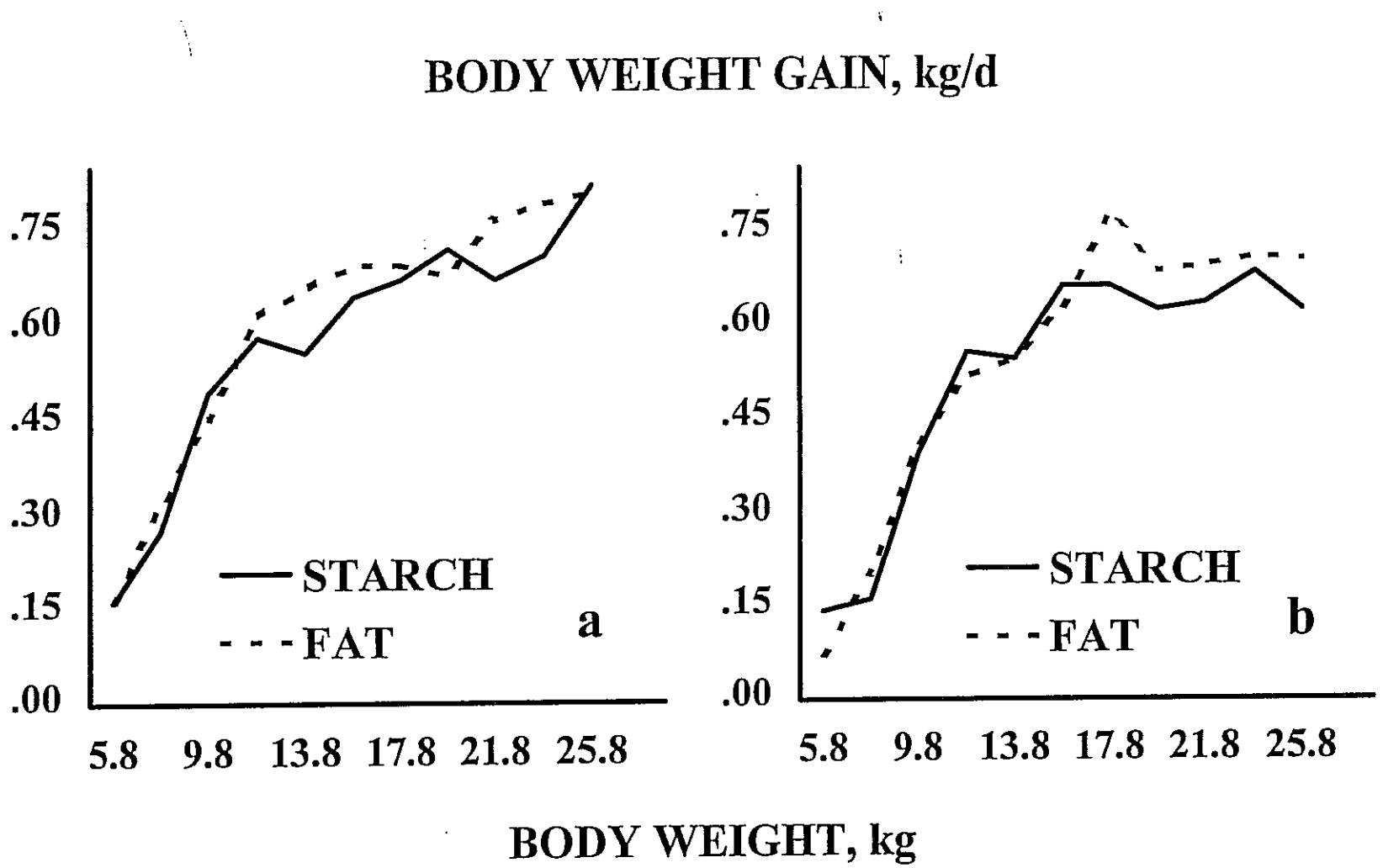

Figure 3. Body weight (BW) gain in (a) moderate and (b) high antigen-exposed (AE) pigs. Moderate and high AE pigs were reared via SEW or conventional schemes, respectively, and allowed ad libitum access to one of three dietary energy regimens from 6 to 27 kg BW. Within each energy regimen, 85% of ME was provided by a basal mixture of ingredients and 15% of ME was provided by supplemental starch, choice white grease or corn oil. AE efect ($P < .01$); Starch vs fat effect ($P < .02$); Pig weight effect ($P < .01$).

