Kansas Agricultural Experiment Station Research Reports

Volume 0
Issue 10 *Swine Day (1968-2014)*

Article 1316

1997

Swine Day 1996

Kansas Agricultural Experiment Station

Recommended Citation

Kansas Agricultural Experiment Station (1997) "Swine Day 1996," *Kansas Agricultural Experiment Station Research Reports*: Vol. 0: Iss. 10. https://doi.org/10.4148/2378-5977.7220

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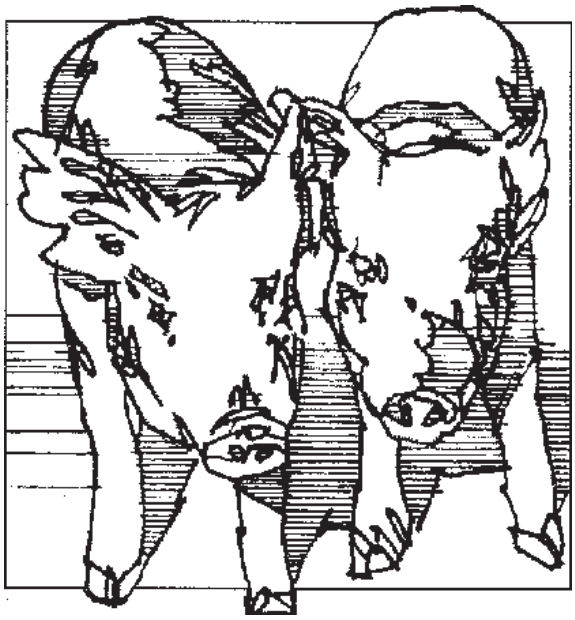

KANSAS
STATE
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SWINE DAY 1996

REPORT OF PROGRESS 772, AGRICULTURAL EXPERIMENT STATION, MARC A. JOHNSON, DIRECTOR

FOREWORD

It is with great pleasure that we present to you the 1996 Swine Industry Day Report of Progress. This report contains updates and summaries of applied and basic research conducted at Kansas State University during the past year. We hope that the information will be of benefit, as we attempt to meet the needs of the Kansas swine industry.

Editors, 1996 Swine Day Report of Progress,

Bob Goodband Mike Tokach Steve Dritz

ABBREVIATIONS USED IN THIS REPORT

ADG	=	average daily gain	g	=	gram(s)	ml	=	cc (cubic centimeters)
ADFI	=	average daily feed intake	gal	=	gallon(s)	mo	=	month(s)
			GE	=	gross energy	μg	=	microgram(s)
avg	=	average	h	=	hour(s)		=	.001 mg
BW	=	body weight	in	=	inch(es)	N	=	nitrogen
cm	=	centimeter(s)	IU	=	international unit(s)	ng	=	nanogram(s)
CP	=	crude protein					=	.001 μg
CV	=	coefficient of variation	kg	=	kilogram(s)	no.	=	number
			Kcal	=	kilocalorie(s)	ppm	=	parts per million
cwt	=	100 lb	lb	=	pound(s)	sec	=	second(s)
d	=	day(s)	Mcal	=	megacalorie(s)	wk	=	week(s)
DM	=	dry matter	ME	=	metabolizable energy	wt	=	weight(s)
°F	=	Fahrenheit						
F/G	=	feed efficiency	mEq	=	milliequivalent(s)	yr	=	year(s)
ft	=	foot(feet)	min	=	minute(s)			
ft^2	=	square foot(feet)	mg	=	milligram(s)			

KSU VITAMIN AND TRACE MINERAL PREMIXES

Diets listed in this report contain the following vitamin and trace mineral premixes unless otherwise specified.

Trace mineral premix: each lb of premix contains 12 g Mn, 50 g Fe, 50 g Zn, 5 g Cu, 90 mg I, and 90 mg Se.

Vitamin premix: each lb of premix contains vitamin A, 2,000,000 IU; vitamin D_3, 200,000 IU; vitamin E, 8,000 IU; menadione, 800 mg; riboflavin, 1,500 mg; pantothenic acid, 5,200 mg; niacin, 9,000 mg; choline, 30,000 mg; and vitamin B_{12}, 6 mg.

Sow add pack: each lb of premix contains choline, 70,000 mg; biotin, 40 mg; and folic acid, 300 mg.

NOTICE

Trade names are used to identify products. No endorsement is intended, nor is any criticism implied of similar products not named.

Some of the research reported here was carried out under special FDA clearances that apply only to investigational uses at approved research institutions. Materials that require FDA clearances may be used in the field only at the levels and for the use specified in that clearance.

DEDICATED TO DR. DAVID A. SCHONEWEIS

The 1996 Swine Industry Day is dedicated to Dr. David A. Schoneweis, a swine veterinarian known to nearly everyone associated with the swine industry in Kansas.

Dave was born on May 8, 1931 in Clay Center, Kansas and he grew up nearby on a livestock and grain farm. Dr. Schoneweis was trained at Kansas State University, earning his BS, DVM, and MS degrees in 1956, 1956, and 1971, respectively. Following graduation in 1956, Dave practiced for a few months and then entered the U.S. Army in October 1956. After two years of service at Fort Snelling, MN, he joined the faculty at Oklahoma State University, where he developed his specialization in swine medicine. After 6 years at Oklahoma State, he accepted an appointment in the College of Veterinary Medicine at Kansas State University, where he served as Professor of Food Animal Medicine.

For veterinary students, Dave has been an important mentor both as a veterinarian and as a person. In the classroom and on farm visits, Dave always explained the medicine and told a story to put the case in context. A former student says that Dave Schoneweis " is the most unselfish teacher I ever had. He'd lie down in front of a train to protect and defend a student and he was always unswerving in the standards of care he set for animals. Dave Schoneweis is a man who didn't recognize the term 'situational ethics'. He always held to the high road."

The Department of Animal Sciences and Industry has benefited greatly from Dave's expertise. He frequently lectured to Animal Science classes and took a personal interest in the success of the KSU Swine Farm. At the university, he is known for doing the things that need to be done. His leadership made the "Birthing Center" at the Kansas State Fair a success. Nationally, he was a charter member of the American Association of Swine Practitioners and twice served as a director of that orgainization.

Dr. Schoneweis is widely known for his expertise in swine medicine and has been a regular contributor to Swine Day programs. He is an important resource for developing herd health programs for Kansas pork producers. He has combined his broad-based knowledge and practical approach with his desire to have his clients succeed. Dave's personal modesty and work ethic are traits widely appreciated by his colleagues and clients, and his career has left its mark on the swine industry of Kansas.

CONTENTS

BIOLOGICAL VARIABILITY AND CHANCES OF ERROR

Variability among individual animals in an experiment leads to problems in interpreting the results. Animals on treatment X may have higher average daily gains than those on treatment Y, but variability within treatments may indicate that the differences in production between X and Y were not the result of the treatment alone. Statistical analysis allows us to calculate the probability that such differences are from treatment rather than from chance.

In some of the articles herein, you will see the notation "P<.05." That means the probability of the differences resulting from chance is less than 5%. If two averages are said to be "significantly different," the probability is less than 5% that the difference is from chance or the probability exceeds 95% that the difference resulted from the treatments applied.

Some papers report correlations or measures of the relationship between traits. The relationship may be positive (both traits tend to get larger or smaller together) or negative (as one trait gets larger, the other gets smaller). A perfect correlation is one (+1 or -1). If there is no relationship, the correlation is zero.

In other papers, you may see an average given as 2.5 ± .1. The 2.5 is the average; .1 is the "standard error." The standard error is calculated to be 68% certain that the real average (with unlimited number of animals) would fall within one standard error from the average, in this case between 2.4 and 2.6.

Many animals per treatment, replicating treatments several times, and using uniform animals increase the probability of finding real differences when they exist. Statistical analysis allows more valid interpretation of the results, regardless of the number of animals. In all the research reported herein, statistical analyses are included to increase the confidence you can place in the results.

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INCREASING VALINE, ISOLEUCINE, AND TOTAL BRANCHED CHAIN AMINO ACIDS FOR THE LACTATING SOW[1]

B. T. Richert, R. D. Goodband, M. D. Tokach, and J. L. Nelssen

Summary

One hundred eighty-five sows were used to evaluate effects of the interrelationship between isoleucine and valine on sow and litter performance. Litter weight and weight gain at weaning increased as dietary valine, isoleucine, and total branched chain amino acids increased. Increasing dietary valine increased concentrations of milk DM and fat. Milk DM, CP, and fat increased as dietary isoleucine increased. Both valine and isoleucine increased litter weights. The independent increases in litter weaning weights from adding valine and isoleucine suggest separate modes of action in the lactating sow.

(Key Words: Valine, Isoleucine, Lactation, Sows.)

Introduction

The increasing productivity of the lactating sow is creating a need to review nutrient requirements for maximizing litter and sow performance. Until recently, branched chain amino acids received little attention in swine nutrition research. Research using mammary vein cannulation in sows and dairy cows has indicated that isoleucine and valine are taken up by the mammary gland in amounts 30 to 80% greater than their output in milk protein. These high extraction rates would result in requirements for these amino acids greater than the sum of milk amino acid output and the sow's maintenance requirement, which has been one of the methods used to estimate amino acid requirements of lactating sows. No research has evaluated the ability of the individual branched chain amino acids to spare each other in meeting the needs of the mammary gland for milk synthesis. Because the dietary requirement for total branched chain amino acids (TBCAA) has implications in practical diet formulation, the objectives of this experiment were to evaluate the effects of increasing valine at deficient isoleucine (.50%), increasing isoleucine at deficient (.72%) and adequate valine (1.07%), and increasing TBCAA in the diet as supplied by supplemental isoleucine and(or) valine on sow lactation performance, milk composition, and litter growth performance.

Procedures

Animals. One hundred eighty-five parity 1 (130) and parity 2 (55) sows from the Kansas State University Swine Teaching and Research farm were used in this experiment. All sows were maternal line (PIC Line C-15) bred to terminal line (PIC Line 326) boars. During gestation, sows were housed in outside dirt lots and fed in individual stalls. Gestating sows were fed 4 to 5 lb/d depending on body condition. The gestation diet was sorghum-soybean meal based formulated to .65% lysine, .90% Ca, and .80% P. On d 110 of gestation, all sows were fed 5 lb/d of the control diet (.50% isoleucine, .72% valine) until farrowing, at which time sows were allotted to one of the seven dietary treatments. Treatments were allotted randomly within groups of seven as sows farrowed to minimize variation in lactation length between treatments. Sows farrowed

[1]Appreciation is expressed to Lonza, Inc., Fair Lawn, NJ for assistance in this research project.

from November, 1994 through June, 1995. Three or four observations were made per treatment per lactation group, and seven lactation groups (blocks) were used. Litter size was equalized by 24 h after farrowing, and all sows began the study with at least 10 pigs.

Diet Formulation. The lactation diets (Table 1) were formulated to be in excess (at least 110% relative to lysine) of all amino acid requirement estimates based on ratios relative to lysine derived from NRC (1988) and ARC (1981), except for isoleucine and valine. All other nutrients were in excess of NRC (1988) requirement estimates. Diets were formulated to .90% lysine, .90% Ca, and .80% P. The control diet contained .50% isoleucine and .72% valine. Crystalline L-isoleucine and L-valine replaced cornstarch in the control diet at .35% increments to create the remaining six diets. The treatments included three levels of valine (.72, 1.07%, or 1.42%) and three levels of isoleucine (.50, .85, and 1.20%). The low and intermediate levels of valine were combined with all three levels of isoleucine, but the highest level of valine was combined only with the low level of isoleucine. This combination of treatments provided TBCAA levels of 2.6, 2.9, 3.3, and 3.6%.

Milk Criteria. Twelve sows per treatment (84 total) were milked manually on either d 17 or 18 of lactation. Sows were separated from their litters for a minimum of 45 min before milking. All sows were milked approximately 2 h after the initial morning feeding. Sows were restrained, and milk was collected from the first and last productive glands on both sides of the body. Each gland was milked until approximately 75 mL of milk was collected. Milk letdown was enhanced by infusing 10 IU of oxytocin into an ear vein of the sow. Samples from each gland were pooled for chemical analysis and stored at 2 to 4°C. All analyses were conducted within 48 h after collection.

Statistical Analysis. The GLM procedure of SAS was used to determine treatment effects. Litter size after cross-fostering was used as a covariate and lactation group as a blocking factor for all response criteria. Days of lactation was used as a covariate for litter weaning weights, litter weight gain, and sow backfat and BW changes from d 0 to weaning and for days to estrus. Initial sow weight and backfat thickness also were used as covariates for changes in these characteristics. Chi-square analysis was used to determine differences in distribution of days to estrus and percentage of sows returning to estrus. Preplanned nonorthogonal contrasts were used to test the effects of valine, isoleucine, and TBCAA. Contrasts were: main effects of valine, isoleucine and their interaction; linear and quadratic effects of increasing valine at deficient isoleucine; linear and quadratic effects of TBCAA; and valine vs isoleucine within a TBCAA level. Additional comparisons of linear and quadratic effects of increasing isoleucine at deficient and adequate valine were conducted to aid in evaluation of the isoleucine response.

Table 1. Diet Composition[a]

Ingredient	Percent
Corn	55.085
Hard red winter wheat	26.635
Soybean meal, (47% CP)	7.475
Spray-dried blood meal	1.428
Soybean oil	3.000
Monocalcium phosphate	2.354
Limestone	1.052
Salt	.500
Corn starch[b]	1.050
Sow add pack	.250
Vitamin premix	.250
Trace mineral premix	.150
L-lysine-HCl	.383
L-threonine	.220
DL-methionine	.113
L-tryptophan	.055
Total	100.0

[a]Basal diet was formulated to 13.6% CP, .90% lysine, .72% valine, .50% isoleucine, 1.35% leucine, .90% Ca, and .80% P.
[b]Corn starch was replaced in .35% increments with L-valine or L-isoleucine or both to provide the remaining six experimental diets.

Results

Valine. Dietary valine had no effect on number of pigs weaned ($\bar{x}$ = 10.9; Table 2) or survival rate after cross-fostering ($\bar{x}$ = 98.1%, data not shown). Increasing dietary valine from 44.7 to 64.7 g/d (.72 to 1.07%; Table 3), regardless of isoleucine level, increased litter weights and weight gains at d 14 and weaning ($P < .08$ and $P < .07$, respectively). Sow ADFI ($P < .08$) and lysine ($P < .08$) and isoleucine ($P < .05$) intakes were reduced when sows were fed 1.07% dietary valine compared to .72% valine (Table 3). Sow BW loss ($P < .02$) and backfat loss ($P < .0001$) increased with increasing valine from .72 to 1.07% across all three isoleucine levels. Increasing valine to 1.07% in the diet increased days to estrus by .5 d (Table 3; $P < .07$).

Increasing valine from .72 to 1.42% at .50% isoleucine (Table 2) tended to increase litter weights at d 14 and weaning (linear; $P < .10$ and .15, respectively) and increased litter weight gains at d 7 and 14 and weaning (linear; $P < .06$, .04, and .08, respectively). Sow ADFI and lysine and isoleucine intakes tended to decrease and then increase (quadratic; $P < .15$) as dietary valine was increased (Table 3) in diets containing .50% isoleucine. Valine intake increased (44.9, 64.2, and 87.9 g/d; linear, $P < .0001$) as dietary valine increased. As dietary valine increased from .72 to 1.42%, sow backfat loss increased (linear, $P < .04$; quadratic, $P < .13$); however, dietary valine had no effect on sow BW change or days to estrus ($P > .21$).

Isoleucine. Dietary isoleucine had no effect on number of pigs weaned or survival rate. Increasing isoleucine across valine levels resulted in increased litter weights (linear, $P < .07$) and weight gains (linear, $P < .06$) at d 7 and 14 and weaning (Table 2). Litter weaning weight increased (linear, $P < .06$) as isoleucine increased to 1.20% in the diet; however, the greatest increase (84% of the incremental gain) was observed at .85% dietary isoleucine. Increasing dietary isoleucine increased sow BW loss (Table 4; linear, $P < .01$) and tended (linear, $P < .14$) to increase sow backfat loss. Dietary isoleucine had no effect on sow feed intake ($P > .77$), but isoleucine intake (g/d) increased (linear, $P < .0001$) as isoleucine increased in the diet.

Total Branched Chain Amino Acids. Total branched chain amino acids increased litter weights and weight gains (Table 2) at d 7 and 14 and weaning (linear; $P < .07$, .03, and .02, respectively). The level of TBCAA in the diet did not affect ADFI ($P > .20$). However, TBCAA intakes increased (linear, $P < .0001$) and isoleucine and valine intakes increased (quadratic, $P < .0001$) as dietary TBCAA increased in the diet (Table 3). Increasing TBCAA in the diet resulted in increased sow BW and backfat losses (linear, $P < .001$).

Milk Composition. Milk composition was affected by dietary isoleucine, valine, and TBCAA levels (Table 4). The only milk criterion to be increased by increasing valine across isoleucine levels (Table 4) was the other N fraction ($P < .07$), which includes all other N besides whey and casein proteins (i.e., urea N, sloughed cellular N, and free amino acids). Increasing isoleucine across valine levels of .72 and 1.07% increased milk DM, CP, fat, and casein (linear, $P < .01$) and decreased whey (linear, $P < .06$) and other N fractions (linear, $P < .01$).

Increasing dietary valine from .72 to 1.42% at .50% isoleucine resulted in increased milk DM (linear, $P < .004$; quadratic, $P < .01$); lipid (linear, $P < .01$); and other N (quadratic, $P < .06$) and decreased lactose (linear, $P < .10$). Increasing isoleucine at either .72 or 1.07% valine increased milk DM (linear, $P < .05$), CP (linear, $P < .09$), and lipid (linear, $P < .04$). In addition, increasing dietary TBCAA increased milk DM (linear, $P < .002$), lipid (linear, $P < .005$), and casein protein fractions (linear, $P < .08$) and decreased the whey fraction (linear, $P < .10$).

Discussion

Increasing dietary valine from .72 to 1.07% across isoleucine levels resulted in a 4 lb increase in litter weight gain with no

interaction between valine and isoleucine levels. This suggests that the responses to valine and isoleucine for litter weaning weight are independent. In addition, litter weaning weight increased linearly up to 1.42% dietary valine (84 g/d).

Summarizing the results of this and previous experiments using high-producing sows on a g/d basis indicates a valine requirement between 70 and 80 g/d, which is double the requirement estimate (37 g/d) for lower-producing sows.

Previous research has suggested a total isoleucine requirement for the lactating sow of .39% (71% of lysine), with sows that were nursing nine pigs and had pig weight gains from d 7 to 21 of 5.25 lb. In comparison, in our experiment, an average of 10.9 pigs were weaned, and pig weight gain was 7.2 lb from d 7 to 20 of lactation for sows fed the .85% isoleucine and 1.07% valine diet. This corresponds to an isoleucine requirement of 94% of lysine, approximately .2% greater than the requirement estimated for the lactating sow by NRC (1988) and ARC (1981).

The data also suggest that a TBCAA requirement exists for the lactating sow. However, only isoleucine and valine were evaluated in this experiment, and leucine will need to be evaluated in future research. Litter weaning weight increased (linear, $P < .02$) through 3.6% TBCAA. However, the litter weaning weight at that level was matched at 3.3% dietary TBCAA, when the 3.3% level was provided by balanced levels of isoleucine (.85%), valine (1.07%), and leucine (1.35%) as compared to high levels of isoleucine or valine alone. This balanced combination of TBCAA provided numerically greater ($P < .16$) litter and pig growth performance than the other diets containing 3.3% TBCAA. Therefore, the TBCAA requirement is at least 3.3% (203 g/d) in the lactating sow diet when a balance of the branched chain amino acids are fed and is higher when an imbalanced branched chain amino acid profile is fed. Future research will need to delineate the possibilities of higher TBCAA inclusion levels and the role leucine has in milk production for sows with the genetic capacity for high milk production.

The lower percentage (74.3 vs 96.3%) of sows returning to estrus when fed higher levels of isoleucine (.85 and 1.20%) at the deficient valine level compared to the higher isoleucine levels at the intermediate valine level is difficult to explain. This response suggests that an altered hormonal or metabolite balance might occur when diets deficient in valine and high in isoleucine are fed. This may be indicative of an amino acid imbalance between the branched chain amino acids. An alternative explanation may be a chance occurrence because of the relatively low number of sows (24 to 28 per treatment) used for reproductive data.

Valine increased milk fat and DM concentrations, with minimal effect on total milk protein concentration and without altering the relative distribution of protein fractions. However, isoleucine increased milk DM, CP, and fat. Isoleucine also consistently increased the casein fraction of the milk protein and decreased the whey fractions. However, when the total whey excreted in the milk was calculated by multiplying the whey fraction percentage and the CP percentage together, very little difference existed between treatments in total whey output. This indicates that the whey proteins truly aren't affected by the isoleucine and(or) valine levels in the diet.

Increasing dietary valine or isoleucine also increased percentage fat in milk samples. However, increasing milk fat concentration alone does not always result in increased pig growth. Higher milk fat provides greater energy for the pig's growth, but this may be at the expense of other important nutrients or volume of milk produced.