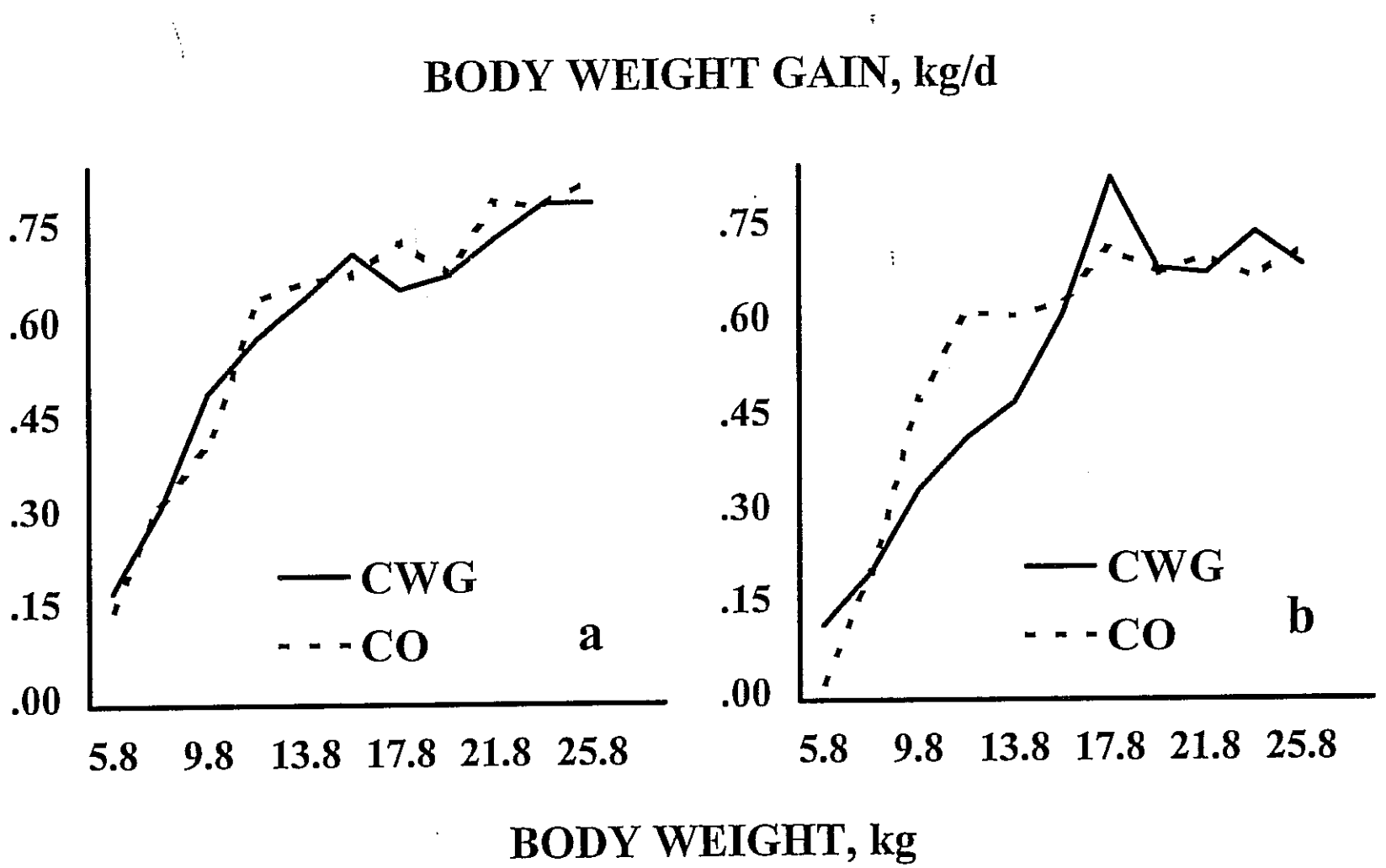

Figure 4. Body weight (BW) gain in (a) moderate and (b) high antigen-exposed (AE) pigs. Moderate and high AE pigs were reared via SEW or conventional schemes, respectively, and allowed ad libitum access to one of three dietary energy regimens from 6 to 27 kg BW. Within each energy regimen, 85% of ME was provided by a basal mixture of ingredients and 15% of ME was provided by supplemental starch, choice white grease or corn oil. AE effect ($P < .01$); Pig weight effect ($P < .01$).