The relative increase in the casein fraction and corresponding reduction in the whey fraction of the milk protein have not been reported before as a result of changing dietary amino acids. Because casein has a greater concentration of lysine as a percentage of protein than whey (8.1 vs 7.1%), milk with more casein may provide greater

amounts of the first limiting amino acid for growth (lysine), improving the milk's biological value for the pig. The increase in milk fat along with the alterations in ratios of casein and whey proteins by the high isoleucine treatments gave the milk much greater nutritional value and was likely one of the reasons for the increased pig growth observed for the increasing isoleucine levels. Valine did not alter the milk protein fractions, and so the possibility remains that increased dietary valine (and isoleucine) may have increased total milk volume output by the sow; however, this was not measured in our experiment.

In conclusion, the isoleucine requirement of the high-producing lactating sow may be higher than current NRC and ARC estimates but does not appear to be greater than 94% of lysine. The independent increases in litter weaning weights and changes in milk composition from added valine and isoleucine suggest separate modes of action for these animo acids in milk synthesis. The importance of valine and isoleucine for milk production must be considered when formulating diets for lactating sows.

Table 2. The Effects of Valine and Isoleucine on Litter Growth Performance[a]

	Valine, %:	.72			1.07			1.42	
	Isoleucine, %:	.50	.85	1.20	.50	.85	1.20	.50	
Item	TBCAA, %[b]:	2.57	2.92	3.27	2.92	3.27	3.62	3.27	CV
No. of sows		26	27	24	28	26	27	27	—
Mean parity		1.3	1.3	1.2	1.3	1.3	1.3	1.3	25.2
No. of pigs after fostering		11.1	11.0	11.1	11.1	11.0	11.2	11.0	5.6
No. pigs weaned[c]		10.9	10.8	11.0	10.8	10.8	10.8	10.9	3.9
Lactation length, d		20.0	20.8	20.5	20.2	20.4	19.7	20.3	9.5
Litter wt, lb									
Day 0		37.0	35.9	37.2	36.6	38.8	37.2	36.6	11.2
Day 7		65.0	64.6	67.5	64.8	69.2	67.9	67.5	11.3
Day 14		101.2	101.0	105.2	101.9	108.9	106.7	105.8	10.9
weaning[c]		139.7	136.0	139.3	136.7	144.4	143.1	140.4	11.3
Litter wt gain, lb									
Day 0 to 7		28.0	28.6	30.2	28.4	30.6	30.6	13.9	19.1
Day 0 to 14		64.2	65.0	67.9	65.5	70.3	69.4	31.4	14.4
Day 0 to weaning[c]		97.7	100.1	102.3	100.1	105.8	105.8	47.1	13.5

Statistical Analysis ($P <$)

	Main Effects				Valine at .50% Isoleucine[d]		TBCAA[e]	
		Isoleucine						
	Valine	Lin.	Quad.	Val × Ile	Lin.	Quad.	Lin.	Quad.
Mean parity	.83	.76	.93	.86	.91	.86	.99	.93
No. of pigs after fostering	.61	.95	.08	.69	.56	.71	.62	.16
No. of pigs weaned	.28	.89	.42	.44	.50	.39	.33	.33
Lactation length	.27	.91	.15	.35	.50	.91	.59	.05
Litter weights								
Day 0	.30	.56	.69	.11	.72	.66	.60	.67
Day 7	.17	.07	.64	.21	.22	.48	.07	.98
Day 14	.06	.05	.51	.20	.10	.56	.03	.95
weaning	.06	.07	.51	.57	.15	.83	.02	.99
Litter weight gain, lb								
Day 0 to 7	.29	.05	.79	.74	.06	.54	.04	.82
Day 0 to 14	.08	.04	.58	.49	.04	.62	.02	.82
Day 0 to weaning	.07	.06	.53	.86	.08	.93	.01	.89

[a]Litter size after fostering used as a covariate.
[b]Total branched chain amino acids (isoleucine + valine + leucine).
[c]Lactation length used as a covariate.
[d]Contrasting dietary valine levels of .72, 1.07, and 1.42% at .50% dietary isoleucine.
[e]Contrasting means of total branched chain amino acid levels 2.57, 2.92, 3.27, and 3.62%.

Table 3. The Effects of Valine and Isoleucine on Sow Feed Intake, BW and Backfat Changes, and Return to Estrus[a]

	Valine, %:	.72			1.07			1.42	
	Isoleucine, %:	.50	.85	1.20	.50	.85	1.20	.50	
Item	TBCAA, %[b]:	2.57	2.92	3.27	2.92	3.27	3.62	3.27	CV
Feed intake/d									
ADFI, lb		13.7	13.5	13.9	13.2	13.6	13.1	6.17	10.2
Lysine, g		56.0	55.0	56.7	54.0	55.6	53.5	55.7	10.2
Valine, g		44.9	44.0	45.1	64.2	66.3	63.6	87.9	10.9
Isoleucine, g		31.4	52.2	76.5	30.1	52.9	71.7	31.1	12.1
TBCAA, g		160.3	178.8	206.7	175.2	202.7	215.4	202.5	10.4
Sow BW, lb									
Day 0		390.2	388.7	396.2	379.2	384.5	388.9	386.0	6.9
Change[c]		5.2	5.3	.5	2.7	-1.1	7.9	2.5	919.7
Sow backfat, in									
Day 0		.71	.67	.64	.60	.59	.70	.63	19.8
Change[d]		.15	-.06	-.19	-.43	-.53	-.53	-.37	273.7
Days to estrus		4.5	5.0	4.5	5.1	5.0	5.1	4.7	23.9
Percentage in estrus[e]		88.5	77.8	70.8	78.6	100.0	92.6	85.2	—

Statistical Analysis ($P <$)

	Main Effects				Valine at .50% Isoleucine[f]		TBCAA[g]	
		Isoleucine						
	Valine	Lin.	Quad.	Val × Ile	Lin.	Quad.	Lin.	Quad.
Feed intake								
ADFI	.08	.92	.77	.22	.83	.15	.20	.58
Lysine	.08	.92	.77	.22	.83	.15	.20	.58
Valine	.0001	.88	.54	.31	.0001	.18	.0001	.0001
Isoleucine	.05	.0001	.89	.07	.83	.15	.0001	.0001
TBCAA	.0001	.0001	.72	.17	.0001	.16	.0001	.44
Sow BW								
Day 0	.08	.13	.64	.81	.62	.21	.95	.48
Change	.02	.01	.44	.64	.53	.54	.001	.15
Sow backfat								
Day 0	.04	.62	.08	.003	.03	.02	.64	.0002
Change	.0001	.14	.74	.63	.04	.13	.001	.37
Days to estrus	.07	.97	.43	.38	.54	.21	.16	.68

[a]Litter size after cross-fostering and lactation length used as covariates.
[b]Total branched chain amino acids (isoleucine + valine + leucine).
[c]Initial sow BW used as a covariate.
[d]Initial sow backfat used as a covariate.
[e]Percentage of sows in estrus by d 10 postweaning. Values differ ($P < .06$) based on Chi-square distribution.
[f]Contrasting dietary valine levels of .72, 1.07, and 1.42% at .50% dietary isoleucine.
[g]Contrasting means of total branched chain amino acid levels 2.57, 2.92, 3.27, and 3.62%.

Table 4. The Effects of Valine and Isoleucine on Milk Composition, %[a]

	Valine, %:	.72			1.07			1.42	
	Isoleucine, %:	.50	.85	1.20	.50	.85	1.20	.50	
Item	TBCAA, %[b]:	2.57	2.92	3.27	2.92	3.27	3.62	3.27	CV
DM		16.17	16.8	17.1	15.86	17.02	17.33	17.6	5.1
CP		5.16	5.31	5.61	4.94	5.39	5.33	5.30	9.5
Fat		5.76	6.00	6.67	5.87	6.38	6.66	6.89	14.7
Lactose		4.47	4.48	4.24	4.50	4.29	4.45	4.23	7.6
Ash		.78	.77	.77	.79	.80	.75	.76	6.5
N fractions									
Casein		53.9	55.2	57.1	51.6	55.3	57.9	53.9	11.5
Whey		35.5	35.0	33.2	36.2	34.7	31.9	34.9	17.1
Other[c]		10.6	9.8	9.7	12.3	10.0	10.3	11.2	18.5

Statistical Analysis ($P <$)

	Main Effects				Valine at .50% Isoleucine[d]		TBCAA[e]	
		Isoleucine						
	Valine	Lin.	Quad.	Val × Ile	Lin.	Quad.	Lin.	Quad.
DM	.93	.0002	.25	.62	.004	.01	.002	.84
CP	.25	.005	.47	.42	.50	.11	.20	.77
Fat	.47	.002	.83	.72	.01	.23	.005	.71
Lactose	.85	.24	.77	.25	.10	.22	.57	.38
Ash	.81	.19	.58	.33	.36	.53	.20	.55
N fractions								
Casein	.73	.01	.94	.67	.97	.33	.08	.33
Whey	.82	.06	.65	.85	.83	.67	.10	.39
Other	.07	.01	.10	.41	.43	.06	.52	.61

[a]Litter size after cross-fostering used as a covariate.
[b]Total branched chain amino acids (isoleucine + valine + leucine).
[c]Other = all other N (free amino acids, urea N, sloughed cellular N).
[d]Contrasting dietary valine levels of .72, 1.07, and 1.42% at .50% dietary isoleucine.
[e]Contrasting means of total branched chain amino acid levels 2.57, 2.92, 3.27, and 3.62%.

EFFECTS OF SELECT MENHADEN FISH MEAL FED DURING LACTATION ON SOW AND LITTER PERFORMANCE [1]

R. E. Musser, R. D. Goodband, M. D. Tokach, J. L. Nelssen, and S. S. Dritz

Summary

A total of 317 lactating sows was fed either a corn-soybean meal diet (1.0% lysine) or a diet with a portion of the soybean meal replaced with 5% select menhaden fish meal on an equal lysine basis. Adding 5% select menhaden fish meal had no overall effect on sow or litter performance. Composition of milk samples collected between d 14 and 16 of lactation was not affected by dietary treatment.

(Key Words: Sows, Lactation Diets, Select Menhaden Fish Meal.)

Introduction

Soybean meal is the predominate protein source used in lactation diets in the U.S. Unfortunately, limited information exists to evaluate the effects of highly palatable and digestible protein sources such as select menhaden fish meal on sow feed intake and performance. Select menhaden fish meal is used widely as a specialty protein source in diets for weanling pigs (weaning to 25 lb) because of its effects on feed intake and growth performance. Therefore, the objective of this experiment was to determine the effects of adding 5% select menhaden fish meal to lactation diets on sow and litter performance.

Procedures

A total of 317 sows (PIC Line, C-15) was used. The experiment was conducted from July to September, 1995, on a 1,600 sow commercial swine farm in northeast Kansas. During gestation, all sows were fed 4 lb/d of a milo-soybean meal gestation diet (.65% lysine) formulated to exceed NRC (1988) nutrient estimates for amino acids, vitamins, and minerals. Feed intake was increased gradually to 6 lb/d during the last 21 days of gestation. Sows were assigned randomly to dietary treatments when they were moved into the farrowing house on or at about d 110 of gestation. Parity distribution was equalized between treatments, and sows were fed 6 lb/d of the experimental diets from d 110 of gestation until farrowing. During lactation, all sows were allowed ad libitum access to feed and water and were fed at least three times per day. The two dietary treatments consisted of a corn-soybean meal control diet or a diet with 5% select menhaden fish meal replacing soybean meal on a lysine basis (Table 1). Both diets contained 2.5% added soybean oil and were formulated to contain 1.0% lysine. Feed intake during lactation was recorded daily. Sows were scanned for last rib fat depth and scored for body condition (5-point scale with 1 = thin and 5 = obese) at farrowing and at weaning (d 20). Litters were standardized between treatments within 24 hours of parturition

[1]The authors thank Zapata Proteins Co., Mandeville, LA for providing the select menhaden fish meal and partial financial support and Keesecker Agri-Business for use of facilities and animal care.

and weighed after equalization. Number of pigs and litter weights were recorded at weaning. Pigs were weaned at approximately d 20 of lactation, and sows were moved to a gestation building where they were monitored for estrus with daily boar exposure.

Subsequent reproductive performance was recorded. The gestation diet and feeding management were identical to those described previously. Criteria measured were days to estrus, farrowing rate, total number of pigs born, and number of pigs born alive.

Table 1. Composition of Experimental Diets[a]

Ingredient, %	Control	Select Menhaden Fish Meal
Corn	64.81	68.85
Soybean meal (46.5% CP)	27.84	19.60
Select menhaden fish meal	---	5.00
Soybean oil	2.50	2.50
Monocalcium phosphate	2.56	2.07
Limestone	1.14	.83
Salt	.50	.50
Sow add pack	.25	.25
Vitamin premix	.25	.25
Trace mineral premix	.15	.15
Total	100.00	100.00

[a]The lactation diets were formulated to contain 1.0% lysine, .94% valine, 1.0% Ca, and .9% P.

Milk samples were collected from 16 randomly selected third parity sows (8 per treatment) between d 14 and 16 of lactation and analyzed for total whole milk composition including crude protein, dry matter, ash, lipid, and lactose.

In the statistical analysis, number of pigs equalized per litter, weight after equalization, and lactation length were used as covariates. In addition, sows were divided into two groups based on parity. First and second parity sows were combined into one group, and parity three, four, five, and six sows were combined into the second. This grouping arrangement (approximately 50% in each group) provided a sufficient number of observations within each parity group to evaluate the effects of added select menhaden fish meal based on sow parity. The statistical model evaluated treatment by parity group interactions; however, there no significant interactions ($P < .10$) were observed.

Results and Discussion

Adding 5% select menhaden fish meal to the lactation diet had no effect ($P > .25$) on sow feed intake (Table 2). However, sows fed added select menhaden fish meal had numerically greater feed intake throughout the experiment. The average number of pigs per litter after equalization was 10.33 vs 10.21 for sows fed the control and added select menhaden fish meal diets, respectively. Adding 5% select menhaden fish meal to the lactation diet had no effect ($P > .10$) on number of pigs weaned, pig survival from birth to weaning, and pig or litter weaning weights. Sow body condition scores decreased from farrowing to weaning but were unaffected by dietary treatment. Sows fed 5% select menhaden fish meal tended ($P < .10$) to have greater last rib fat depth at farrowing and at weaning; however, no difference was observed for change in backfat thickness based on dietary treatment.

Although the difference was not statistically significant, sows fed select menhaden fish meal tended to have a higher farrowing rate and .3 pigs more total pigs born (10.86 vs 11.17, respectively). However, number of pigs born alive was similar (10.28 vs 10.23) for sows fed the control or select menhaden fish meal diet.

Composition of milk samples collected between d 14 and 16 of lactation was not affected ($P > .10$) by dietary treatment (Table 3).

No parity × dietary treatment interactions were observed for any of the response criteria. However, to determine if parity affected the results with menhaden fish meal, we divided the sows into two parity groups; first and second parity sows in one group (Table 4), and sows greater than second parity into a second group (Table 5). First

and second parity sows fed select menhaden fish meal tended to have numerically greater (3%) feed intake (d 0 to 14; $P < .11$) than sows fed the control diet. However, litter and pig weaning weights were not affected by dietary treatment. Sows fed select menhaden fish meal tended to have greater backfat thickness at farrowing and weaning but also tended ($P < .14$) to loose less backfat during lactation. The slightly greater backfat thickness at farrowing could have been a random, nontreatment-related effect, because sows were assigned to their respective treatments at farrowing. However, the trend for higher feed intakes by sows fed select menhaden fish meal could have contributed to the decreased backfat loss during lactation. First and second parity sows fed select menhaden fish meal tended to have greater subsequent farrowing rate (72.74 vs 60.89%; $P > .13$) compared with those fed the control diet. This response also may be related to slightly greater feed intake and less loss of backfat thickness during lactation.

Surprisingly, older parity sows (> 2) fed 5% menhaden fish meal during lactation had decreased pig and litter weaning weight and litter weight gain when compared to those fed the control diet ($P < .05$). No differences were observed between sows fed the two diets for other response criteria (Table 5).

In conclusion, these results suggest that 5% select menhaden fish meal can replace soybean meal in a lactation diet with mixed effects on sow or litter performance. In first and second parity sows, select menhaden fish meal tended to increase daily feed intake and improve farrowing rate; however, in older parity sows, addition of select menhaden fish meal reduced litter weaning weights. These responses were not of a large enough magnitude to indicate a parity × select menhaden fish meal interaction, and the overall data showed no differences in sow or litter performance. In addition, no differences were observed in milk composition or subsequent reproductive performance.

Table 2. Effects of Select Menhaden Fish Meal Fed during Lactation on Sow and Litter Performance (All Parities)[a]

Item	Control	Select Menhaden Fish Meal	CV	P-Value
No. of sows	164	153		
ADFI, lb				
d 0 to 7	9.92	10.08	19.5	.4845
d 7 to 14	12.08	12.32	18.3	.3427
d 0 to 14	11.00	11.20	16.6	.3449
d 0 to 21	11.44	11.66	14.7	.2830
No. pigs equalized per litter	10.32	10.22	7.4	.1994
No. pigs weaned per litter	9.80	9.76	7.4	.6092
Survivability, %	95.60	95.25	7.1	.6570
Litter wt gain, lb	90.19	87.40	16.1	.1566
Litter wt at birth, lb	37.77	36.25	14.8	.0170
Litter wt at weaning, lb	127.22	124.43	13.4	.1566
Pig wt gain, lb	9.21	8.96	16.1	.1433
Pig wt at birth, lb	3.62	3.62	1.5	.4947
Pig wt at weaning, lb	13.00	12.77	11.0	.1724
Sow body condition[b]				
Postfarrowing	3.38	3.45	18.4	.3528
Weaning	3.23	3.23	17.6	.9570
Change	.156	.219	246.6	.2448
Sow last rib fat depth, mm				
Postfarrowing	19.94	20.75	19.4	.0801
Weaning	17.95	19.03	20.3	.0145
Change	1.98	1.69	106.2	.2091
Subsequent reproductive performance				
Days to estrus	5.21	5.46	73.5	.5845
Farrowing rate, %	67.6	72.3	65.9	.3788
Total born per litter	10.86	11.17	31.5	.5249
Born live per litter	10.28	10.23	31.1	.9122

[a]Covariates used in the statistical analysis were: days of lactation, pigs equalized, and parity.
[b]Body condition based on five-point scale (1 = thin and 5 = obese).

Table 3. Analysis of Whole Fresh Sow Milk on D 14 to 16 of Lactation[a]

Analyses, %	Control	5% Menhaden Fish Meal	CV	P-Value
Lipid	6.54	6.04	16.63	.3788
Dry matter	17.38	16.55	6.16	.1471
Ash	0.77	0.76	153.04	.3137
Crude protein	5.92	5.70	8.96	.4232
Lactose	69.39	70.96	5.16	.7889

[a]Values represent the means of eight (control) and seven (select menhaden fish meal) observations per treatment.

Table 4. Effects of Select Menhaden Fish Meal Fed during Lactation on Sow and Litter Performance (Parities 1 and 2)[a]

Item	Control	Select Menhaden Fish Meal	CV	P-Value
No. of sows	86	82		
ADFI, lb				
d 0 to 7	9.48	9.93	19.09	.1334
d 7 to 14	11.26	11.73	19.36	.1907
d 0 to 14	10.37	10.83	16.72	.1087
d 0 to 21	10.86	11.21	15.50	.1984
No. pigs weaned per litter	9.73	9.78	7.70	.7221
Survivability, %	94.88	95.33	7.42	.6911
Litter wt gain, lb	84.27	84.11	20.50	.9519
Litter wt at weaning, lb	119.35	119.18	14.46	.9519
Pig wt gain, lb	8.67	8.61	17.30	.8333
Pig wt at birth, lb	3.43	3.43	1.50	.7191
Pig wt at weaning, lb	12.30	12.24	11.85	.7963
Sow body condition[b]				
Postfarrowing	3.20	3.21	17.65	.8915
Weaning	3.01	3.01	17.15	.9903
Change	.19	.20	228.63	.9083
Sow last rib fat depth, mm				
Postfarrowing	18.90	19.96	17.83	.0581
Weaning	16.78	18.22	19.32	.0090
Change	2.11	1.74	78.78	.1366
Subsequent reproductive performance				
Days to estrus	5.27	5.38	84.30	.8724
Farrowing rate, %	60.89	72.74	70.90	.1208
Total born per litter	11.00	10.62	32.50	.5875
Born alive per litter	10.42	9.81	31.80	.3428

[1]Covariates used in the statistical analysis were: days of lactation, pigs equalized, treatment, and parity.
[2]Body condition based on five-point scale (1 = thin and 5 = obese).