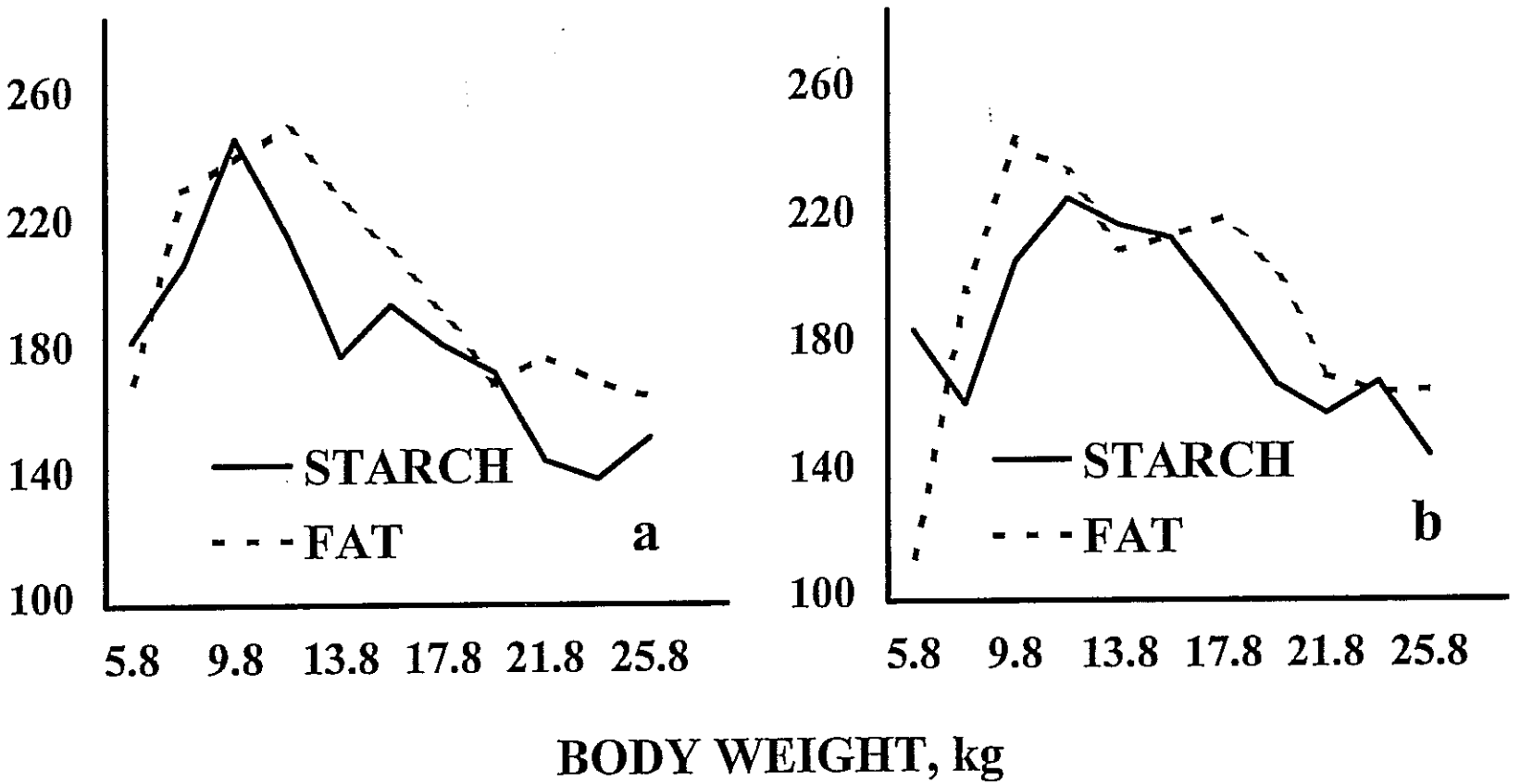

Figure 5. Body weight (BW) gain in (a) moderate and (b) high antigen-exposed (AE) pigs. Moderate and high AE pigs were reared via SEW or conventional schemes, respectively, and allowed ad libitum access to one of three dietary energy regimens from 6 to 27 kg BW. Within each energy regimen, 85% of ME was provided by a basal mixture of ingredients and 15% of ME was provided by supplemental starch, choice white grease or corn oil. Starch vs fat effect ($P < .01$); Pig weight effect ($P < .01$).