Table 5. Effects of Select Menhaden Fish Meal Fed during Lactation on Sow and Litter Performance (Parities > 3)[a]

Item	Control	Select Menhaden Fish Meal	CV	P-Value
No. of sows	78	71		
ADFI, lb				
d 0 to 7	10.39	10.22	19.74	.6102
d 7 to 14	12.92	12.91	17.18	.9673
d 0 to 14	11.66	11.56	16.40	.7670
d 0 to 21	12.06	12.09	13.71	.9289
No. pigs weaned per litter	9.87	9.75	6.88	.2816
Survivability, %	96.37	95.26	6.50	.3000
Litter wt gain, lb	96.16	90.65	17.36	.0494
Litter wt at weaning, lb	135.39	129.88	12.23	.0494
Pig wt gain, lb	9.74	9.28	14.74	.0570
Pig wt at birth, lb	3.84	3.84	1.33	.4924
Pig wt at weaning, lb	13.73	13.32	10.14	.0831
Sow body condition[b]				
Postfarrowing	3.58	3.69	18.89	.3327
Weaning	3.46	3.45	17.95	.9963
Change	.12	.24	265.74	.1519
Sow last rib fat depth, mm				
Postfarrowing	21.03	21.52	20.54	.5241
Weaning	19.17	19.82	20.88	.3561
Change	1.85	1.63	135.90	.6035
Subsequent reproductive performance				
Days to estrus	5.16	5.54	59.60	.4933
Farrowing rate, %	74.21	71.51	61.37	.7245
Total born per litter	10.77	11.65	30.38	.2044
Born alive per litter	10.17	10.61	30.27	.4907

[a]Covariates used in the statistical analysis were: days of lactation, pigs equalized, treatment, and parity.
[b]Body condition based on five-point scale (1 = thin and 5 = obese).

EFFECTS OF SPRAY-DRIED BLOOD CELLS IN LACTATION DIETS ON SOW AND LITTER PERFORMANCE [1]

S. S. Dritz [2], M. D. Tokach, J. L. Nelssen, R. D. Goodband, and E. Weaver [3]

Summary

High producing sows were used to evaluate the effect of spray-dried blood cells as a dietary protein source on lactation performance and subsequent reproductive performance. No significant differences were observed between sows fed a corn-soybean cells-based diet or a diet containing 2.5% spray-dried blood cells for lactation performance or subsequent reproductive performance. Therefore, spray-dried blood cells can be used as a partial replacement for the protein source in lactation diets.

(Key Words: Spray-Dried Blood Cells, Lactation, Reproduction.)

Introduction

Several experiments have showed the improved sow milk production and increased litter growth rate for sows fed diets containing greater amounts of dietary lysine than recommended by NRC (1988). Thus, recommendations for commercial herds range from 45 to 55 g/d of lysine (.9 to 1.2% of the diet). Soybean meal is the predominate protein source used in lactation diets; however, diets formulated to 1.0% lysine or greater, contain high levels of soybean meal (> 550 lb/ton). Little information is available to evaluate the effects of highly palatable and digestible protein sources such as spray-dried blood cells on sow feed intake and performance. Therefore, the objective of this experiment was to evaluate the effect of spray-dried blood cells in a lactation diet on sow and litter performance.

Procedures

A total of 417 sows (PIC Camborough genotype) was assigned randomly at farrowing to one of two dietary treatments in an on-farm field study (208 sows fed diets containing spray-dried blood cells and 209 sows fed the control lactation diet). Care was taken to equalize the number of gilts and sows of each parity to each treatment. Sows used in the experiment farrowed from June 30, 1995 to August 23, 1995.

Sows were fed corn-soybean meal-based diets formulated to contain 1.2% lysine and 3% added fat during the lactation period (Table 1). The dietary treatments consisted of the corn-soybean meal control or a diet formulated with 2.5% granular spray-dried blood cells (AP 301 G) substituted on an equal lysine basis. All sows then were fed a common gestation diet in the subsequent gestation period.

Sow feed intake was recorded daily during lactation. Sows were provided ad

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[1]Appreciation is expressed to Eric Weaver and American Proteins Corp., Ames, IA for providing partial financial support. We also thank Jerry and Leslie Bauman for overseeing data collection and organization and to Global Ventures Inc., Pipestone, MN for use of animals and facilities.

[2]Food Animal Health and Management Center.

[3]American Proteins Corp, Ames, IA.

libitum access to feed throughout lactation. Number of pigs born (total, stillborn, mummies, and alive) and weaned, sow weight at entry into the farrowing room and weaning, sow parity, lactation length, and litter weaning weights also were recorded. Litters were equalized across dietary treatments within 48 hours of farrowing. Pigs were not transferred among litters after 48 hours postfarrowing.

Following weaning, sows were moved to an environmentally controlled breeding facility, and all parity 1 sows were injected with PG-600 on the day of weaning. Sows were checked for estrus daily with a boar. Once estrus was detected, sows were artificially inseminated once every 24 hours until they were not in standing estrus. Sows culled or returning to estrus after insemination were removed from the experiment, and removal reason was recorded. Total and live births in subsequent parities also were recorded.

Sow weight; ADFI; and farrowing, weaning, and subsequent farrowing performance were analyzed using a General Linear Model with treatment and parity as the independent variables. In addition, lactation length was used as a covariate for sow weight, ADFI, and weaning performance. No parity by treatment interactions were observed and number of sows within parity did not differ among treatment; therefore, main effect means are reported in the tables. A chi square statistic was calculated for breeding performance, removal reasons, and farrowing rate.

Results and Discussion

No differences were detected in sow weight, ADFI, and farrowing or weaning performance (Table 2). However, numerical trends were observed for improvements in ADFI ($P < .14$) and litter weaning weight ($P < .15$). Similar to observations noted in nursery pigs, farrowing house personnel observed that the piglets in litters from sows fed the spray-dried blood cells were “dirtier” in appearance. However, this appearance was not associated with a decrease in litter performance. Removal reasons, total removals, or farrowing rate were not different among treatments (Table 3). Spray-dried blood cells fed in lactation did not influence the wean to estrus interval or the litter size (total or live births) of the sows that farrowed in the subsequent parity (Table 4).

Sow and litter performance by parity was examined (data not shown). The sows' lysine requirement was calculated assuming that 49 mg lysine × $BW^{.75}$ + 26 g lysine per kg litter growth/day is required. This calculation is based on maximizing litter growth performance and the fact that lysine is the limiting amino acid. The calculations indicate that the average sow in parities 1 to 4 was consuming lysine below her projected requirement. Therefore, if the lysine from the spray-dried blood cells is more available, the litter performance should have improved.

In conclusion, spray-dried blood cells can be used as a partial replacement for soybean meal in the lactation diet of high-producing sows without adverse effects on feed intake.

Table 1. Diet Composition (%) As-Fed

	Lactation		
Item	Blood Cells	Control	Gestation
Ingredient, %			
Corn	62.65	57.4	74.9
Soybean meal (46.5% CP)	27.2	35.1	15.6
Spray-dried blood meal	2.5	--	--
Alfalfa meal	--	--	5.0
Choice white grease	3.0	3.0	--
Monocalcium phosphate (21% P)	2.6	2.5	2.7
Limestone	1.1	1.2	.8
Salt	.50	.50	.50
Sow add pack premix[a]	.125	.125	.125
Vitamin premix[a]	.125	.125	.125
Trace mineral premix[a]	.15	.15	.15
DL-methionine	.055	--	--
Nutrient, %			
Lysine	1.20	1.20	.70
Methionine	.36	.33	.25
Methionine + cystine	.72	.72	.55
Crude protein			
Calculated	20.3	21.3	14.6
Analyzed	21.1	21.8	--
Calcium	1.00	1.00	1.00
Phosphorus	.90	.90	.90

[a]Premixes to provide 60,000 IU vitamin E per ton and all other vitamins and trace minerals as specified in the Kansas Swine Nutrition Guide.

Table 2. Influence of 2.5% Spray-Dried Blood Cells Fed in Lactation to High-Producing Sows[a]

	Lactation Diet			
Item	Spray-Dried Blood Cells	Control	Probability *P* <	CV
No. of sows	208	209	--	--
Sow Weight				
Prefarrowing, lb	531	533	.66	8.5
Weaning, lb	502	504	.62	8.3
Weight loss, lb	29.8	29.7	.97	76.2
ADFI, lb	11.2	10.9	.14	16.2
Farrowing performance				
Total births	10.9	10.7	.57	29.2
Stillbirths	.7	.9	.17	189.9
Mummies	.1	.2	.30	299.4
Live births	10.2	9.6	.20	31.7
Weaning performance				
Number weaned	9.1	8.9	.23	11.8
Litter weight, lb	106.9	103.2	.15	18.1
Avg pig weight, lb	11.7	11.5	.39	14.6

[a]Lactation length (15.6 d) was used as a covariate for sow weight, ADFI, and weaning performance. Sows farrowed from June 30, 1995 to August 25, 1995.

Table 3. Influence of 2.5% Spray-Dried Blood Cells Fed in Lactation on Subsequent Reproductive Performance and Removal Reasons[a]

	Lactation Diet	
Item, % (No.)	Spray-Dried Blood Cells	Control
No heat (No.)	3.4 (7)	3.8 (8)
Did not conceive (No.)	3.4 (7)	3.3 (7)
Regular returns (No.)	5.8 (12)	6.7 (14)
Irregular returns (No.)	5.8 (12)	5.7 (12)
Total reproductive removals (No.)	18.3 (38)	20.1 (42)
Nonreproductive (No.)	5.3 (11)	3.3 (7)
Unknown (No.)	.5 (1)	.5 (1)
Total removals (No.)	24.0 (50)	23.4 (49)
Farrowing rate	76.0	76.6

[a]No significant differences observed.

Table 4. Influence of 2.5% Spray-Dried Blood Cells Fed in Lactation on Subsequent Wean to Estrus Interval and Parity Litter Size[a]

	Lactation Diet			
Item	Spray-Dried Blood Cells	Control	*P* <	CV
No. of Sows	158	160	--	--
Wean to estrus, d	5.2	5.2	.87	13.3
Total births	11.0	11.2	.72	33.7
Live births	10.1	9.6	.40	34.6

[a]Five animals from each treatment group with wean to estrus intervals of > 15 d and 9 animals from each treatment group culled before exhibiting estrus were removed from the data set.

DETERMINING THE OPTIMAL THREONINE:LYSINE RATIO IN STARTER DIETS FOR THE SEGREGATED EARLY-WEANED PIG[1]

J. R. Bergström, J. L. Nelssen, M. D. Tokach, R. D. Goodband, W. B. Nessmith, Jr., and C. A. Civis

Summary

A 14-day growth trial was conducted to determine the threonine:lysine ratio necessary to optimize growth performance of the segregated early-weaned (SEW) pig. Twelve experimental diets included two levels of lysine (1.15% and 1.5% apparent digestible lysine) and six apparent digestible threonine:lysine ratios (40, 45, 50, 55, 60, and 65%) in a 2 × 6 factorial arrangement. Growth performance was improved by feeding 1.5% rather than 1.15% digestible lysine. Growth performance decreased linearly as the digestible threonine:lysine ratio increased. Although a significant quadratic response was not observed, this reduction in growth performance did not appear to occur until the threonine ratio exceeded 45% of lysine on an apparent digestible basis. These data indicate that the threonine requirement for the SEW pig is approximately 45% of digestible lysine.

(Key Words: Early-Weaned Pigs, Amino Acids, Threonine.)

Introduction

The development of high nutrient-dense diets for early-weaned pigs has facilitated the implementation of segregated early weaning (SEW) as a common management practice. However, much remains to be discovered regarding optimum nutrition of the early-weaned pig. Although several studies have focussed on the lysine and methionine requirements of SEW-reared pigs, the appropriate level of the other amino acids necessary to optimize growth performance has been an area of considerable debate. The ideal amino acid ratio developed by the University of Illinois indicates that methionine and threonine are deficient in typical diets formulated to meet the lysine requirement of the SEW pig, unless they are added as synthetic amino acids. Recent research at Kansas State University agrees closely with the University of Illinois ideal amino acid ratio for methionine. However, in a study conducted recently to determine the threonine requirement of the SEW pig, growth performance was not affected by increasing the digestible threonine:lysine ratio above 50%. Therefore, the objective of this experiment was to confirm our previous results and evaluate threonine:lysine ratios below 50%.

Procedures

Three hundred high-lean growth pigs (Newsham Hybrids) were weaned at 14 ± 2 d of age and delivered to the segregated early weaning (SEW) facilities at Kansas State University. The pigs were blocked by weight (initially 10.0 ± 2 lb) and allotted to one of 12 experimental diets, with a total of five pigs/pen and five pens/treatment. The 12 experimental diets consisted of two levels of lysine (1.15% and 1.5% digestible lysine) and six digestible threonine:lysine ratios (40, 45, 50, 55, 60, and 65%) in a 2 × 6 factorial arrangement (Table 1). The 1.15% digestible lysine diets (1.31% total lysine) were corn-soybean meal based and contained 10%

[1]The authors extend appreciation to Newsham Hybrids of Colorado Springs, CO for providing the pigs used in this research. We also thank Heartland Lysine for providing the crystalline amino acids.

dried whey, 15% lactose, 6% spray-dried plasma protein, and 3% select menhaden fish meal. The six 1.15% digestible lysine diets were calculated to contain .460, .518, .575, .633, .690, and .748% apparent digestible threonine. The level of soybean meal was increased in order to achieve the 1.5% digestible lysine diets (1.7% total lysine). The six 1.50% digestible lysine diets were calculated to contain .600, .675, .750, .825, .900, and .975% digestible threonine.

Crystalline isoleucine, methionine, cystine, valine, and tryptophan (L-isoleucine, DL-methionine, L-cystine, L-valine, L-tryptophan) were included in the basal diets to ensure that they contained all the essential amino acids suggested by the Illinois ideal amino acid ratio adjusted for an apparent digestible basis. Crystalline threonine (L-threonine) was added to the basal diets at the expense of corn starch to provide the six levels of threonine. The experimental diets were pelleted and fed from d 0 to 14 postweaning.

Pigs were housed in the Kansas State University SEW nurseries in 4 × 4 ft pens for the duration of the trial. Pens were equipped with one self-feeder and a nipple waterer to provide ad libitum access to feed and water.

The pigs were weighed and feed disappearance was determined on d 7 and 14 postweaning. Average daily gain, ADFI, and F/G were the response criteria. Also, the pigs were withheld from feed for 2 h on d 14, and blood was collected from two pigs/pen for plasma urea nitrogen (PUN) determination.

Data were analyzed as a randomized complete block design, with pen as the experimental unit. Pigs were blocked on the basis of initial weight. Analysis of variance was performed using the GLM procedure of SAS. Linear, quadratic, and cubic polynomials were evaluated for dietary threonine levels.

Results and Discussion

No dietary threonine × lysine interactions were observed during the trial (Table 2). From d 0 to 7 postweaning, ADG and F/G were improved ($P < .0001$) by feeding the diets containing 1.5% digestible lysine rather than 1.15% digestible lysine. Feed intake was not affected by either lysine or threonine level of the diet during this period. Also, no differences occurred in growth performance with increasing threonine:lysine ratio.

From d 7 to 14 postweaning, ADG and F/G were improved ($P < .0001$) by feeding the 1.5% digestible lysine diets. Although ADFI was not affected by dietary lysine, ADFI and ADG decreased linearly ($P < .002$) as the threonine:lysine ratio increased. Feed efficiency was not affected by increasing the threonine:lysine ratio during this period.

For the entire trial (d 0 to 14 postweaning), pigs fed 1.5% apparent digestible lysine had greater ($P < .0001$) ADG and F/G than pigs fed 1.15% apparent digestible lysine. Also, ADG decreased linearly ($P < .01$) as the digestible threonine:lysine ratio increased. Although a significant quadratic response was not observed, this reduction in growth performance did not appear to occur until the threonine ratio exceeded 45% of lysine on an apparent digestible basis. No differences in ADFI occurred.

On d 14, PUN was greater ($P < .0001$) for pigs fed 1.5% digestible lysine. A quadratic decrease ($P < .05$) in PUN also occurred as the threonine:lysine ratio increased.

The results of this study agree with previous research (see Kansas State University Swine Day 1995, Report of Progress 746). Pigs that were fed 1.5% apparent digestible lysine (1.7% total lysine) gained faster and more efficiently than pigs fed 1.15% apparent digestible lysine (1.31% total lysine). Also, a previous study found that increasing the digestible threonine:lysine ratio above the basal level of 50% did not affect growth

performance. In this study, growth performance was numerically greatest for pigs fed 45% threonine:lysine and decreased linearly as the ratio increased. Additionally, PUN was reduced by feeding the 45% threonine:lysine ratio.

In conclusion, these data suggest that the optimum level of threonine for the SEW pig is 45% of lysine on an apparent digestible basis. This corresponds to a ratio of approximately 53% threonine:lysine on a total amino acid basis.

Table 1. Composition of Basal Diets[a]

	Digestible Lysine, %	
Ingredient, %	1.15	1.50
Corn	52.58	40.56
Dried whey	10.00	10.00
Lactose	15.00	15.00
Spray-dried plasma protein	6.00	6.00
Soy oil	6.00	6.00
Select menhaden fish meal	3.00	3.00
Soybean meal (46.5% CP)	1.12	12.93
Monocalcium phosphate	1.89	1.68
Antibiotic[b]	1.00	1.00
Limestone	0.74	0.77
L-lysine HCl	0.63	0.72
Zinc oxide	0.38	0.38
L-isoleucine	0.29	0.32
Corn starch[c]	0.29	0.38
Vitamin premix	0.25	0.25
DL-methionine	0.18	0.24
Trace mineral premix	0.15	0.15
L-cystine	0.14	0.19
L-valine	0.17	0.25
L-tryptophan	0.10	0.10
Salt	0.10	0.10
Total	100.00	100.00

[a]Diets were formulated to contain all essential amino acids (except threonine) at the University of Illinois ideal amino acid ratio adjusted for an apparent digestible basis. Diets also were formulated to contain .9% Ca and .8% P.
[b]Provided 50 g/ton carbadox.
[c]L-threonine replaced corn starch in the 1.15% and 1.50% digestible lysine basal diets to provide .460, .518, .575, .633, .690, and .748% digestible threonine and .600, .675, .750, .825, .900, and .975% digestible threonine, respectively. This provided 12 experimental diets in a 2 × 6 factorial arrangement, with two levels of lysine and six levels of digestible threonine:lysine (40, 45, 50, 55, 60, and 65%).

Table 2. Influence of Increasing the Level of Digestible Threonine:Lysine on SEW Pig Performance[a]

	Digestible Threonine: Lysine Ratio, %						Digestible Lysine, %		
Item	40	45	50	55	60	65	1.15	1.50	CV
d 0 to 7									
ADG, lb[b]	.29	.32	.27	.30	.27	.28	.24	.34	22.1
ADFI, lb	.29	.29	.30	.30	.28	.30	.29	.30	18.1
F/G[b]	.98	.90	1.10	1.02	1.05	1.06	1.19	.88	16.5
d 7 to 14									
ADG, lb[bc]	.59	.59	.61	.56	.49	.51	.51	.61	15.5
ADFI, lb[c]	.81	.81	.81	.77	.68	.71	.78	.75	13.2
F/G[b]	1.37	1.35	1.32	1.39	1.37	1.37	1.53	1.22	9.0
d 0 to 14									
ADG, lb[bd]	.44	.46	.44	.43	.38	.40	.37	.47	14.5
ADFI, lb	.55	.55	.55	.54	.48	.50	.54	.52	13.1
F/G[b]	1.23	1.20	1.25	1.27	1.25	1.27	1.43	1.10	7.0
d 14									
PUN, mg/dL[be]	3.22	1.52	1.95	2.05	2.05	2.33	1.33	3.03	63.7

[a]Three hundred weanling pigs were used (initially 10.0 lb and 14 d of age), five pigs/pen, five pens/treatment.
[b]Lysine effect ($P < .0001$).
[c]Threonine effect (linear, $P < .002$).
[d]Threonine effect (linear, $P < .01$).
[e]Threonine effect (quadratic, $P < .05$).

DETERMINING THE OPTIMAL THREONINE:LYSINE RATIO FOR THE 25 TO 50 LB PIG[1]

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Summary

A 21-day growth trial was conducted to determine the threonine:lysine ratio necessary to optimize growth performance of the 25 to 50 lb pig reared in a high-health, segregated early-weaning (SEW) system. Ten experimental diets, including two levels of lysine (.75% and 1.10% apparent digestible lysine) and five apparent digestible threonine:lysine ratios (40, 47.5, 55, 62.5, and 70%), were used in a 2 × 5 factorial arrangement. Growth performance was improved by feeding 1.10% rather than .75% digestible lysine. Also, results indicated that the apparent digestible threonine requirement for the SEW-reared, 25 to 50 lb pig is approximately 55% of digestible lysine.

(Key Words: Early-Weaned Pigs, Amino Acids, Threonine.)

Introduction

Two previous experiments were conducted to determine the appropriate threonine:lysine ratio necessary to optimize the growth performance of the segregated early-weaned (SEW) pig weighing approximately 10 to 18 lb. The threonine ratio supporting optimum growth was determined to be no more than 45% of lysine on an apparent digestible basis. Because a pig's needs for a particular amino acid may change as the animal grows, the objective of this experiment was to determine the appropriate threonine:lysine ratio necessary to optimize growth performance of the SEW-reared pig weighing 25 to 50 lb.

Procedures

Two hundred and sixty high-lean growth pigs (Newsham Hybrids) were blocked by weight (initially 24.3 ± 1.8 lb and 33 ± 2 d of age) and allotted to one of 10 experimental diets, with a total of four or five pigs/pen (equal number of pigs/pen within a block) and six pens/treatment. The 10 experimental diets consisted of two levels of lysine (.75% and 1.10% digestible lysine) and five apparent digestible threonine:lysine ratios (40, 47.5, 55, 62.5, and 70%) in a 2 × 5 factorial arrangement (Table 1). The pigs had been used in a previous trial to determine the optimal threonine:lysine ratio for the 10 to 18 lb pig and then were placed on a common phase II diet for 5 days prior to being reallotted for this study.

The .75% and 1.10% digestible lysine basal diets were corn-soybean meal based. Crystalline isoleucine, methionine, cystine, valine, and tryptophan (L-isoleucine, DL-methionine, L-cystine, L-valine, and L-tryptophan) were included in the basal diets to ensure that they contained all the essential amino acids suggested by the Illinois ideal amino acid ratio adjusted for an apparent digestible basis. Crystalline threonine (L-threonine) was added to the basal diets at the expense of corn starch to provide the five levels of threonine. The levels of digestible threonine in the .75% digestible lysine diets were .300, .356, .413, .469, and .525%. The levels of digestible threonine in the 1.10% digestible lysine diets were .440, .523, .605, .688, and

[1]The authors extend appreciation to Newsham Hybrids of Colorado Springs, CO for providing the pigs used in this research. We also thank Heartland Lysine for providing the crystalline amino acids.

.770%. The experimental diets were fed in a meal form for 21 d.

Pigs were housed in the Kansas State University SEW nurseries in 4 × 4 ft pens for the duration of the trial. Pens were equipped with one self-feeder and a nipple waterer to provide *ad libitum* access to feed and water.

The pigs were weighed and feed disappearance was determined on d 7, 14, and 21 of the experiment. On d 14, the pigs were withheld from feed for 2 h, after which two pigs/pen were bled for plasma urea nitrogen (PUN) determination. Average daily gain (ADG), ADFI, F/G, and d 14 PUN were the response criteria.

The data were analyzed as a randomized complete block design, with pen as the experimental unit. Pigs were blocked on the basis of initial weight. Analysis of variance was performed using the GLM procedure of SAS. Linear, quadratic, and cubic polynomials were evaluated for dietary threonine levels.

Results and Discussion

Average daily gain and F/G were improved ($P<.01$) from d 0 to 7 by feeding the diets containing 1.10% rather than .75% apparent digestible lysine (Table 2). Additionally, ADFI was greater for pigs fed the diets containing 1.10% digestible lysine. Average daily gain and F/G also were improved (linear, $P<.01$; quadratic, $P<.03$; and linear, $P<.01$; quadratic, $P<.08$; respectively) as the digestible threonine:lysine ratio increased up to 55%.

During the d 7 to 14 period, ADG and F/G were improved ($P<.01$) by feeding 1.10% digestible lysine. Increasing the threonine:lysine ratio up to 55% improved ADG (linear, $P<.01$; quadratic, $P<.03$) and F/G (linear, $P<.01$). However, there was a lysine × threonine interaction ($P<.02$) for ADFI. This resulted from the greatly reduced feed intake observed among pigs fed the .75% digestible lysine diet formulated to 40% digestible threonine:lysine. In addition, d 14 PUN was greater ($P<.01$) for pigs fed 1.10% rather than .75% digestible lysine. Increasing the digestible threonine:lysine ratio to 62.5% resulted in a decrease (linear, $P<.01$; quadratic, $P<.03$) in PUN.

As observed during the first 2 weeks, ADG and F/G were improved ($P<.01$) from d 14 to 21 when pigs were fed the diets containing 1.10% digestible lysine. Also, ADG and F/G were improved (linear, $P<.01$; quadratic, $P<.03$; and linear, $P<.01$; respectively) by increasing the threonine:lysine ratio to 55%. There was also a lysine × threonine interaction ($P<.01$) for ADFI, because of the reduced feed intake observed among pigs fed the low lysine diet formulated to 40% digestible threonine:lysine.

Overall, from d 0 to 21, ADG and F/G were improved by feeding 1.1% rather than .75% apparent digestible lysine. Average daily gain and F/G also were improved (linear, $P<.01$; quadratic, $P<.03$) by increasing the digestible threonine:lysine ratio to 55%. There was also a lysine × threonine interaction ($P<.02$) for ADFI. This occurred as a result of the low feed intake observed among pigs fed the .75% digestible lysine diet formulated to the 40% threonine:lysine ratio.

In conclusion, these data indicate that the SEW-reared, 25 to 50 lb pig requires an apparent digestible threonine:lysine ratio of at least 55% to optimize growth performance. This corresponds to a threonine:lysine ratio of approximately 63% to 65% when expressed on a total basis.

Table 1. Composition of the Basal Diets[a]

	Digestible Lysine, %	
Ingredient, %	.75%	1.10%
Corn	84.96	72.53
Soybean meal (46.5% CP)	6.72	18.60
Soy oil	2.40	2.72
Monocalcium phosphate	2.00	1.79
Antibiotic[b]	1.00	1.00
Limestone	1.02	1.05
L-lysine HCl	0.56	0.65
Copper sulfate	0.08	0.08
Corn starch[c]	0.23	0.33
Vitamin premix	0.25	0.25
L-isoleucine	0.09	0.12
DL-methionine	0.05	0.10
Trace mineral premix	0.15	0.15
L-cystine	0.03	0.08
L-valine	0.07	0.14
L-tryptophan	0.07	0.08
Salt	0.35	0.35
TOTAL	100.00	100.00

[a]Diets were formulated to contain all essential amino acids (except threonine) at the University of Illinois ideal amino acid ratio adjusted for an apparent digestible basis. Diets also were formulated to contain .9% Ca and .8% P.

[b]Provided 50 g/ton carbadox.

[c]L-threonine replaced corn starch in the .75% and 1.10% digestible lysine basal diets to provide .300, .356, .413, .469, and .525% digestible threonine and .440, .523, .605, .688, and .770% digestible threonine, respectively. This provided 10 experimental diets in a 2 × 5 factorial arrangement, with two levels of lysine and five levels of digestible threonine:lysine (40, 47.5, 55, 62.5, and 70%).

Table 2. Influence of Increasing the Digestible Threonine:Lysine Ratio (40 to 70%) on Pig Performance[a]

	.75% Digestible Lysine					1.10% Digestible Lysine					
Item	40	47.5	55	62.5	70	40	47.5	55	62.5	70	CV
d 0 to 7											
ADG, lb[bc]	.55	.59	.73	.69	.78	.98	1.12	1.20	1.23	1.18	11.8
ADFI, lb[d]	1.72	1.74	1.86	1.82	1.89	1.88	1.84	2.00	1.90	1.83	7.5
F/G[be]	3.23	2.94	2.50	2.63	2.44	1.92	1.64	1.67	1.54	1.56	10.7
d 7 to 14											
ADG, lb[bc]	.93	1.08	1.15	1.21	1.14	1.37	1.49	1.57	1.42	1.53	10.2
ADFI, lb[f]	2.19	2.48	2.54	2.48	2.56	2.57	2.63	2.57	2.45	2.44	7.2
F/G[bg]	2.38	2.27	2.22	2.04	2.27	1.89	1.75	1.64	1.72	1.59	10.3
d 14 to 21											
ADG, lb[bc]	1.01	1.27	1.40	1.38	1.38	1.64	1.81	1.67	1.77	1.74	10.7
ADFI, lb[h]	2.56	2.84	2.99	2.96	3.01	2.98	3.06	2.89	2.91	2.93	6.0
F/G[bg]	2.56	2.22	2.13	2.13	2.17	1.82	1.69	1.72	1.64	1.69	8.8
d 0 to 21											
ADG, lb[bc]	.83	.98	1.10	1.10	1.10	1.33	1.47	1.48	1.47	1.48	6.4
ADFI, lb[f]	2.16	2.35	2.46	2.42	2.49	2.47	2.50	2.49	2.42	2.40	6.0
F/G[bc]	2.63	2.38	2.22	2.22	2.27	1.85	1.69	1.67	1.64	1.61	5.5
d 14											
PUN, mg/dL[bc]	4.48	3.54	2.29	1.36	1.89	6.19	5.17	3.68	2.62	3.67	38.5

[a]Two hundred and sixty pigs were used (initially 24.3 lb and 33 d of age), 4 or 5 pigs/pen (depending upon the block) , 6 pens/treatment.
[b]Lysine effect ($P<.0001$)
[c]Threonine effect (linear, $P<.003$; quadratic, $P<.03$)
[d]Lysine effect ($P<.03$)
[e]Threonine effect (linear, $P<.0001$; quadratic, $P<.08$)
[f]Lysine × threonine interaction ($P<.02$)
[g]Threonine effect (linear, $P<.01$)
[h]Lysine × threonine interaction ($P<.002$)

DETERMINING THE OPTIMAL ISOLEUCINE:LYSINE RATIO IN DIETS FOR THE SEGREGATED EARLY-WEANED PIG [1]

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Summary

A 14-d growth trial was conducted to evaluate effects of increasing isoleucine: lysine ratios on growth performance of the segregated early-weaned pig. Twelve experimental diets included two levels of lysine (1.15% and 1.50% digestible lysine) and six digestible isoleucine:lysine ratios (40, 45, 50, 55, 60, and 65% relative to lysine) in a 2 × 6 factorial arrangement. From d 0 to 14, growth performance was improved by feeding 1.50% digestible lysine. A linear improvement in growth performance occurred from d 0 to 7 as the isoleucine:lysine ratio increased. Although a significant quadratic response was not observed, little improvement in pig performance occurred above the 60% apparent digestible isoleucine:lysine ratio. Increasing isoleucine had no effect on the overall growth performance from d 0 to 14, but plasma urea nitrogen (PUN) was linearly reduced on d 14. These data suggest that the isoleucine requirement for the SEW pig is approximately 60% of lysine on an apparent digestible basis. However, because this response was observed only in the first week postweaning, further research is required to confirm this high a requirement for isoleucine.

(Key Words: Early-Weaned Pigs, Amino Acids, Isoleucine.)

Introduction

The development of nutrient-dense diets for early-weaned pigs has facilitated the implementation of segregated early-weaning (SEW) as a common management practice. A current limitation in the nutrition of the early-weaned pig is the lack of a thorough understanding of appropriate dietary amino acid levels. Recent research at Iowa State University and Kansas State University has determined the dietary lysine requirement of the SEW pig to be approximately 1.65% to 1.80%. Additionally, research conducted at Kansas State University has agreed closely with the University of Illinois recommendation of 30% for the methionine:lysine ratio, and recent research at Kansas State University has determined the threonine requirement of the SEW pig to be approximately 45% of lysine on an apparent digestible basis. The University of Illinois ideal amino acid ratio suggests that isoleucine may be the third limiting amino acid in plasma-based diets for the SEW pig. Therefore, the objective of this experiment was to determine the apparent digestible isoleucine:lysine ratio necessary to optimize growth performance of the SEW pig.

Procedures

Three hundred and sixty, high-lean growth pigs (PIC, 326 × C15) were

[1]The authors extend appreciation to Keesecker Agribusiness of Washington, KS for providing the pigs used in this research. We also thank Heartland Lysine for donation of synthetic amino acids.

weaned at 14 ± 2 d of age and delivered to the SEW facilities at Kansas State University. The pigs were blocked by weight (initially 12.2 ± 2.3 lb) and allotted to one of 12 experimental diets, with a total of five pigs/pen and six pens/treatment. The 12 experimental diets consisted of two levels of lysine (1.15% and 1.50% digestible lysine) and six digestible isoleucine:lysine ratios (40, 45, 50, 55, 60, and 65%) in a 2 × 6 factorial arrangement (Table 1).

The 1.15% digestible lysine diets (1.32% total lysine) were corn-soybean meal based and contained 20% dried whey, 15% lactose, 6.5% spray-dried plasma protein, 3% select menhaden fish meal, and 2% spray-dried blood meal. The levels of digestible isoleucine in the six 1.15% lysine diets were .460, .518, .575, .633, .690, and .748%.

The amount of soybean meal in the 1.15% lysine basal diet was increased from .89% to 10.23% of the diet in order to achieve the 1.50% digestible lysine basal diet (1.72% total lysine). The level of all other protein sources remained constant across all treatments. The levels of digestible isoleucine in the six 1.50% lysine diets were .600, .675, .750, .825, .900, and .975%.

Crystalline threonine, methionine, cystine, valine, and tryptophan (L-threonine, DL-methionine, L-cystine, L-valine, and L-tryptophan) were included in the basal diets to ensure that they contained all the essential amino acids suggested by the Illinois ideal amino acid ratio adjusted for an apparent digestible basis. Crystalline isoleucine (L-isoleucine) was added to the basal diets at the expense of corn starch to provide the six levels of isoleucine. The experimental diets were pelleted and fed from d 0 to 14 postweaning.

Pigs were housed in the Kansas State University SEW nurseries in 4 × 4 ft pens for the duration of the trial. Pens were equipped with one self-feeder and a nipple waterer to provide *ad libitum* access to feed and water.

The pigs were weighed and feed disappearance was determined on d 7 and 14 postweaning. Also, two pigs/pen were bled on d 14 postweaning for determination of PUN. Average daily gain (ADG), ADFI, F/G, and d 14 PUN were the response criteria.

The data were analyzed as a randomized complete block design, with pen as the experimental unit. Pigs were blocked on the basis of initial weight. Analysis of variance was performed using the GLM procedure of SAS, and linear and quadratic polynomials were evaluated for dietary isoleucine levels.

Results and Discussion

No dietary isoleucine by lysine interactions were observed during this study. From d 0 to 7 postweaning, ADG and F/G were improved ($P<.01$) for pigs fed 1.50% apparent digestible lysine (Table 2). Average daily gain and F/G also improved (linear, $P<.02$) as the digestible isoleucine:lysine ratio increased. Although a significant quadratic response was not observed, little improvement in pig performance occurred above the 60% apparent digestible isoleucine:lysine ratio. However, ADFI was not affected by either the lysine or isoleucine level in the diet.

During the d 7 to 14 postweaning period, ADG and F/G were improved ($P<.01$) by feeding 1.50% digestible lysine. Also, ADFI tended ($P<.10$) to be greater for pigs fed the high lysine diets. Pigs fed 1.50% digestible lysine also had greater ($P<.03$) PUN on d 14 than pigs fed 1.15% digestible lysine. Altering the ratio of isoleucine:lysine in the diets had no effect on growth performance during this period. However, increasing the isoleucine ratio of the diet resulted in a linear decrease ($P<.03$) in d 14 PUN, with pigs fed 60% apparent digestible isoleucine:lysine having the lowest PUN.

During the entire d 0 to 14 postweaning period, pigs fed 1.50% apparent digestible lysine had improved ($P<.01$) ADG and F/G. Also, ADFI tended ($P<.09$) to be greater for pigs fed 1.50% rather than 1.15% digestible lysine. However, overall ADG, ADFI, and F/G were not affected by the level of isoleucine in the diet.

In conclusion, the linear improvement in growth performance observed from d 0 to 7 postweaning and the linear reduction of PUN on d 14 suggest that the optimum ratio of isoleucine:lysine for the SEW pig is approximately 60% on an apparent digestible basis. However, because this response was observed only in the first week postweaning, further research is required to confirm this high a requirement for isoleucine.

Table 1. Composition of the Basal Diets[a]

	Digestible Lysine, %	
Ingredient, %	1.15%	1.50%
Corn	41.47	31.75
Dried whey	20.00	20.00
Lactose	15.00	15.00
Spray-dried plasma protein	6.50	6.50
Soy oil	6.00	6.00
Select menhaden fish meal	3.00	3.00
Soybean meal (46.5% CP)	0.89	10.23
Spray-dried blood meal	2.00	2.00
Monocalcium phosphate	1.62	1.46
Antibiotic[b]	1.00	1.00
Limestone	0.64	0.66
L-lysine HCl	0.36	0.52
Zinc oxide	0.38	0.38
Corn starch[c]	0.25	0.25
Vitamin premix	0.25	0.25
L-threonine	0.09	0.18
DL-methionine	0.16	0.23
Trace mineral premix	0.15	0.15
L-cystine	0.09	0.15
L-valine	-	0.11
L-tryptophan	0.07	0.09
Salt	0.10	0.10
Total	100.00	100.00

[a]Diets were formulated to contain all essential amino acids (except isoleucine) at the University of Illinois ideal amino acid ratio adjusted for an apparent digestible basis. Diets also were formulated to contain .9% Ca and .8% P.

[b]Provided 50 g/ton carbadox.

[c]L-isoleucine replaced corn starch in the 1.15% and 1.50% digestible lysine basal diets to provide .460, .518, .575, .633, .690, and .748% digestible isoleucine and .600, .675, .750, .825, .900, and .975% digestible isoleucine, respectively. This provided 12 experimental diets in a 2 × 6 factorial arrangement, with two levels of lysine and six levels of digestible isoleucine:lysine (40, 45, 50, 55, 60, and 65%).

Table 2. Main Effects of Increasing the Digestible Isoleucine:Lysine Ratio on SEW Pig Performance[a]

	Digestible Isoleucine: Lysine Ratio, %						Digestible Lysine, %		
Item	40	45	50	55	60	65	1.15	1.50	CV
d 0 to 7									
ADG, lb[bc]	.27	.24	.29	.30	.33	.32	.25	.33	28.3
ADFI, lb	.37	.34	.36	.37	.38	.38	.35	.37	20.0
F/G[bc]	1.35	1.41	1.25	1.25	1.15	1.19	1.41	1.14	19.1
d 7 to 14									
ADG, lb[b]	.54	.58	.58	.52	.56	.57	.50	.62	17.7
ADFI, lb	.64	.67	.72	.70	.71	.69	.67	.71	14.6
F/G[b]	1.20	1.14	1.23	1.37	1.27	1.20	1.32	1.15	16.6
d 0 to 14									
ADG, lb[b]	.41	.41	.44	.41	.45	.45	.38	.47	14.6
ADFI, lb	.50	.50	.54	.54	.54	.53	.51	.54	13.2
F/G[b]	1.25	1.22	1.23	1.32	1.20	1.19	1.35	1.14	9.7
d 14									
PUN, mg/dL[bc]	3.22	2.59	2.52	2.94	2.32	2.48	2.46	2.89	28.1

[a]Three hundred and sixty wea nling pigs were used (initially 12.2 lb and 14 d of age), five pigs/pen, six pens/treatment.
[b]Lysine effect ($P<.03$).
[c]Isoleucine effect (linear, $P<.03$).

DETERMINING THE OPTIMAL ISOLEUCINE:LYSINE RATIO FOR THE 25 TO 50 LB PIG[1]

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Summary

A 21-day growth trial was conducted to determine the isoleucine:lysine ratio necessary to optimize growth performance of the 25 to 50 lb nursery pig reared in a segregated early-weaning (SEW) system. Ten experimental diets, including two levels of lysine (.75% and 1.10% digestible lysine) and five apparent digestible isoleucine:lysine ratios (45, 50, 55, 60, and 65%), were used in a 2 × 5 factorial arrangement. Growth performance was improved by feeding 1.10% rather than .75% digestible lysine. Also, results indicated that the apparent digestible isoleucine requirement for the SEW-reared, 25 to 50 lb pig is approximately 50% of digestible lysine.

(Key Words: Early-Weaned Pigs, Amino Acids, Isoleucine.)

Introduction

In a previous experiment, the optimal isoleucine:lysine ratio for the SEW pig weighing 12 to 18 lb was found to be approximately 60% of lysine on an apparent digestible basis. However, the amount of isoleucine necessary to maximize the pig's growth will change continually as the pig grows. Because amino acids and protein are some of the most expensive nutrients in a typical animal diet, determining the animal's requirements also is important, so that these important nutrients are not under- or overfed. Therefore, the objective of this experiment was to determine the isoleucine:lysine ratio necessary to optimize growth performance of the SEW-reared pig weighing 25 to 50 lb.

Procedures

Two hundred and seventy high-lean growth pigs were blocked by weight (initially 25.14 ± 1.85 lb and 33 ± 2 d of age) and allotted to one of 10 experimental diets, with a total of four or five pigs/pen (depending upon the block) and six pens/treatment. The 10 experimental diets consisted of two levels of lysine (.75% and 1.10% apparent digestible lysine) and five apparent digestible isoleucine:lysine ratios (45, 50, 55, 60, and 65%) in a 2 × 5 factorial arrangement (Table 1). The pigs had been used in a previous trial to determine the optimal isoleucine: lysine ratio for the 12 to 18 lb pig and then were placed on a common phase II diet for 7 days prior to being reallotted for this study.

The .75% and 1.10% digestible lysine basal diets were corn-soybean meal based. Crystalline threonine, methionine, cystine, valine, and tryptophan (L-threonine, DL-methionine, L-cystine, L-valine, and L-tryptophan) were included in the basal diets to ensure that they contained all the essential amino acids suggested by the Illinois ideal amino acid ratio adjusted for an apparent digestible basis. Synthetic isoleucine (L-isoleucine) was added to the basal diets at the expense of corn starch to provide the five levels of isoleucine. The levels of digestible isoleucine in the .75% digestible lysine diets were .338, .375, .413, .450, and .488%. The levels of

[1]The authors extend appreciation to Keesecker Agribusiness of Washington, KS for providing the pigs used in this research. We also thank Heartland Lysine for donation of synthetic amino acids.

digestible isoleucine in the 1.10% digestible lysine diets were .495, .550, .605, .660, and .715%. The experimental diets were fed in a meal form for 21 d.