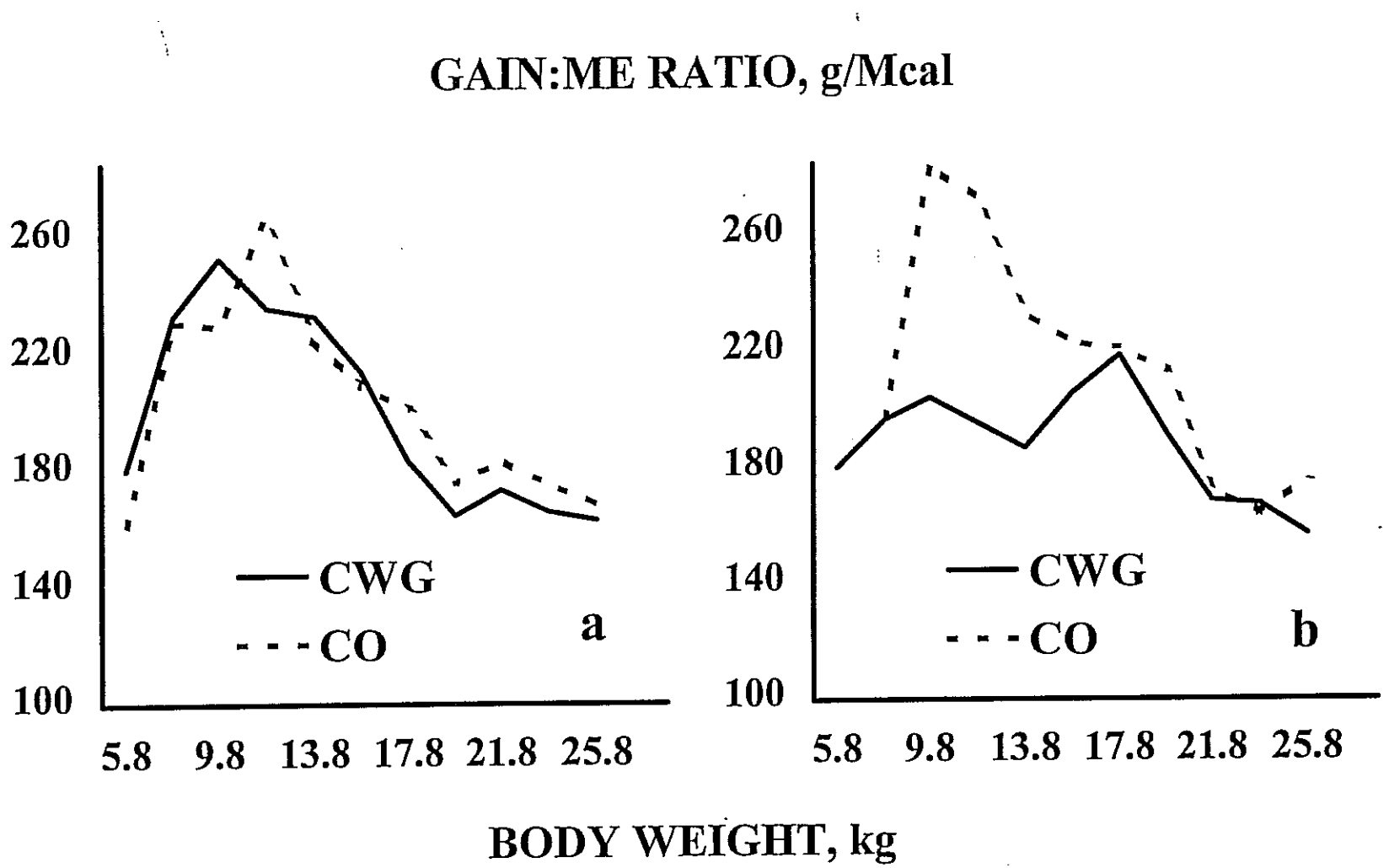

Figure 6. Body weight (BW) gain in (a) moderate and (b) high antigen-exposed (AE) pigs. Moderate and high AE pigs were reared via SEW or conventional schemes, respectively, and allowed ad libitum access to one of three dietary energy regimens from 6 to 27 kg BW. Within each energy regimen, 85% of ME was provided by a basal mixture of ingredients and 15% of ME was provided by supplemental starch, choice white grease or corn oil. Pig weight effect ($P < .01$).