Pigs were housed in the Kansas State University SEW nurseries in 4 × 4 ft pens for the duration of the trial. Pens were equipped with one self-feeder and a nipple waterer to provide ad libitum access to feed and water.

The pigs were weighed and feed disappearance was determined on d 7, 14, and 21 of the experiment. Average daily gain (ADG), ADFI, and F/G were the response criteria.

The data were analyzed as a randomized complete block design, with pen as the experimental unit. Pigs were blocked on the basis of initial weight. Analysis of variance was performed using the GLM procedure of SAS. Linear, quadratic, and cubic polynomials were evaluated for dietary isoleucine levels.

Results and Discussion

From d 0 to 7, pigs fed the diets containing 1.10% apparent digestible lysine had improved ($P<.05$) ADG, ADFI, and F/G (Table 2). Average daily gain and ADFI also were improved (linear, $P<.02$; quadratic, $P<.01$; cubic, $P<.06$) as the digestible isoleucine:lysine ratio increased up to 55%, with no significant improvement thereafter. Similarly, F/G was improved (linear, $P<.04$; quadratic, $P<.09$) by increasing the isoleucine:lysine ratio in the diet to 55%.

During the d 7 to 14 period, pigs fed diets containing 1.10% digestible lysine had improved ($P<.05$) ADG and F/G compared with those fed .75% digestible lysine. The level of isoleucine in the diet had no effect on ADG or F/G. However, there was a lysine × isoleucine interaction ($P<.02$) for ADFI. This resulted from the greatly reduced feed intake observed among pigs fed the .75% digestible lysine diet formulated to the 45% digestible isoleucine:lysine ratio.

As observed during the first 2 weeks, ADG and F/G were improved ($P<.05$) from d 14 to 21 when pigs were fed the diets containing 1.10% digestible lysine. Also, ADG and ADFI were improved (linear, $P<.01$; and linear, $P<.01$; quadratic, $P<.01$; cubic, $P<.06$; respectively) by increasing the isoleucine:lysine ratio.

Overall, from d 0 to 21, ADG and F/G were improved by feeding 1.10% rather than .75% apparent digestible lysine. Average daily gain also was improved (linear, $P<.01$; quadratic, $P<.09$; cubic, $P<.03$) by increasing the digestible isoleucine:lysine ratio to 50%. There was a lysine × isoleucine interaction ($P<.09$) for ADFI. This occurred as a result of the low feed intake observed among pigs fed the .75% digestible lysine diets that were formulated to the 45% isoleucine:lysine ratio.

In conclusion, these data indicate that the SEW-reared, 25 to 50 lb pig requires an apparent digestible isoleucine:lysine ratio of at least 50% to optimize growth performance.

Table 1. Composition of the Basal Diets[a]

	Digestible Lysine, %	
Ingredient, %	.75%	1.10%
Corn	84.25	73.54
Soybean meal (46.5% CP)	4.96	15.44
Soy oil	3.00	3.00
Spray-dried blood meal	2.00	2.00
Monocalcium phosphate	2.03	1.85
Antibiotic[b]	1.00	1.00
Limestone	1.00	1.02
L-lysine HCl	0.44	0.57
Copper sulfate	0.08	0.08
Corn starch[c]	0.25	0.25
Vitamin premix	0.25	0.25
L-threonine	0.10	0.18
DL-methionine	0.05	0.12
Trace mineral premix	0.15	0.15
L-cystine	0.03	0.09
L-valine	-	0.06
L-tryptophan	0.06	0.08
Salt	0.35	0.35
TOTAL	100.00	100.00

[a]Diets were formulated to contain all essential amino acids (except isoleucine) at the University of Illinois ideal amino acid ratio adjusted for an apparent digestible basis. Diets also were formulated to contain .9% Ca and .8% P.

[b]Provided 50 g/ton carbadox.

[c]L-isoleucine replaced corn starch in the .75% and 1.10% digestible lysine basal diets to provide .338, .375, .413, .450, and .488% digestible isoleucine and .495, .550, .605, .660, and .715% digestible isoleucine, respectively. This provided 10 experimental diets in a 2 × 5 factorial arrangement, with two levels of lysine and five levels of digestible isoleucine:lysine (45, 50, 55, 60, and 65%).

Table 2. Influence of Increasing the Digestible Isoleucine:Lysine Ratio (45-65%) on Pig Performance[a]

	.75% Digestible Lysine					1.10% Digestible Lysine					
Item	45	50	55	60	65	45	50	55	60	65	CV
d 0 to 7											
ADG, lb[bc]	.54	.81	.84	.83	.86	1.06	1.16	1.22	1.20	1.22	10.4
ADFI, lb[e]	1.40	1.85	1.75	1.84	1.91	1.73	1.90	1.94	1.86	1.93	8.7
F/G[bd]	2.63	2.27	2.08	2.22	2.22	1.64	1.64	1.59	1.54	1.59	10.4
d 7 to 14											
ADG, lb[b]	.74	.97	.81	.94	.98	1.20	1.27	1.24	1.20	1.30	19.6
ADFI, lb[f]	1.58	2.25	2.12	2.18	2.22	2.04	2.19	2.27	2.17	2.23	8.9
F/G[b]	2.17	2.33	2.70	2.33	2.22	1.69	1.72	1.82	1.79	1.72	19.0
d 14 to 21											
ADG, lb[bg]	.92	1.12	1.09	1.13	1.13	1.34	1.39	1.37	1.41	1.45	10.3
ADFI, lb[c]	1.87	2.43	2.36	2.38	2.45	2.27	2.47	2.56	2.35	2.42	11.1
F/G[b]	1.96	2.17	2.13	2.08	2.17	1.69	1.79	1.85	1.67	1.67	11.4
d 0 to 21											
ADG, lb[bh]	.73	.97	.91	.97	.99	1.20	1.27	1.28	1.27	1.32	8.4
ADFI, lb[e]	1.62	2.18	2.07	2.13	2.19	2.02	2.19	2.26	2.12	2.19	7.3
F/G[b]	2.22	2.27	2.27	2.22	2.22	1.67	1.72	1.75	1.67	1.67	6.8

[a]Two hundred and seventy pigs were used (initially 25.1 lb and 33 d of age), four or five pigs/pen (depending upon the block), six pens/treatment.
[b]Lysine effect ($P<.05$).
[c]Isoleucine effect (linear, $P<.01$; quadratic, $P<.01$; cubic, $P<.06$).
[d]Isoleucine effect (linear, $P<.04$; quadratic, $P<.09$).
[ef]Lysine × Isoleucine interaction ($P<.09$ and $P<.02$, respectively).
[g]Isoleucine effect (linear, $P<.01$).
[h]Isoleucine effect (linear, $P<.01$; quadratic, $P<.09$; cubic, $P<.03$).

EVALUATION OF VARIOUS SPECIALTY PROTEIN SOURCES AS REPLACEMENTS FOR SPRAY-DRIED ANIMAL PLASMA IN DIETS FOR SEGREGATED EARLY-WEANED PIGS [1]

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Summary

We used high-health status, weanling pigs to evaluate six different protein sources as replacements for spray-dried animal plasma. Spray-dried blood meal, spray-dried egg, spray-dried wheat gluten, extruded soy protein concentrate, select menhaden fish meal, and soybean meal each replaced 2.5 or 5.0% spray-dried animal plasma. Pigs fed increasing levels of spray-dried blood meal, spray-dried egg, or soybean meal had decreased ADFI; however, increasing levels of select menhaden fish meal, extruded soy protein concentrate, and spray-dried wheat gluten had no influence or increased ADFI. For the high-health pigs used in this trial, select menhaden fish meal, extruded soy protein concentrate, and soybean meal appear to be effective in replacing a portion of the spray-dried plasma in the segregated-early weaned (SEW) diet. However, in contrast to other studies, the level of spray-dried animal plasma was not observed to have an effect on SEW pig performance. The conflicting results between this study and past trials in the performance of spray-dried blood meal and spray-dried egg indicate that quality standards should be established for all protein sources.

(Key Words: Protein Source, Weanling Pigs.)

Introduction

Specialty protein sources present palatable, highly digestible ingredients to assist in stimulating ADFI and maximizing ADG after weaning. Much research has been accumulated demonstrating the beneficial aspects of adding specialty proteins to weanling pig diets. However, little research has compared performance of pigs fed several specialty proteins in one experiment. Therefore, our objective was to compare various specialty proteins replacing 2.5 or 5% animal plasma in diets for weanling pigs.

Procedures

Animals and Housing. A total of 390 barrows (initially 9.3 lb and 13 ± 2 d of age; Newsham Hybrids) was used in a 26 d growth assay to evaluate different protein sources as replacements for spray-dried plasma. All pigs were housed in 4 × 4 ft pens with one nipple waterer, a five hole self-feeder, and tri-bar flooring in the KSU SEW nurseries. Pigs were allowed ad libitum access to water and feed. For the first week of the trial, nurseries were maintained at 85
week.

Diet Formulation. Dietary treatments, fed from d 0 to 14 (Table 1) after weaning, were arranged in a 2 × 6 factorial with an additional control treatment. All diets contained 25% dried whey, 5% lactose, and

[1]Appreciation is expressed to Newsham Hybrids, Colorado Springs, CO for providing the pigs used in this experiment.

[2]Food Animal Health and Management Center.

6% select menhaden fish meal; were formulated to contain 1.7% lysine, at least .48% methionine, .9% Ca, and .8% P; and were pelleted. The control diet contained 7.5% plasma and 15.7% soybean meal. Main effects included two levels of spray-dried animal plasma (2.5% and 5%) and six protein sources: spray-dried blood meal (AP 301G), spray-dried egg, spray-dried wheat gluten, extruded soy protein concentrate (Profine-E), select menhaden fish meal, and soybean meal. The protein sources replaced 2.5 or 5.0% spray-dried animal plasma in the control diet on a lysine basis except in the diets containing spray-dried wheat gluten. In these diets, spray-dried animal plasma was replaced on a protein basis, and synthetic lysine was added to compensate for the difference in lysine.

All pigs were fed the same diets from d 14 to 19 and d 19 to 26. The diet fed from d 14 to 19 was formulated to 1.45% total lysine, .40% methionine, .9% Ca, and .8% P. This diet was pelleted and contained 2.5% spray-dried animal plasma, 2.5% spray-dried blood meal, 2.5% select menhaden fish meal, and 20% dried whey. Pigs were fed a common diet from d 19 to 26, formulated to contain 1.35% lysine, .38% methionine, .9% Ca, and .8% P. This diet was fed in meal form and contained 10% dried whey and 2.5% spray-dried blood meal.

Statistical Analysis. Data were analyzed as a randomized complete block design in a 2 × 6 factorial arrangement with contrast statements investigating the mean differences between the control and other diets. Pigs were blocked by initial body weight, and pen served as the experimental unit. Data were analyzed for main effect differences (protein source and plasma replacement level) and two-way interactions. Analysis of variance was performed using the GLM procedure of SAS.

Results and Discussion

A protein source × protein source level interaction ($P<.05$) was observed for ADFI from d 0 to 14 after weaning (Table 2). The interaction was a result of pigs fed increasing levels of spray-dried blood meal, spray-dried egg, or soybean meal having decreased ADFI. However, pigs fed increasing levels of select menhaden fish meal, extruded soy protein concentrate, and spray-dried wheat gluten had constant or increased ADFI (data not shown). We did not observe an effect from increasing the level of plasma. Therefore, the interaction appeared to be influenced more by the amount of other protein sources in the diet than by the level of spray-dried animal plasma.

The level of protein source replacing spray-dried animal plasma did not influence ADG or feed efficiency for the d 0 to 14 period. However, the protein source did. Pigs fed diets containing select menhaden fish meal or extruded soy protein concentrate had increased ($P<.05$) ADG compared to pigs fed spray-dried blood meal, spray-dried egg, or spray-dried wheat gluten. The inclusion of soybean meal in the diet resulted in higher ADG ($P<.05$) than spray-dried egg. Pigs fed the control diet had intermediate ADG. Pigs fed diets containing spray-dried wheat gluten or soybean meal had intermediate F/G, whereas pigs fed diets containing spray-dried egg had decreased F/G ($P<.05$) as compared spray-dried blood meal, select menhaden fish meal, or extruded soy protein concentrate. In addition, pigs fed extruded soy protein concentrate had higher F/G than those fed the control diet.

From d 14 to 26 after weaning, when pigs were fed the same diet, ADG and F/G were not influenced ($P>.05$) by the protein source fed from d 0 to 14. Furthermore, ADG, ADFI, and F/G were not influenced by the amount of spray-dried animal plasma replaced in previous diets. However, pigs previously fed select menhaden fish meal subsequently consumed more feed ($P<.05$) than pigs fed spray-dried wheat gluten, extruded soy protein concentrate, spray-dried egg, spray-dried blood meal, or the control diet. Pigs fed soybean meal from d 0 to 14 after weaning subsequently consumed more feed than pigs initially fed the control diet.

For the overall trial (d 0 to 26 after weaning), the level of spray-dried animal plasma in the diet from d 0 to 14 after weaning had no

effect on growth performance. Pigs initially fed spray-dried egg had lower ($P<.05$) ADG than pigs fed select menhaden fish meal, extruded soy protein concentrate, soybean meal, or spray-dried wheat gluten. Additionally, pigs fed select menhaden fish meal from d 0 to 14 after weaning had overall higher ($P<.05$) ADG than pigs fed spray-dried blood meal. Pigs previously fed the control diet had intermediate cumulative ADG. Pigs fed spray-dried blood meal or spray-dried egg from d 0 to 14 after weaning had lower ($P<.05$) ADFI for the overall trial than pigs fed diets containing select menhaden fish meal, extruded soy protein concentrate, and soybean meal. Additionally, pigs initially fed select menhaden fish meal had higher ADFI than pigs initially fed spray-dried wheat gluten or the control. Feed efficiency for the overall trial was not influenced by the dietary protein source fed from d 0 to 14 after weaning.

Spray-dried blood meal has been shown previously to be a superior protein source. In our study, however, the inclusion of spray-dried blood meal did not result in superior performance compared to other protein sources. In fact, spray-dried blood meal resulted in lower ADG than select menhaden fish meal and extruded soy protein concentrate from d 0 to 14 and lower ADG and ADFI than select menhaden fish meal from d 0 to 28.

Spray-dried egg resulted in decreased growth performance when compared to soybean meal, extruded soy protein concentrate, and select menhaden fish meal. In addition, when spray-dried egg replaced more of the spray-dried animal plasma in the diet, the pigs' ADFI was lower from d 0 to 14 after weaning. More research is needed to define quality standards for spray-dried egg to help explain the differences in performance in different trials. Spray-dried wheat gluten has been shown to be an efficacious protein source to replace up to 50% of the spray-dried animal plasma in the diets for weanling pigs. In the present study, spray-dried wheat gluten had intermediate ADG and ADFI compared to the other protein sources.

Soybean meal proved to be as an efficacious protein replacement for spray-dried animal plasma. For pigs of high-health status, extruded soy protein concentrate had no advantage over soybean meal.

Pigs fed select menhaden fish meal consistently had excellent performance for the entire growth study. In addition, pigs had slightly improved ADFI from d 0 to 14 when select menhaden fish meal replaced larger amounts of spray-dried animal plasma. For the cumulative experiment (d 0 to 28) pigs fed select menhaden fish meal had higher ADG than pigs fed spray-dried blood meal and spray-dried egg.

Spray-dried blood meal and spray-dried egg have been shown to be a efficacious protein sources in nursery pig diets. However, in the present study, these sources resulted in the poorest growth performance throughout the experiment. Quality differences might explain the differences in growth performance between trials, so quality standards for protein sources should be established. These standards also would ensure an improvement in weanling pig growth performance as a result of the inclusion of the protein source.

Table 1. Diet Composition (As-Fed Basis), %[a]

		Protein Sources[b] plus Spray-Dried Animal Plasma (5.0-2.5%)											
		SDBM		SDEP		SMFM		ESPC		SBM		SDWG	
Ingredient, %	Control	5.0	2.5	5.0	2.5	5.0	2.5	5.0	2.5	5.0	2.5	5.0	2.5
Corn	31.40	31.67	31.94	29.11	26.82	30.96	30.41	29.78	28.11	27.99	24.58	31.28	31.12
SBM (48% CP)	15.74	15.74	15.74	15.74	15.74	15.74	15.74	15.74	15.74	21.68	27.61	15.74	15.74
SDAP	7.50	5.00	2.50	5.00	2.50	5.00	2.50	5.00	2.50	5.00	2.50	5.00	2.50
Lactose	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Soybean oil	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
SDBM	--	2.13	4.25	--	--	--	--	--	--	--	--	--	--
SDEP	--	--	--	4.95	9.90	--	--	--	--	--	--	--	--
SMFM	6.00	6.00	6.00	6.00	6.00	9.61	13.15	6.00	6.00	6.00	6.00	6.00	6.00
ESPC	--	--	--	--	--	--	--	4.14	8.27	--	--	--	--
SDWG	--	--	--	--	--	--	--	--	--	--	--	2.40	4.84
Dried whey	25.00	25.000	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Monocalcium phosphate (21% P, 18% Ca)	.66	.80	.94	.68	.71	.34	.04	.72	.78	.69	.73	.80	.94
Antibiotic[c]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Limestone	.66	.44	.38	.38	.27	.18	--	.46	.41	.46	.41	.44	.38
L-lysine HCl	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.33	.50
DL-methionine	.17	.20	.22	.10	.03	.15	.13	.16	.16	.16	.15	.14	.10

Premix	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40
Zinc oxide	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38
Salt	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
Total	100.00	100.00	100.00	10-0.00	100.00	10-0.00	100.00	10-0.00	100.00	10-0.00	100.00	100.00	100.00

[a]Experimental diets were fed from d 0 to 14 and formulated to contain 1.7% lysine, .48% methionine, .9% Ca, and .8% phosphorus.
[b]SDBM (spray-dried blood meal), SDEP (spray-dried egg), SMFM (select menhaden fish meal), ESPC (extruded soy protein concentrate), SDWG (spray-dried wheat gluten), SBM (soybean meal).
[c]Provided 55

Table 2. Main Effects of Replacing a Portion of Spray-Dried Animal Plasma with Specialty Proteins on the Growth Performance of Early-Weaned Pigs[a]

		Protein Source[b]						Plasma Level		
Item	Control	SDBM	SDEP	SMFM	ESPC	SBM	SDWG	5.0	2.5	CV, %
Day 0 to 14										
ADG, lb[c]	.64^{e,f}	.59^{f,g}	.57^{f}	.67^{e}	.68^{e}	.65^{e,g}	.60^{f,g}	.63	.63	11.6
ADFI, lb[d]	.67	.59	.61	.68	.67	.66	.62	.64	.64	8.5
F/G[c]	1.04^{e,g}	.99^{f,g}	1.08^{e}	1.01^{f,g}	.98^{f}	1.02^{e,f,g}	1.02^{e,f,g}	1.01	1.02	6.5
Day 14 to 26										
ADG, lb	1.03	1.06	.99	1.12	1.05	1.06	1.10	1.06	1.07	10.1
ADFI, lb[c]	1.43^{g}	1.47^{f,g}	1.46^{f,g}	1.57^{e}	1.49^{f,g}	1.52^{e,f}	1.48^{f,g}	1.50	1.50	6.3
F/G	1.39	1.39	1.47	1.41	1.41	1.45	1.35	1.41	1.41	9.2
D 0 to 26										
ADG, lb[c]	.82^{e,f,g}	.81^{e,g}	.76^{e}	.88^{f}	.85^{f,g}	.84^{f,g}	.83^{f,g}	.83	.83	8.8
ADFI, lb[c]	1.02^{e,f,g}	.99^{e}	1.00^{e}	1.09^{g}	1.05^{f,g}	1.06^{f,g}	1.02^{e,f}	1.04	1.04	6.2
F/G	1.25	1.23	1.32	1.23	1.22	1.27	1.22	1.25	1.25	6.5

[a]Three hundred ninety pigs (initially 4.2 kg and 13 ± 2 d of age) were used with five pigs/pen and six pens/treatment.
[b]SDBM (spray-dried blood meal), SDEP (spray-dried egg), SMFM (select menhaden fish meal), ESPC (extruded soy protein concentrate), SDWG (spray-dried wheat gluten), SBM (soybean meal)
[c]Portein source main effect ($P<.05$).
[d]Interaction (protein source × plasma replacement level) $P<.05$.
[e,f,g,h]Means on the same row within control or protein source with different subscripts differ ($P<.05$).

THE EFFECT OF CARBOHYDRATE SOURCE AND EXTRUSION PROCESSING ON GROWTH PERFORMANCE ON SEGREGATED EARLY-WEANED PIGS [1]

K. Hongtrakul, J. R. Bergstrom, R. D. Goodband, K. C. Behnke [2], I. H. Kim, W. B. Nessmith, Jr, M. D. Tokach, and J. L. Nelssen

Summary

A 21-day growth trial was conducted to determine the effect of various carbohydrate sources with or without moist extrusion processing on growth performance of segregated early-weaned pigs. Treatments included five different carbohydrate sources (corn, corn starch, rice, wheat flour, and grain sorghum) with or without moist extrusion processing in a 2 × 5 factorial arrangement. No interactions were observed among carbohydrate sources and extrusion processing. Growth performance was not improved by extrusion processing. Surprisingly, pigs fed corn had poorer growth performance compared to those fed other carbohydrate sources. These results suggest that corn starch, rice, wheat flour, and grain sorghum are suitable alternatives to corn in diets for segregated early-weaned pigs.

(Key Words: Segregated Early-Weaned Pigs, Extrusion, Carbohydrate Sources.)

Introduction

In the United States, corn is the predominate energy source used in swine diets. However, in Asia and other parts of the world, many other carbohydrate sources are available and less expensive than corn. Therefore, the objective of this study was to evaluate the effects of various carbohydrate sources on growth performance of the segregated early-weaned pig. In addition, a second objective was to determine the possible beneficial effects of moist extrusion processing of the carbohydrate sources and effects of any potential interactions between the different carbohydrate sources and moist extrusion processing on pig growth performance.

Procedures

Three hundred and fifty high-lean growth potential and high health pigs were weaned initially at 10 ± 2 d of age and delivered to the segregated early-weaning (SEW) facilities at Kansas State University. The pigs were blocked by weight (initially 9.7 ± 2.0 lb) and allotted to one of 10 experimental diets. Each treatment had five pigs per pen and seven replications (pens). Treatments were arranged in a 2 × 5 factorial with main effects including carbohydrate sources (corn, corn starch, wheat flour, rice, and grain sorghum) with or without moist extrusion processing.

In this study, only carbohydrate sources were extruded through a Wenger X-20 single screw extruder, mixed in the respective diets, then pelleted in a pellet mill equipped with a 3/32 in. die. The extruder conditions were 280°F barrel jacket temperature at 8th head, 300 psig cone pressure, 5 lb/min retention time, and approximately 212°F temperature of materials exiting the extruder.

The trial was divided into two phases (Table 1). Pigs were weaned and fed a complex diet from d 0 to 7 postweaning. All diets contained 42% of the respective carbohydrate sources, 20% dried whey, 10% moist extruded soy protein concentrate, 6.7% spray-

[1]The authors thank Newsham Hybrids, Colorado Springs, CO, for providing the pigs used in this experiment.

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dried plasma protein, and 6% select menhaden fish meal. Diets were formulated to 1.7% total lysine, with all other amino acids above suggested estimates based on current ratios relative to lysine. The amounts of synthetic lysine and methionine varied slightly among experiment diets based on differences in lysine concentration of the carbohydrate sources. During d 7 to 21 postweaning, pigs were fed transition diets containing 47% of their respective carbohydrate source, 15.5% soybean meal, 10% dried whey, 5% select menhaden fish meal, and 3% spray-dried plasma protein. Diets were formulated to 1.5% total lysine.

In our diet formulation, the various carbohydrate sources were maximized by reducing the amount of dried whey and supplemental lactose as well as decreasing the amounts of fat added to the diets compared to levels typically observed in some commercial diet formulations. Therefore, the addition of carbohydrate sources was maximized to better evaluate them in this study.

During the experiment, pigs were housed at the Kansas State University SEW facilities in environmentally controlled 4 × 4 ft pens and allowed ad libitum access to water and feed. Temperature was maintained at 95°F for the first week and then gradually reduced for pig comfort. The pigs were weighed and feed disappearance was determined on d 7,14, and 21 postweaning. Average daily gain, ADFI, and F/G were the response criteria. Data were analyzed as a randomized block design in a 2 × 5 factorial arrangement for carbohydrate × extrusion processing. Analysis of variance was performed using the GLM procedure of SAS.

Results and Discussion

In this study, no carbohydrate sources by extrusion processing interactions ($P>.10$) were observed (Table 2). From d 0 to 7 postweaning, ADG surprisingly was poorer for pigs fed diets containing corn compared to pigs fed any of the other carbohydrate sources ($P<.01$). Pigs fed rice or grain sorghum had the greatest ADG, whereas pigs fed corn starch and wheat flour had intermediate ADG. Pigs fed the extruded diets had an ADG of .51 lb/d, which was not different than that of pigs fed the nonextruded diets (.54 lb/d, $P>.10$). Average daily feed intake followed a similar trend, in that pigs fed corn had the lowest ADFI. However, pigs fed corn only tended to be different from those pigs fed either rice or grain sorghum ($P<.10$). Pigs fed corn starch and wheat flour had intermediate ADFI. Extrusion processing had no effect on ADFI ($P>.10$); pigs fed the extruded carbohydrate sources diet had an ADFI of .46 lb/d and those fed the nonextruded diet had an ADFI of .44 lb/d. Feed efficiencies were excellent across all dietary treatments. The excellent F/G observed during the first week of the study was a result of the pigs rehydrating after delivery from Colorado. The different carbohydrate sources had no effect on F/G for the first 7 d of the study ($P>.10$). However, numerical trends were the same as for ADG and ADFI; pigs fed diets containing corn had numerically poorer F/G than those fed corn starch, rice, wheat flour, or grain sorghum. In addition, extrusion processing of carbohydrate sources had significant effects on F/G ($P<.05$), and pigs fed the extruded diets had poorer F/G than those fed the nonextruded diets. This was the only significant extrusion effect that was observed throughout the study.

From d 7 to 21, pigs were fed their respective transition diet. Average daily gain during this transition period followed the same trends with pigs fed the corn-based diet having significantly poorer ADG ($P<.10$) compared to pigs fed corn starch, wheat flour, or grain sorghum. Those pigs fed rice had intermediate ADG. No significant differences in ADG ($P>.10$) occurred for pigs fed extruded versus nonextruded carbohydrate sources. Average daily feed intake was not influenced by either carbohydrate source or moist extrusion processing of carbohydrate sources ($P>.10$). However, pigs fed the corn-based diet had poorer F/G compared to those fed either corn starch, wheat flour, or grain sorghum ($P<.10$). Pigs fed the rice-based diet had poorer F/G compared to those fed either corn starch, wheat flour, or grain sorghum ($P<.10$). Moist extrusion processing of carbohydrate sources had no significant effects on F/G ($P>.10$).

For the overall study (d 0 to 21 postweaning), pigs fed the corn-based diet sur-

prisingly had poorer ADG than those fed either corn starch, rice, wheat flour, or grain sorghum ($P<.01$). In addition, extrusion processing of carbohydrate sources had no effect on ADG. However, ADFI was not influenced by either carbohydrate sources or moist extrusion processing. Finally, for the overall study, pigs fed the corn-based diet had poorer F/G than those fed either corn starch, rice, wheat flour, or grain sorghum ($P<.01$). Again, no overall differences were observed in terms of F/G ($P>.10$) for pigs fed either extruded carbohydrate sources or nonextruded carbohydrate sources.

Based on these results, pigs fed the corn-based diet had decreased ADG and F/G compared to pigs fed other carbohydrate sources. We have no explanation for that negative response. Analyses of corn quality (test weight, nutrients, etc.) were within normal allowances. In addition, the corn was checked and found to be free of mycotoxins. Therefore, results of this study suggest that ingredients such as corn starch, wheat flour, rice, and grain sorghum are viable alternatives for use as carbohydrate sources in diets for segregated early-weaned pigs.

Table 1. Compositions of Experimental Diets

Ingredient, %	SEW[a]	Transition[b]
Carbohydrate source[c]	42.00	47.00
Dried whey	20.00	10.00
Moist extruded soy protein concentrate	10.38	6.00
Plasma protein	6.70	3.00
Fish meal	6.00	5.00
Soybean meal	5.00	15.49
Soybean oil	4.00	4.00
Egg protein	2.00	2.50
Wheat gluten	---	2.50
Vitamins and minerals	3.83	4.49
Lysine and methionine[d]	---	---
Antibiotic[e]	1.00	1.00
Total	100.00	100.00

[a]Diets were formulated to contain 1.7% lysine, .48% methionine.
[b]Diets were formulated to contain 1.5% lysine, .42% methionine.
[c]Carbohydrate sources included corn, corn starch, wheat flour, rice, and grain sorghum with or without moist extrusion processing.
[d]The amounts of synthetic lysine and methionine varied slightly among experimental diets based on differences in lysine concentration of the carbohydrate source.
[e]Provided 50 g/ton carbadox.

Table 2. The Effects of Extruding Carbohydrate Sources on Growth Performance of Early-Weaned Pigs[a]

	Extruded					Nonextruded					
Item,	Corn	Corn Starch	Rice	Wheat Flour	Grain Sorghum	Corn	Corn Starch	Rice	Wheat Flour	Grain Sorghum	CV
d 0 to 7											
ADG, lb[b]	.45	.46	.54	.49	.61	.45	.58	.58	.54	.56	17.06
ADFI, lb[c]	.46	.43	.49	.44	.51	.39	.46	.48	.45	.43	13.48
F/G[d]	1.02	.93	.91	.90	.84	.87	.79	.83	.83	.77	16.60
d 7 to 21											
ADG, lb[c]	1.04	1.11	1.11	1.10	1.09	.96	1.11	1.06	1.22	1.12	12.69
ADFI, lb	1.33	1.34	1.36	1.31	1.34	1.29	1.37	1.38	1.35	1.35	7.03
F/G[c]	1.28	1.21	1.23	1.19	1.23	1.34	1.23	1.30	1.11	1.21	10.58
d 0 to 21											
ADG, lb[b]	.75	.77	.81	.78	.83	.71	.85	.79	.83	.80	8.48
ADFI, lb	.90	.88	.93	.88	.93	.85	.93	.94	.92	.89	6.97
F/G[b]	1.20	1.14	1.15	1.13	1.12	1.20	1.09	1.19	1.11	1.11	6.63

[a]Three hundred and fifty weanling pigs (initially 9.7 ± 2 lb and 10 ± 2 d of age were used with five pigs/pen and seven pens/treatment.
[b,c]Carbohydrate effect ($P<.01$ and .10, respectively).
[d]Extrusion effect ($P<.05$).

THE EFFECT OF INGREDIENT PROCESSING AND DIET COMPLEXITY ON GROWTH PERFORMANCE OF THE SEGREGATED EARLY-WEANED PIG[1]

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Summary

A 14-day growth trial was conducted to determine the interactive effects of ingredient processing and diet complexity on growth performance of segregated early-weaned pigs. Three processing combinations were used with either a simple or complex diet formulation in 2 × 3 factorial arrangement. Diets were pelleted (control); the corn was moist-extruded, then the complete diet pelleted (extruded); or the complete diet was expanded then pelleted (expanded). An interaction was observed between ingredient processing and diet complexity. Pigs fed the control or extruded diets had improved growth performance as diet complexity increased. However, pigs fed the expanded diets showed little response to increasing diet complexity. Under these experimental conditions, pigs fed moist-extruded corn had the best growth performance. However, further research is warranted to evaluate expander conditioning of complex starter diets.

(Key Words: Segregated Early-Weaned Pigs, Diet Complexity, Feed Processing.)

Introduction

In a previous study, we evaluated extrusion processing of the carbohydrate source in diets for segregated early-weaned pigs. We observed no beneficial effects of extrusion processing on pig performance. Because previous experiments have reported positive effects of extrusion processing on starter pig performance, the objective of this study was to investigate possible interactive effects of different ingredient processing and diet complexity on pig growth performance.

Procedures

Three hundred and sixty high-lean growth potential high-health barrows were initially weaned at 10 ± 2 d of age and delivered to the segregated early weaning facilities at Kansas State University. The pigs were blocked by weight (initially 10 lb ± 1.0 lb) and allotted randomly to one of six experimental diets. Each treatment had five pigs per pen and 12 replications (pens). Treatments were arranged in a 3 × 2 factorial with main effects including ingredient processing and diet complexity. Processing treatments included a pelleted (3/32 in. diameter) diet (control), moist extrusion processing of only the corn, then pelleting of the complete diets (extruded), and expander conditioning of the complete diet followed by pelleting (expanded).

The extruder conditions were: 280°F barrel jacket temperature at the 8th head, 300 psig cone pressure, 5 lb/min retention time, and approximately 212°F exit temperature. Extruded corn then was mixed in the complex and simple diets and pelleted through a 3/32 in. die. The expander conditions were .9 ton/hr production rate, 175 psig cone pressure, and 130°F conditioner temperature. For all diets, the conditioner temperature of the pellet mill was 140°F.

[1]The authors thank Newsham Hybrids, Colorado Springs, CO, for providing the pigs used in this experiment.

[2]Department of Grain Science and Industry.

Diet complexity main effects included a relatively simple (1% spray-dried plasma protein and 15% dried whey) or complex (6% spray-dried plasma protein and 25% dried whey) diet (Table 1). All diets were formulated to 1.7% total lysine and .48% methionine, with all other amino acids above suggested estimates. Pigs were housed in 4 ft × 4 ft pens and allowed ad libitum access to water and feed. Pigs were weighed and feed disappearance was determined on d 7 and 14 postweaning. Average daily gain, ADFI, and F/G were the response criteria. In addition, fecal samples were collected on d 14 from at least three pigs per pen to calculate apparent digestibility of DM, CP, and energy.

Results and Discussion

From d 0 to 7 and 0 to 14 postweaning, ingredient processing by diet complexity interactions ($P < .10$) were observed (Table 2). These interactions appeared to be the results of a large improvement in growth performance as diet complexity increased for pigs fed either the control or extruded diets compared to a small improvement with increasing diet complexity for pigs fed the expanded diets.

From d 0 to 7 postweaning, pigs fed the complex diets had increased ($P < .05$) ADG and ADFI compared with those fed the simple diets. Diet complexity had no effect on F/G ($P > .10$). Pigs fed extruded corn had increased ADG and ADFI compared with those fed either the control or expanded diets. Pigs fed expanded diets had poorer F/G compared with those fed control or extruded diets ($P < .01$).

From d 7 to 14, no ingredient processing by diet complexity interactions were observed ($P > .10$). Pigs fed complex diets had increased ($P < .05$) ADG compared with those fed the simple diets. Average daily feed intake and F/G were not affected by diet complexity; however, pigs fed the complex diets had numerically better F/G than those fed the simple diets. Pigs fed extruded corn had increased ADG compared with those fed either the control or expanded diets. Average daily feed intake of pigs fed either the extruded corn or expanded diets was higher than that of pigs fed the control diet. As a result, F/G was best for pigs fed extruded corn, followed by control, and pigs fed the expanded diets had the poorest F/G.

For the overall study (d 0 to 14 postweaning), ingredient processing by diet complexity interactions were observed for ADG, ADFI, and F/G ($P < .10$). The interaction appeared to be a result of a large increase in ADG of pigs fed the control or extruded diets as diet complexity increased compared with a smaller increase for pigs fed the expanded diets. For ADFI, the interaction appeared to be the result of a large increase in ADFI for pigs fed the extruded and expanded diets compared with no change in feed intake for pigs fed the control diets as diet complexity increased. Finally, for F/G, the interaction appeared to be the result of improved efficiency of pigs fed the control and extruded diets as diet complexity increased compared with poorer F/G of pigs fed the expanded diets.

On d 14, fecal samples were collected from at least three of the pigs in each pen to calculate apparent digestibility of DM, CP and energy. No ingredient processing by diet complexity interactions were observed ($P > .10$). Pigs fed the complex diets had greater apparent digestibility of DM, CP, and energy than those fed simple diets. Pigs fed extruded diets had greater apparent digestibility of DM, CP, and energy than those fed either the control or expanded diets.

Under the ingredient processing conditions used in this experiment, pigs fed extruded corn had improved ADG and F/G compared with those fed control or expanded diets. Pigs fed expanded diets and extruded diets had similar ADFI; however, F/G for the former was much poorer. This was especially evident for those fed the complex diets. Because the complete diet was expanded, temperatures or other expander conditions may have negatively affected the milk products or specialty protein sources contained in the diet. Therefore, further research is warranted to evaluate expander conditioning in

association with complex starter diets. Furthermore, the beneficial response observed to extrusion processing of the corn in this study and variable results in others may be explained by correlations between extruder conditions (degree of cook) and growth performance.

Table 1. Compositions of Experimental Diets[a]

Ingredient, %	Complex	Simple
Corn	31.96	37.17
Dried whey	25.00	15.00
Plasma protein	6.00	1.00
Fish meal	6.00	4.00
Soybean meal	14.70	33.73
Soybean oil	6.00	4.00
Lactose	5.00	---
Spray-dried blood meal	1.75	1.00
Monocalcium phosphate	.76	1.09
Limestone	.45	.68
Zinc oxide	.38	.38
Vitamin premix	.25	.25
Lysine-HCL	.15	.15
Methionine	.15	.10
Trace minerals	.15	.15
Salt	.10	.10
Antibiotic[b]	1.00	1.00
Cromic oxide	.20	.20
Total	100.00	100.00

[a]All diets were formulated to contain 1.70% lysine, .48% methionine, .90% Ca, and .80% P. Complex and simple diets were either pelleted (control); the corn was extruded, then the complete diet was pelleted (extruded); or the complete diet was expanded then pelleted (expanded) to provide the experimental treatments. Diets were fed from weaning to d 14.
[b]Provided 50 g/ton carbadox.

Table 2. The Effects of Ingredient Processing and Diet Complexity on Weanling Pig Growth Performance[a]

	Simple			Complex			
Item	Control	Extruded	Expanded	Control	Extruded	Expanded	CV
d 0 to 7							
ADG, lb[bcd]	.35	.38	.35	.36	.47	.38	17.77
ADFI, lb[bcd]	.31	.33	.34	.32	.40	.39	13.24
F/G[c]	.89	.87	.97	.89	.85	1.03	16.62
d 7 to 14							
ADG, lb[bc]	.66	.75	.63	.73	.87	.66	13.27
ADFI, lb[c]	.80	.82	.84	.77	.90	.87	11.65
F/G[c]	1.21	1.09	1.33	1.05	1.03	1.32	11.62
d 0 to 14							
ADG, lb[bcd]	.50	.57	.49	.54	.67	.51	11.32
ADFI, lb[bcd]	.55	.57	.59	.54	.65	.63	10.39
F/G[bcd]	1.10	1.00	1.20	1.00	.97	1.24	8.21
Apparent digestibility, %							
DM[bc]	89.88	90.94	90.07	93.48	94.03	93.22	.99
N[bc]	85.78	88.44	86.75	90.37	91.27	90.30	1.91
DE[bc]	90.39	91.73	90.67	93.76	94.58	93.73	.99

[a]Three hundred sixty weaning pigs (initially 10 ± 1.0 lb and 10 ± 2 d of age), five pigs/pen, 12 pens/treatment. All diets were pelleted through a 3/32 inch die. Complex and simple diets were either pelleted (control); the corn was extruded, then the complete diet was pelleted (extruded); or the complete diet was expended then pelleted (expanded) to provide the experimental treatments. Diets were fed from weaning to d 14.
[b]Complexity effect ($P < .05$).
[c]Processing effect ($P < .01$).
[d]Complexity × processing interaction ($P < .10$).

THE EFFECTS OF DIETARY ENERGY DENSITY AND LYSINE:CALORIE RATIO ON THE GROWTH PERFORMANCE OF THE 20 TO 55 LB PIG[1]

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Summary

A total of 336 barrows (initially 21.8 lb and 31 ± 2 d of age) was used to evaluate the results of increasing levels of choice white grease and lysine:calorie ratio on pig performance. Increasing levels of both choice white grease and lysine:calorie ratio improved the growth rate and efficiency of pigs fed from 20 to 55 lb.

(Key Words: Energy Density, Lysine:Calorie Ratio, Performance.)

Introduction

The recent increases in diet costs have pushed pork producers to improve the efficiency of their pigs. One way to achieve this is to increase the energy density of the diet by adding fat, traditionally soybean oil or choice white grease. Research at the University of Alberta showed that increasing the caloric content and lysine:digestible energy ratio improved feed efficiency of newly weaned pigs. Therefore, the objective of this experiment was to evaluate the effects of energy density and lysine:calorie ratio on the growth of pigs reared in a segregated early-weaning system fed from 20 to 55 lb.

Procedures

Three hundred-thirty six barrows (initially 21.8 lb and 31 ± 2 d of age) were used in a 21 d growth assay to evaluate the effects of dietary energy density and lysine:calorie ratio on growth performance. Pigs were allotted initially by weight in a 3 × 4 factorial arrangement with six replicate pens per treatment. There were four or five pigs per pen with an equal number of pigs per pen within replicate. Pigs were fed increasing levels of choice white grease (CWG; 0, 3, and 6%) and lysine:calorie ratios (3, 3.45, 3.9, and 4.35 g lysine:Mcal ME; Table 1). All diets contained .15% L-lysine HCl and were formulated to contain .80 Ca and .70% and P. Methionine and threonine levels were maintained relative to lysine with the addition of DL-methionine and L-threonine. All diets were fed in meal form. Pigs were weighed on d 7, 14, and 21 to determine ADG, ADFI, and F/G. Additionally, two pigs per pen were scanned ultrasonically on d 21 to determine tenth rib fat depth.

Data from this experiment were analyzed as a randomized complete block design using the GLM function of SAS. The main and interactive effects of energy density and lysine:calorie ratio were analyzed. Energy density and lysine:calorie ratio evaluated further using linear and quadratic polynomials. Fat depth measurements were analyzed using d 21 weight as a covariable.