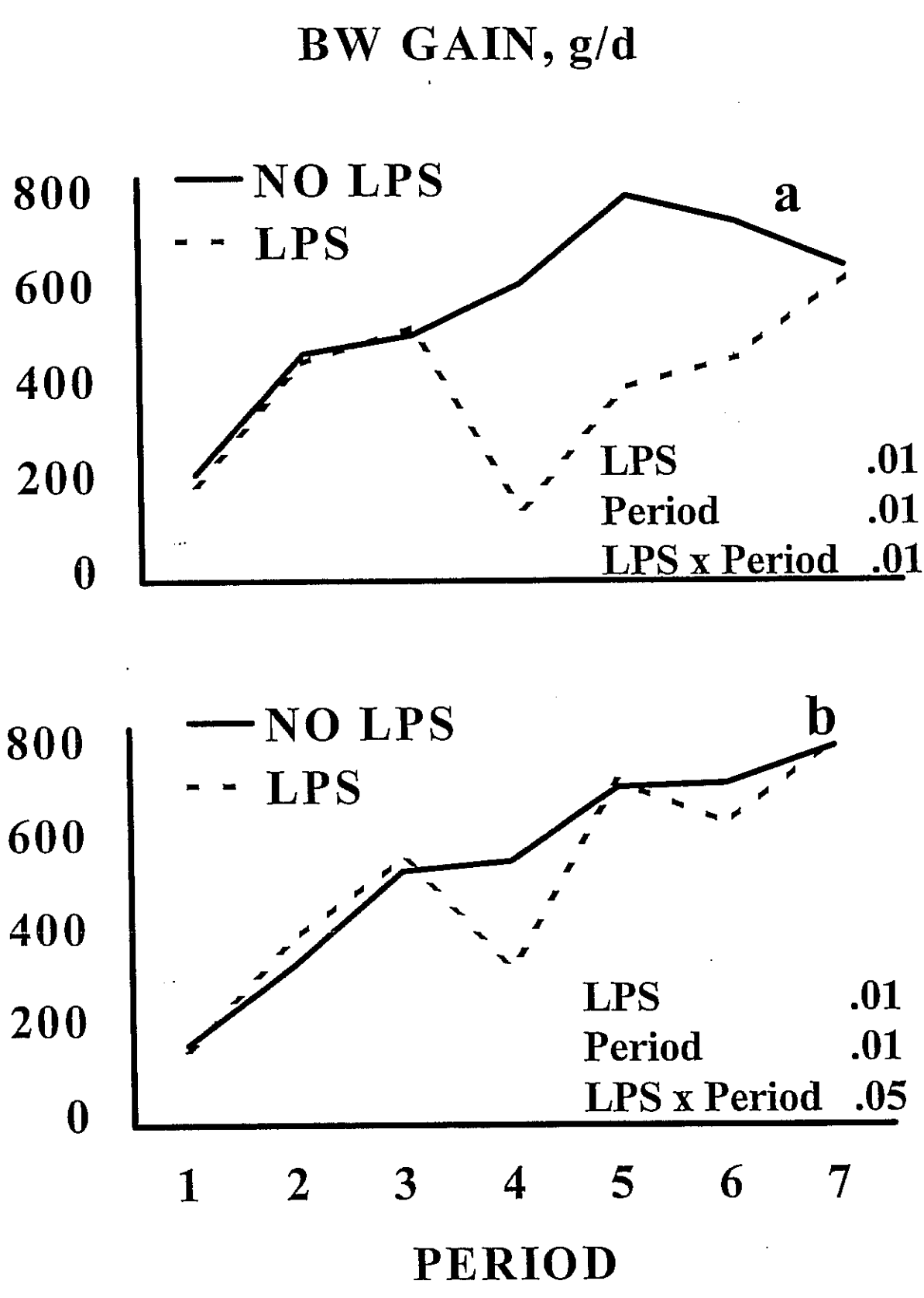

Figure 7. a) Impact of LPS BW gain in trial 1. b) Impact of LPS on BW gain in trial 2.

APPENDIX

TABLE 1. Fatty acid composition of fat

	Fat Source	
Fatty acid	**CWG**	**CO**
10:0	< 0.1	< 0.1
12:0	< 0.1	< 0.1
14:0	1.3	< 0.1
16:0	23.1	10.1
16:1	2.8	0.1
17:0	0.4	< 0.1
17:1	0.3	< 0.1
18:0	12.5	1.8
18:1	42.1	25.0
18:2	10.7	57.9
18:3	0.4	0.9
20:0	0.2	0.4
20:1	1.2	0.3
20:2	0.6	< 0.1
20:4	.3	< 0.1
22:0	< 0.1	0.1
Unsaturated	12.4	58.4
Saturated	84.2	37.5
Total Fat %	96.6	95.9

[a]Analyses performed by Hazelton Laboratories, Madison, Wisconsin. Data are expressed as a percentage of total fat.

ACKNOWLEDGEMENT

Appreciation expressed to National By-Products, Inc., Des Moines, Iowa, for providing the choice white grease used in these studies.

CITATION

BIBLIOGRAPHY

Johnson, R., and E. von Borell. 1993. Lipopolysaccharide induced sickness behavior in pigs is inhibited by pretreatment with indomethicin. Iowa State University Swine Research Report, p. 55.

Kelly, D. S., G. J. Nelson, C. M. Serrato, D. C. Schmidt, and L. B. Branch. 1988. *J. Nutr.* 118:1376-1384.

Kiser, R. H., J. C. Pennistion, J. G. McGann, J. Kaplan, W. H. Alder, M. D. Kastello, and W. R. Beigel. 1973. *Infect. Immun.* 8:105-109.

NRC, 1988. Nutrient Requirements of Swine. National Academy of Science, 2101 Constitution Avenue, Washington, D.C.

Stahly, T.S. 1984. Use of fats in diets for growing pigs: In Fats in Animal Nutrition, Butterworths Publishing, London, 313-332.

Williams, N. H., T. S. Stahly, and D. R. Zimmerman. 1994. Impact of immune system activation and dietary amino acid regimen of pigs on growth and carcass characteristics of 6-114 kg pigs. *J. Anim. Sci.* 72 (Suppl. 2):57.