Results and Discussion

From d 0 to 7, increasing the lysine:calorie ratio improved ADG and F/G (linear, $P < .001$). Also, increasing CWG improved F/G (linear, $P < .05$).

During d 7 to 14, an interaction between CWG and lysine affected ADG ($P < .01$).

[1]The authors acknowledge Nesaham Hybrids, Colorado Springs, CO, for providing the pigs used in this trial.

Table 1. Basal Diet Composition[a]

Ingredient	Percent
Corn	72.85
SBM (46.5% CP)	22.41
Monocalcium phosphate (21% P)	1.68
Limestone	1.08
Antibiotic	1.00
Salt	.35
Vitamin premix	.25
Trace mineral premix	.15
L-lysine HCl	.15
Copper sulfate	.08
Choice white grease[c]	--
DL-methionine	--
L-threonine	--
Total	100.00

[a]Diets were fed in the meal form.
[b]Provided 50 g/ton carbadox.
[c]Choice white greased replaced corn and SBM at 3 and 6% of the diet.

The interaction can be explained by the poor performance of the pigs fed the 3% CWG diet at 4.35 g lysine:Mcal ME. These pigs performed much more poorly than expected. However, increasing the lysine:calorie ratio increased ADFI and improved F/G (linear, $P < .01$). Adding CWG to the diet decreased ADFI and improved F/G ($P < .05$ and .001, respectively).

During the final week of the trial, pigs fed increasing CWG were more efficient (linear and quadratic, $P < .01$) and ate less feed (linear, $P < .001$). Increasing the lysine:calorie ratio increased ADFI and improved F/G (linear, $P < .02$). Average daily gain was not affected by either CWG or lysine:calorie ratio.

For the entire 21 d trial, increasing the lysine:calorie ratio resulted in pigs that grew faster and ate more feed (linear, $P < .01$). Pigs fed increasing CWG had decreased ADFI (linear, $P < .01$). Additionally, F/G improved as both CWG and lysine:calorie ratio increased (linear and quadratic, $P < .01$). Tenth rib backfat depth decreased (linear, $P < .001$) as the lysine:calorie ratio increased and was greater as CWG increased (linear, $P < .01$). This indicates that although CWG did not affect energy intake, the pigs used the increased fat as a storage component rather than an immediate energy source for lean growth.

These data indicate that CWG can be added to the phase III diet to improve feed efficiency. However, the addition of CWG, or any other fat source, must be evaluated based upon the cost of the energy compared to the gains in efficiency. Although ADG appeared to be maximized for pigs fed 3.9 g lysine/Mcal ME, F/G improved linearly through 4.35 g lysing/Mcal ME. The impact of increasing the lysine:calorie ratio also must be evaluated based upon the economic returns.

Table 2. Influence of Increasing Energy Density and Lysine:Calorie Ratio in the Diet on Pig Performance[a]

	CWG, %			g Lysine:Mcal ME[b]					Main Effects			Fat		Lysine	
Item	0	3	6	3.0	3.35	3.9	4.35	CV	Fat	Lysine	Fat × Lysine	Lin.	Quad.	Lin.	Quad.
Day 0 to 7															
ADG. lb	1.17	1.14	1.19	1.04	1.13	1.25	1.24	10.4	.3703	.0001	.4829	.741	.1722	.0001	.0974
ADFI, lb	1.72	1.66	1.65	1.69	1.66	1.70	1.65	8.7	.2007	.6516	.7535	.4638	.5876	.5665	.7040
F/G	1.48	1.47	1.40	1.64	1.48	1.36	1.33	8.8	.0485	.0001	.7233	.0244	.3116	.0001	.0452
Day 7 to 14															
ADG, lb	1.39	1.39	1.44	1.30	1.39	1.47	1.46	7.5	.1082	.0001	.0067	.0619	.3364	.0001	.0491
ADFI, lb	2.23	2.16	2.13	2.21	2.22	2.19	2.08	6.6	.0854	.0173	.1001	.0318	.5664	.0082	.0802
F/G	1.63	1.56	1.49	1.70	1.60	1.49	1.43	7.2	.0004	.0001	.4993	.0001	.9984	.0001	.4235
Day 14 to 21															
ADG, lb	1.49	1.53	1.49	1.44	1.55	1.49	1.53	9.8	.6149	.1843	.8547	.9239	.3287	.2034	.3911
ADFI, lb	2.64	2.44	2.37	2.58	2.48	2.51	2.38	8.5	.0002	.0487	.5708	.0001	.2368	.0123	.7043
F/G	1.78	1.59	1.60	1.79	1.61	1.67	1.56	8.8	.0001	.0001	.7975	.0001	.0144	.0002	.3177
Day 0 to 21															
ADG, lb	1.35	1.35	1.37	1.26	1.35	1.40	1.41	5.3	.4508	.0001	.0638	.2946	.4737	.0001	.0021
ADFI, lb	2.20	2.08	2.05	2.16	2.12	2.12	2.03	5.6	.0002	.0173	.2598	.0001	.1173	.0035	.4512
F/G	1.63	1.54	1.50	1.71	1.57	1.51	1.44	3.1	.0001	.0001	.4177	.0001	.031	.0001	.002
Fat depth, in	.303	.310	.328	.331	.322	.308	.294	14.0	.0199	.0066	.0643	.0071	.4601	.0005	.6966

[a]Means derive from 336 barrows (initially 21.8 lb) housed at four or five pigs per pen with six replicate pens per treatment.
[b]Mcal ME = megacalorie of metabolizable energy.

THE EFFECTS OF EXPERIMENTAL POTATO PROTEIN ON STARTER PIG GROWTH PERFORMANCE [1]

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Summary

This study suggested that experimental potato protein can be an effective replacement for a portion of spray-dried animal plasma in starter diets. Pigs fed combinations of experimental potato protein and spray-dried plasma had greater ADG than those fed either protein source alone. In phase II diets, pigs fed experimental potato protein had similar ADG and F/G compared with those fed spray-dried blood meal and select menhaden fish meal.

(Key Words: Starter Pig Performance, Potato Protein.)

Introduction

Swine producers have continually decreased the age at weaning in order to increase the number of pigs weaned per sow and ultimately improve profitability. However, the age at weaning is dependent on good management factors including nutrition, environmental regulation, and health status. Because of improvements in technology in these areas, weaning ages below 21 days are now commonplace throughout the U.S. swine industry. Important developments facilitating early weaning are the use of high nutrient dense diets and the concept of phase feeding. These practices involve the use of highly digestible ingredients such as dried whey, spray-dried animal plasma and blood meal, and select menhaden fish meal. Because of the relatively high cost of these ingredients, research has continually focused on examining other ingredients to improve pig growth performance and lower feed costs per unit of gain. Potato protein is one such ingredient that may be a cost-effective replacement for the more commonly used animal protein sources in starter diets. In the 1994 Kansas State University Swine Day Report of Progress, we evaluated the use of potato protein in starter diets. These trials demonstrated that high levels of potato protein (5 to 7.5%) can result in decreased feed intake and growth of weanling pigs. This may have been the result of a bitter off-flavor stemming from the presence of glycoalkaloids contained in potato and potato protein. Complaints from the feed industry about the off-flavor of potato protein have led to the development of an experimental potato protein with improved palatability. By including a special refinery step in the production process, bitter components can be removed. Therefore, the objective of this experiment was to evaluate the use of an experimental potato protein as a replacement for spray-dried animal plasma in high nutrient density phase I diets for weanling pigs and to compare pigs fed experimental potato protein, conventional potato protein, spray-dried blood meal, and select menhaden fish meal in phase II diets.

[1]Appreciation is expressed to Avebe America, Inc. Princeton, NJ for partial financial support and to Ellen Johncock and Eichman Brothers Farms, St George, KS for providing animals and facilities in Exp.2. We also thank Dr. Mendel Friedman, USDA-ARS Western Regional Research Center for glycoalkoloid analysis of the potato proteins used in these experiments.

Procedures

Experiment 1. A total of 180 weanling pigs (PIC C15 x L 326) with an average initial weight of 12.98 lb and 20 +/- 2 days of age was used in a 35-d growth assay to determine the effects of replacing spray-dried animal plasma with experimental potato protein on starter pig growth performance. Pigs were blocked by initial weight, randomized across treatments by sex and ancestry, and allotted to each of five dietary treatments. Each treatment had six pigs per pen and six replications (pens). The control diet (Table 1) was a high nutrient density diet containing 20% dried whey, 4% select menhaden fish meal, and 7% spray-dried animal plasma and formulated to 1.5% total lysine (1.26% apparent digestible lysine) and at least .42% total methionine (.35% apparent digestible methionine). The apparent digestible lysine values were 5.18% for experimental potato protein and 5.92% for spray-dried animal plasma. Other amino acid requirements were balanced on a total amino acid basis to meet or exceed NRC (1988) estimates as well as meet or exceed ARC (1981) digestible amino acid estimates based on a ratio relative to lysine. Additional diets consisted of experimental potato protein replacing 25, 50, 75, or 100% of the spray-dried animal plasma on a digestible lysine basis. Thus, the five experimental diets contained the following blends of spray-dried animal plasma and experimental potato protein: 7.0:0, 5.25:2.0, 3.50:4.0, 1.75:6.0, or 0:8.0%, respectively. The experimental diets were fed from d 0 to 14 postweaning (phase I). Diets were pelleted and offered ad libitum. No creep feed was offered to pigs prior to weaning. From d 14 to 35 postweaning, all pigs were fed a common corn-soybean meal diet containing 10% dried whey and 2.5% spray dried blood meal and formulated to 1.35% total lysine and .38% total methionine. Pigs were weighed and feed disappearance was determined weekly for the 35-day trial to calculate ADG, ADFI, and feed efficiency (F/G).

Experiment 2. Two hundred fifty-five weanling pigs (PIC C15 x L 326), initially 11.72 lb and 17 +/- 2 days of age, were used to compare the effects of spray-dried blood meal, select menhaden fish meal, experimental potato protein, and conventional potato protein in phase II diets (d 7 to 28 postweaning) on growth performance. Pigs were blocked by initial weight, randomized across treatments by sex, and allotted to each of five dietary treatments. Eight, nine, or 10 pigs per pen within weight block and six replications (pens) per treatment were used. Pigs were all fed the same pelleted, high nutrient density diet (20% dried whey and 9% animal plasma) from d 0 to 7 postweaning. On day 7 postweaning, pigs were switched to experimental diets containing 2.5% spray dried blood meal, 5.51% select menhaden fish meal, 4.17% conventional potato protein, 4.17% experimental potato protein, or 8.34% experimental potato protein (Table 3). All diets contained 10% dried whey with experimental protein sources substituted on an apparent digestible lysine basis with the exception of the 8.34% experimental potato protein diet, which also replaced a portion of the soybean meal on a digestible lysine basis. The apparent digestible lysine values were 8.64% for spray-dried blood meal, 3.93% for select menhaden fish meal, and 5.18% for both experimental and commercial potato proteins. Diets were formulated to contain 1.05% apparent digestible lysine (at least 1.25% total lysine) and at least .30% apparent digestible methionine (.34% total methionine). Other amino acid requirements met or exceeded NRC (1988), estimates for total amino acids and met or exceeded ARC (1981) digestible amino acid estimates based on a ratio relative to lysine. Pigs were weighed and feed disappearance was determined weekly for the 28-d trial to calculate ADG, ADFI, and F/G.

Experiment 3. Two hundred ten weanling pigs (PIC C15 x L 326), with an average initial weight of 12.21 lb and 20 +/- 3 d of age, were used in a 35-d growth assay to determine the effects of increasing experimental potato protein or spray-dried animal plasma on starter pig growth performance. A second objective was to compare growth performance of pigs fed either the original experimental potato protein or a second experimental potato protein. Pigs were

blocked by initial weight, randomized across treatments by sex and ancestry, and allotted to each of six dietary treatments. Each treatment had seven pigs per pen and five replications (pens). The control diet (Table 3) was a high nutrient density diet containing 20% dried whey, 17.5% dried skim milk, and 4% select menhaden fish meal and formulated to at least 1.46% total lysine (1.26% apparent digestible lysine) and at least .42% total methionine (.35% apparent digestible methionine). Additional diets consisted of either 3.5 and 7.0% spray-dried animal plasma or 4.0 and 8.0% experimental potato protein and lactose added at the expense of dried skim milk. Experimental potato protein and spray-dried animal plasma were substituted on an equal digestible lysine basis. In diet formulation, apparent digestibilities of amino acids and requirement estimates were similar to those outlined for Exp. 1. The sixth dietary treatment was provided by replacing 8.0% experimental potato protein with 8.0% of a second experimental potato protein.

Samples of the individual protein sources used in these experiments were collected and analyzed for amino acid concentrations (Table 4). In addition, potato protein samples were analyzed for glycoalkaloid concentration.

Results and Discussion

The amino acid profiles of the individual protein sources used in Exp. 1, 2, and 3 are consistent with previously published values for spray-dried blood meal and select menhaden fish meal. Amino acid values for conventional potato protein also were within analytical variation for published values, and most of those for experimental potato protein were slightly higher compared with conventional potato protein. Total glycoalkaloids of the new experimental potato protein were reduced considerably compared to the conventional potato protein. Little difference in glycoalkaloid concentrations occurred between the two new experimental potato proteins.

In Exp. 1, from d 0 to 7 postweaning, ADG and ADFI increased then decreased with increasing experimental potato protein (quadratic, $P < .01$). Feed efficiency also improved (quadratic, $P < .05$) with increasing potato protein. Pigs fed any of the blends of spray-dried animal plasma and experimental potato protein had greater ADG, ADFI, and better F/G than pigs fed either of the two protein sources alone (Table 5). From d 0 to 14 postweaning, ADG tended (linear and quadratic, $P < .11$) to increase with increasing experimental potato protein. Average daily feed intake increased then decreased (quadratic, $P < .05$) while F/G improved (linear, $P < .05$) with increasing experimental potato protein. However, pigs fed 8% experimental potato protein had greater ADG and better F/G than those fed 7% spray-dried animal plasma from d 0 to 14 postweaning (individual contrast, $P < .05$) From d 14 to 35 when all pigs were fed a common diet containing 10% dried whey and 2.5% spray-dried blood meal and for the overall trial (d 0 to 35), no differences in growth performance resulted from experimental diets fed from d 0 to 14 postweaning.

In Exp. 2, when all pigs were fed the same high nutrient density diet from d 0 to 7 postweaning, ADG, ADFI, and F/G were .39 lb, .48 lb, and 1.20, respectively. This resulted in pigs averaging 14.47 lb when switched to the experimental diets. Throughout the experiment, no differences ($P > .10$) were observed in growth performance among pigs fed any of the protein sources (Table 6). However, throughout the trial, pigs fed the experimental potato protein had numerically greater ADG and better F/G than those fed conventional potato protein. Pigs fed the other protein sources had intermediate ADG compared with those fed either potato protein source. Pig performance was not improved by feeding 8.34% experimental potato protein compared with 4.17% experimental potato protein.

Because of the excellent growth performance of pigs fed experimental potato protein compared with those fed spray-dried animal plasma in Exp. 1, we felt it necessary to confirm these results in a third experiment. In addition, a second experimental potato protein was evaluated. From d 0 to 7 post-

weaning, ADG and ADFI increased (linear, $P < .05$) with increasing animal plasma. However, ADG and ADFI increased then decreased (quadratic, $P < .10$ and $P < .05$, respectively) with increasing experimental potato protein. Feed efficiency (F/G) was not affected by animal plasma level and was poorer for pigs fed increasing amounts of experimental potato protein. Average daily gain and ADFI for pigs fed either 3.5% spray-dried animal plasma or 4.0% potato protein were similar and greater than those for pigs fed the control diet; however, adding 8.0% experimental potato protein decreased ADFI compared with that of pigs fed 4.0% experimental potato protein. The reduction in ADFI coupled with poorer F/G of pigs fed the 8.0% experimental potato protein resulted in decreased daily gains. No differences in performance occurred between pigs fed either of the experimental potato protein sources. From d 0 to 14 postweaning, increasing spray-dried animal plasma had no effect on ADG, ADFI, or F/G. However, ADG increased then decreased (quadratic, $P < .10$) as experimental potato protein increased. This response was similar to that observed from d 0 to 7 postweaning, in that 4.0% added potato protein improve ADG compared with that of pigs fed the control diet; however, adding 8.0% experimental potato protein decreased ADG.

From d 14 to 28 when pigs were fed a common diet, no differences were observed in ADG or ADFI. However, F/G improved then worsened (quadratic, $P < .10$) for pigs fed increasing animal plasma from d 0 to 14 postweaning. For the cumulative study (d 0 to 28 postweaning), no differences in ADG resulted from protein source or level fed from d 0 to 14 postweaning. Average daily feed intake decreased then increased (quadratic, $P < .05$), whereas F/G improved then worsened (quadratic, $P < .10$) with increasing spray-dried animal plasma fed from d 0 to 14 postweaning. No differences in performance throughout the trial occurred among pigs fed the two experimental potato protein source.

The response observed to added potato protein from d 0 to 14 postweaning in Exp. 3 is contradictory to results of Exp. 1, in which pigs fed 8.0% experimental potato protein had increased ADG compared with those fed 7.0% spray-dried animal plasma. However, pigs fed an intermediate level of potato protein (4.0%) had similar growth performance to those fed 3.5% spray-dried animal plasma. Perhaps variation in processing of spray-dried animal plasma and(or) potato protein could account for the differences in growth performance between the two studies. Regardless, these results suggest that experimental potato protein can be a cost-effective replacement for a portion of the spray-dried animal plasma in diets for early-weaned pigs.

Table 1. Composition of Diets (Exp. 1)[a]

	Animal Plasma, %:Experimental Potato Protein, %				
Ingredient, %	7.0:0	5.25:2.0	3.50:4.0	1.75:6.0	0:8.0
Ground corn	45.12	44.82	44.51	44.20	43.89
Soybean meal (46.5%)	15.19	15.19	15.19	15.19	15.19
Dried whey	20.00	20.00	20.00	20.00	20.00
Animal plasma, spray-dried	7.00	5.25	3.50	1.75	—
Potato protein	—	2.00	4.00	6.00	8.00
Soybean oil	5.00	5.00	5.00	5.00	5.00
Select menhaden fish meal	4.00	4.00	4.00	4.00	4.00
Medication[b]	1.00	1.00	1.00	1.00	1.00
Monocalcium phosphate	.98	1.11	1.23	1.35	1.47
Limestone	.63	.58	.52	.47	.41
Zinc oxide	.38	.38	.38	.38	.38
Vitamin premix	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15
L-lysine HCL	.10	.10	.10	.10	.10
Salt	.10	.10	.10	.10	.10
DL-methionine	.09	.08	.07	.06	.05
Total	100.00	100.00	100.00	100.00	100.00

[a]Experimental diets were fed from d 0 to 14 postweaning and were formulated to contain 1.5% total lysine (1.26% apparent digestible lysine), at least .42% total methionine (.35% apparent digestible methionine), 90% Ca, and .80% P.
[b]Provided 150 g/ton apramyacin.

Table 2. Composition of Diets (Exp. 2)[a]

Ingredient, %	Spray-Dried Blood Meal	Select Menhaden Fish Meal	Potato[b] Protein	Exp. Potato[c] Protein
Ground corn	53.41	51.47	51.77	56.10
Soybean meal (46.5%)	26.40	26.50	26.40	17.70
Dried whey	10.00	10.00	10.00	10.00
Spray-dried blood meal	2.50	—	—	—
Select menhaden fish meal	—	5.51	—	—
Potato protein	—	—	4.17	8.34
Soybean oil	3.00	3.00	3.00	3.00
Monocalcium phosphate	1.88	1.10	1.94	2.14
Medication[d]	1.00	1.00	1.00	1.00
Limestone	.84	.42	.81	.82
Zinc oxide	.25	.25	.25	.25
Vitamin premix	.25	.25	.25	.25
Salt	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15
DL-methionine	.07	.01	.01	—

[a]Experimental diets were fed from d 7 to 28 postweaning and were formulated to contain at least 1.25% total lysine and .34% total methionine (1.05% and .30% apparent digestible lysine and methionine, respectively). Protein sources (except exp. potato protein, 8.34%) were substituted on an equal digestible lysine basis.
[b]Potato protein and experimental potato protein were included at 4.17% to provide two experimental diets.
[c]Experimental potato protein was added at twice the inclusion rate for digestible lysine of other protein sources.
[d]Provided 50 g/ton carbadox.

Table 3. Composition of Diets (Exp. 3)[a]

Ingredient, %	Dried Skim Milk	Animal Plasma, % 3.5	Animal Plasma, % 7.0	Potato Protein, % 4.0	Potato Protein, % 8.0[b]
Ground corn	34.72	35.18	35.65	34.57	34.42
Soybean meal (46.5%)	15.84	15.84	15.84	15.84	15.84
Dried whey	20.00	20.00	20.00	20.00	20.00
Dried skim milk	17.50	8.75	—	8.75	—
Lactose	—	4.38	8.75	4.38	8.75
Animal plasma, spray-dried	—	3.50	7.00	—	—
Potato protein	—	—	—	4.00	8.00
Soybean oil	5.00	5.00	5.00	5.00	5.00
Select menhaden fish meal	4.00	4.00	4.00	4.00	4.00
Medication[c]	1.00	1.00	1.00	1.00	1.00
Monocalcium phosphate	.73	.91	1.08	1.16	1.58
Limestone	.12	.38	.58	.27	.36
Zinc oxide	.38	.38	.38	.38	.38
Vitamin premix	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15
L-lysine HCL	.10	.10	.10	.10	.10
Salt	.10	.10	.10	.10	.10
DL-methionine	.05	.08	.12	.06	.07
Total	100.00	100.00	100.00	100.00	100.00

[a]Experimental diets were fed from d 0 to 14 postweaning and were formulated to contain at least 1.46% total lysine (1.26% apparent digestible lysine), at least .42% total methionine (.35% apparent digestible methionine), .90% Ca, and .80% P.
[b]A second experimental potato protein replaced the first on an equal weight basis to provide the sixth dietary treatment.
[c]Provided 150 g/ton apramyacin.

Table 4. Amino Acid Analysis of Protein Sources[a]

Item	Spray-Dried Animal Plasma	Select Menhaden Fish Meal	Spray-Dried Blood Meal	Potato Protein	Experimental Potato Protein
Essential and semi-essential amino acids, %					
Arginine	4.59	3.43	3.77	4.09	4.09
Cysteine	2.54	.58	.74	1.45	1.55
Histidine	2.62	1.55	7.03	1.80	1.87
Isoleucine	2.84	2.35	.47	4.44	4.46
Leucine	7.64	4.40	12.98	8.18	8.47
Lysine	6.95	4.52	8.52	5.94	6.27
Methionine	.72	1.65	.84	1.75	1.80
Phenylalanine	4.50	2.42	6.64	5.11	5.35
Threonine	4.38	2.52	3.20	4.33	4.53
Tryptophan	1.30	.64	1.66	1.08	1.12
Tyrosine	4.07	1.87	2.14	4.37	4.50
Valine	5.23	2.95	8.81	5.60	5.63
Nonessential amino acids, %					
Alanine	4.20	3.96	7.89	3.81	3.91
Glutamic acid	10.33	7.36	7.30	8.27	8.25
Glycine	2.81	4.12	4.50	4.05	4.24
Ornithine	.04	.04	.03	.03	.02
Proline	4.57	2.61	3.28	3.87	4.18
Serine	3.85	2.16	3.90	3.82	4.03

[a]Values expressed on an as-fed basis. Total glycoacaloid concentrations (mg/100 g) were: potato protein, 303 and experimental potato protein, 15.6. The second experimental potato protein contained 18.3 mg/100 g glycoalkaloid (amino acid analysis not provided).

Table 5. Effect of Experimental Potato Protein on Starter Pig Performance (Exp. 1)[a]

	Animal Plasma, %:Experimental Potato Protein, %					
Item	7.0:0	5.25:2.0	3.50:4.0	1.75:6.0	0:8.0	CV
Day 0 to 7						
ADG, lb[b]	.54	.68	.65	.68	.58	12.7
ADFI, lb[b]	.58	.68	.61	.66	.56	8.4
F/G[cd]	1.10	1.00	.94	.98	.99	8.7
Day 0 to 14						
ADG, lb[ef]	.64	.77	.71	.74	.73	9.9
ADFI, lb[d]	.77	.85	.77	.83	.75	7.5
F/G[c]	1.20	1.12	1.09	1.12	1.03	6.1
Day 14 to 35						
ADG, lb	1.33	1.30	1.32	1.35	1.35	7.2
ADFI, lb	1.79	1.75	1.75	1.83	1.84	11.4
F/G	1.33	1.35	1.32	1.33	1.35	7.7
Day 0 to 35						
ADG, lb	1.06	1.08	1.08	1.11	1.10	7.1
ADFI, lb	1.38	1.39	1.36	1.43	1.41	9.9
F/G	1.30	1.28	1.27	1.28	1.27	6.3

[a]A total of 180 weanling pigs (initially 12.98 lb and 20 ± 2 days of age). Each treatment had six pigs per pen and six replications (pens). Pigs were fed experimental diets from d 0 to 14 postweaning. From d 14 to 25, all pigs were fed a corn-soybean meal-based diet containing 10% dried whey and 2.5% spray-dried blood meal (1.35% lysine).
[b]Quadratic effect of experimental potato protein ($P < .01$).
[c,d]Linear and quadratic effect of experimental potato protein ($P < .05$), respectively.
[e,f]Linear and quadratic effect of experimental potato protein ($P < .11$), respectively.

Table 6. Effect of Protein Sources on Starter Pig Growth Performance (Exp. 2)[a]

Item	Spray-Dried Blood Meal	Select Menhaden Fish Meal	Potato Protein	Exp. Potato Protein	Exp. Potato Protein (8.34%)	CV
Day 7 to 14[b]						
ADG, lb	.44	.45	.41	.47	.43	18.2
ADFI, lb	.79	.75	.76	.68	.78	13.0
F/G	1.82	1.64	1.85	1.51	1.82	16.4
Day 7 to 21[b]						
ADG, lb	.64	.65	.61	.65	.66	9.2
ADFI, lb	1.02	.95	.95	.94	1.00	9.0
F/G	1.56	1.45	1.59	1.95	1.51	7.4
Day 7 to 28[b]						
ADG, lb	.79	.78	.75	.79	.79	6.7
ADFI, lb	1.26	1.18	1.17	1.18	1.23	6.1
F/G	1.56	1.49	1.56	1.49	1.56	4.8

[a]A total of 255 pigs (initially 11.72 lb and 17 ± 2 d of age) were used with eight to 10 pigs per pen and six replications (pens) per treatment. Day 0 to 7 ADG, ADFI, and F/G were: .39, .48 lb, and 1.20, respectively.
[b]No treatment differences were observed ($P > .10$).

Table 7. Effect of Added Animal Plasma or Potato Protein in Starter Pig Diets (Exp. 3)[a]

Item	Dried Skim Milk	Animal Plasma		Exp. Potato Protein		Exp. Potato Protein 2	CV
		3.5%	7.0%	4.0%	8.0%	8.0%	
Day 0 to 7							
ADG, lb[bcd]	.63	.67	.73	.65	.53	.58	10.13
ADFI, lb[be]	.53	.61	.67	.60	.53	.54	10.90
F/G[c]	.85	.92	.91	.93	1.00	.94	9.40
Day 0 to 14							
ADG, lb[df]	.83	.81	.83	.86	.77	.76	7.87
ADFI, lb	.85	.83	.87	.89	.82	.82	7.34
F/G	1.02	1.03	1.05	1.03	1.06	1.09	4.78
Day 14 to 28							
ADG, lb	1.11	1.06	1.07	1.08	1.12	1.17	7.25
ADFI, lb	1.93	1.76	1.98	1.86	1.82	1.96	9.10
F/G[g]	1.72	1.67	1.85	1.72	1.63	1.69	6.90
Day 0 to 28							
ADG, lb	.97	.93	.95	.97	.94	.96	5.94
ADFI, lb[h]	1.39	1.29	1.43	1.37	1.32	1.39	6.69
G:F[g]	1.42	1.39	1.49	1.41	1.41	1.44	4.59

[a]Two hundred ten weanling pigs were used (initially 12.21 lb and 20 lb of age ±3 d of age) with seven pigs per pen. Day 0 to 14 diets were formulated to contain 1.5% lysine, .42% methionine, .9% Ca, and .8% P.

[b]Linear effect of animal plasma ($P < .05$).

[c,f]Linear effect of potato protein ($P < .05$); ($P < .10$), respectively.

[d,e]Quadratic effect of potato protein ($P < .10$); ($P < .05$), respectively.

[g,h]Quadratic effect of animal plasma ($P < .10$); ($P < .05$), respectively.

EFFECTS OF DIFFERENT SPECIALTY PROTEIN SOURCES ON GROWTH PERFORMANCE OF STARTER PIGS

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Summary

Two hundred and ten weanling pigs were fed diets containing either soybean meal, spray-dried blood meal, spray-dried red blood cells, select menhaden fish meal, or synthetic amino acids. From d 0 to 7 postweaning, pigs fed either spray-dried whole blood meal or red blood cells had greater ADG and ADFI than pigs fed select menhaden fish meal or added synthetic amino acids. However, from d 0 to 14 and 0 to 21, no differences in growth performance occurred among pigs fed the various protein sources. However, pigs fed added synthetic amino acids had poorer ADG compared with the mean for pigs fed the other protein sources.

(Key Words: Starter Pig Performance, Protein Source.)

Introduction

Spray-dried blood meal has been an essential ingredient in starter pig diets because of its stimulatory effects on feed intake and subsequent increases in growth rate. However, because of the demand for spray-dried animal plasma, the remaining red blood cell fraction is now available for use in swine diets in addition to spray-dried whole blood meal. Little information is available to compare growth performance of pigs fed spray-dried whole blood meal and spray-dried red blood cells. Therefore, the objective of this experiment was to compare performance of pigs fed diets containing various specialty protein sources, including spray-dried whole blood meal, spray-dried red blood cells, select menhaden fish meal, synthetic amino acids, and soybean meal.

Procedures

A total of 210, weanling pigs (initially 13.58 lb and 21-d of age) was blocked by weight, equalized for gender and ancestry, and randomly allotted to each of five dietary treatments. Pigs were fed a soybean meal-based control diet containing 10% dried whey or diets containing 2.5% spray-dried whole blood meal, 2.5% spray-dried red blood cells, or 3.96% select menhaden fish meal (Table 1). The specialty protein sources were substituted for soybean meal in the control diet on a lysine basis. Because of past discrepancies between amino acid concentrations provided by the supplier and analyzed values, the spray-dried whole blood meal and spray-dried red blood cells were both assumed to contain 7.44% lysine (NRC, 1988). All diets were formulated to 1.35% lysine (slightly below the pig's estimated requirement) to emphasize amino acid availability of the various protein sources. The diet containing synthetic amino acids replacing those from the intact protein sources had added lysine, methionine, and threonine to equal the essential amino acid requirements based on a total and digestible amino acid basis using the Illinois ideal amino acid ratio. All diets contained 10% dried whey and were pelleted. Each treatment had seven pigs/pen and six pens (replications). Experimental diets were fed from d 0 to 21 postweaning. Pigs were weighed and feed disappearance determined on d 0, 7, 14, and 21 postweaning to calculate ADG, ADFI, and F/G.

Results and Discussion

Because of discrepancies we have observed with analyzed amino acids profiles and those reported by the manufacturer, we

analyzed each protein source for amino acids. These results are reported in Table 2.

Amino acid analysis of the protein sources revealed slight differences between calculated and analyzed values. Soybean meal contained slightly less lysine than the 3.01% used in diet formulation. Spray-dried red blood cells contained 8.64% lysine, greater than the 7.44% used in diet formulation but lower than the 9.0% suggested by the manufacturer. Concentrations of most amino acids in the spray-dried whole blood and select menhaden fish meal were similar to reference values (NRC, 1988).

From d 0 to 7 postweaning, no differences were observed in ADG, ADFI, and F/G between pigs fed either blood meal source (Table 3). However, pigs fed select menhaden fish meal had decreased ADG and ADFI compared with the mean for pigs fed either blood meal source. Pigs fed the diets containing added synthetic amino acids had decreased ADG compared with the mean for those fed the other protein sources. Feed efficiency was not affected by dietary treatment.

From d 0 to 14 postweaning, no differences were observed in ADG, ADFI, and F/G between pigs fed either blood meal source or select menhaden fish meal. However, pigs fed added amino acids had decreased ADG compared with the mean for those fed the other protein sources. Average daily feed intake was not affected by dietary treatment, but was highest for pigs fed the blood meal sources and lowest for those fed select menhaden fish meal or added synthetic amino acids. Pigs fed soybean meal tended to have poorer F/G than the mean for those fed the other protein sources.

For the cumulative study (d 0 to 21), no differences were observed among pigs fed any of the intact protein sources; however, pigs fed added synthetic amino acids had decreased ADG compared with the mean for those fed the other protein sources.

These results suggest that little difference occurs in growth performance of pigs fed spray-dried whole blood meal and spray-dried red blood cells. In addition, pigs fed either blood meal source had greater initial (d 0 to 7 postweaning) ADG than those fed select menhaden fish meal; however, no differences in ADG were observed by d 14. Furthermore, pigs fed added synthetic amino acids in place of specialty protein sources had consistently poorer ADG. Therefore, the decision on which protein source to use in diet formulation should be based on relative ingredient price (including changes in diet formulation based on the different protein sources, i.e., added methionine) and availability, as well as diet factors such as flowability and handling characteristics.

Table 1. Diet Composition[a]

	Amino Acid Sources				
Ingredient, %	Soybean Meal	Red Blood Cells	Whole Blood Meal	Select Menhaden Fish Meal	Amino Acids
Corn	48.30	52.22	52.22	51.53	54.37
Soybean meal	33.79	27.28	27.28	27.28	27.28
Red blood cells	—	2.50	—	—	—
Whole blood meal	—	—	2.50	—	—
Select menhaden fish meal	—	—	—	3.96	—
Dried whey	10.00	10.00	10.00	10.00	10.00
Soy oil	3.00	3.00	3.00	3.00	3.00
Monocalcium phosphate	1.76	1.87	1.87	1.37	1.88
Limestone	1.02	.98	.98	.71	1.00
Medication[b]	1.00	1.00	1.00	1.00	1.00
Salt	.25	.25	.25	.25	.25
Vitamin premix	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15
Zinc oxide	.25	.25	.25	.25	.25
L-lysine HCl	.15	.15	.15	.15	.15
DL-methionine	.08	.10	.10	.10	.11
Threonine	—	—	—	—	.07

[a]All diets were formulated to 1.35% lysine and at least .38% methionine, .90% Ca, and .80% P.
[b]Provided 50 g/ton carbadox.

Table 2. Amino Acid Analysis of Protein Sources[a]

Item	Soybean Meal	Red Blood Cells	Whole Blood Meal	Select Menhaden Fish Meal
Arginine	3.26	3.66	3.92	3.74
Cystine	.73	.66	1.21	.55
Histidine	1.21	6.39	4.79	1.44
Isoleucine	1.97	.46	1.79	2.32
Leucine	3.55	12.67	10.24	4.41
Lysine	2.88	8.64	7.64	4.77
Methionine	.65	1.04	.99	1.68
Threonine	1.81	3.83	4.37	2.53
Tryptophan	.63	1.53	1.49	.63
Tyrosine	1.65	2.36	2.85	1.89
Phenylalanine	2.33	6.82	5.74	2.48
Valine	2.13	8.38	6.29	2.85

[a]Values are expressed on as-fed basis and represent the mean of one sample.

Table 3. Evaluation of Different Specialty Protein Sources on Starter Pig Growth Performance

		Amino Acid Sources					Probability ($P <$)			
Item	SBM	Red Blood Cells	Whole Blood Meal	Select Menhaden Fish Meal	Amino Acids	CV	1 vs. 2,3,4,5	2 vs. 3	4 vs. 2,3	5 vs. 1,2,3,4
d 0 to 7										
ADG, lb	.29	.31	.34	.27	.26	18.8	.93	.25	.07	.09
ADFI, lb	.39	.41	.43	.36	.39	10.1	.57	.42	.01	.43
F/G	1.33	1.35	1.26	1.35	1.49	15.3	.77	.43	.59	.98
d 7 to 14										
ADG, lb	.57	.67	.60	.69	.59	16.5	.18	.22	.29	.32
ADFI, lb	.77	.76	.77	.76	.73	11.8	.68	.85	.81	.36
F/G	1.35	1.09	1.29	1.09	1.23	18.1	.11	.12	.38	.67
d 0 to 14										
ADG, lb	.43	.49	.47	.48	.42	11.8	.19	.57	.95	.08
ADFI, lb	.58	.59	.60	.56	.56	9.1	.98	.64	.20	.29
F/G	1.35	1.19	1.28	1.16	1.31	11.0	.11	.23	.31	.27
d 7 to 21										
ADG, lb	.99	1.00	.98	.94	.93	12.1	.57	.65	.50	.37
ADFI, lb	1.20	1.30	1.20	1.20	1.20	10.3	.98	.72	.86	.26
F/G	1.23	1.27	1.27	1.30	1.27	10.7	.47	.90	.58	.98
d 0 to 21										
ADG, lb	.62	.66	.64	.64	.59	7.2	.49	.41	.60	.04
ADFI, lb	.79	.81	.81	.79	.76	8.5	.97	.99	.44	.22
F/G	1.28	1.23	1.28	1.23	1.30	5.5	.39	.25	.61	.30

[a]A total of 210 weanling pigs was used (initially 13.58 lb and 21 d of age), seven pigs per pen and six pens per treatment. Experimental diets were fed from d 0 to 21 postweaning.

EVALUATION OF SPRAY-DRIED CHEESE FOOD AS A SUPPLEMENTAL PROTEIN SOURCE FOR WEANLING PIGS[1]

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Summary

A growth study was conducted to determine the effects of substituting spray-dried cheese food for spray-dried plasma protein on weanling pig performance. Five dietary treatments included the control diet or diets with cheese food replacing 25, 50, 75, and 100% of the plasma on an equal lysine basis. Day 0 to 14 ADG and ADFI were decreased linearly as spray-dried cheese food increased. However, this decrease was most apparent when cheese food was included at more than 4% of the diet. No effects of cheese food inclusion were seen for F/G from d 0 to 14 postweaning or for growth performance from d 14 to 28 or from d 0 to 28 postweaning. These results indicate that spray-dried cheese food resulted in a linear reduction in ADG and ADFI. However, the growth reduction was not apparent until cheese food was included at more than 4% of the diet.

(Key Words: Cheese Food, Protein, Nursery Pigs.)

Introduction

The early-weaned pig presents several unique challenges in diet formulation and feeding. The pig needs a highly palatable diet containing ingredients with highly available nutrient profiles. This has led to the development of a complex nursery diet with highly digestible ingredients. Spray-dried plasma protein is one of these ingredients proven effective in nursery diets. It is a highly palatable feedstuff that stimulates feed intake in nursery pigs. Its high cost, however, has led to evaluation of lower cost proteins as substitutes.

Spray-dried cheese food is a pure cheese product made from leftovers in cutting and wrapping rooms at cheese plants. The leftovers are reliquified and spray-dried to form a powdered cheese product similar to powdered cheese found in high quality macaroni and cheese products. It has high protein and energy contents coupled with a low ash content. The amino acid profile has high levels of many essential amino acids (Table 1). These factors all contribute to the potential of spray-dried cheese food as a potential protein source for early-weaned pigs.

A cheese food product containing added soy flour was evaluated as a substitute for dried skim milk by researchers at the University of Minnesota in 1991. They noted decreased performance in nursery pigs as increased levels of cheese food were included in the nursery diet. They hypothesized several reasons for this, noting possible antinutritional factors from the soy flour or increased salt and decreased lactose levels in the cheese food. Therefore, the objectives of our experiment were to evaluate the effects of pure spray-dried cheese food (with no soy flour) on the growth performance of early-weaned pigs.

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[1]The authors thank Land O' Lakes Inc., Arden Hills, MN for supplying the spray-dried cheese food and for partial funding of this experiment. The authors also thank Ellen Johncock and Eichman Brothers, St. George, KS for the use of facilities and animals in this experiment.

[2]Land O'Lakes, Inc., Arden Hills, MN.

Table 1. Compositions of Spray-Dried Cheese Food and Spray-Dried Plasma Protein[a]

Item, %	Cheese Food	Plasma Protein
Protein	36.00	70.00
Fat	41.69	2.00
Ash	6.46	13.00
Lysine	2.50	6.10
Methionine	.61	.53
Tryptophan	NA	1.33
Isoleucine	1.69	1.96
Leucine	3.42	5.56
Valine	2.36	4.12
Threonine	1.34	4.13

[a]Values expressed on an as-fed basis.

Procedures

A total of 249 pigs (initially 10.9 lb and 18 d of age) was used in a 28-day growth trial. Pigs were blocked by weight and allotted to one of five dietary treatments with a total of eight or nine pigs per pen and six pens per treatment. Phase I dietary treatments (d 0 to 14 postweaning) were based on levels of spray-dried cheese food (4, 8, 12, and 16%) replacing spray-dried plasma protein on an equal lysine basis plus the control diet.

The trial had two phases with the experimental diets being fed from d 0 to 14 postweaning. The phase I experimental diets were pelleted and formulated to contain 1.5% lysine, .9% Ca, .8% P and at least .42% methionine (Table 2). The experimental diets all contained 20% dried whey, 1.75% spray-dried blood meal, 19.71% soybean meal, and .1% added L-lysine HCl. Corn, DL-methionine, soybean oil, and spray-dried plasma all were varied as increasing levels of spray-dried cheese food were included to maintain similar amino acid and fat levels. In phase II (d 14 to 28), a common corn-soybean meal diet was fed in meal form and contained 2.5% spray-dried blood meal and 10% dried whey. This phase II diet was formulated to contain 1.35% lysine, .9% Ca, and .8% P.

Pigs were housed in an environmentally controlled nursery in 5 ft × 5 ft pens with ad libitum access to feed and water. Weekly gain and feed disappearance values were measured to calculate ADG, ADFI, and F/G.

Data were analyzed as a randomized complete block design using general linear model procedures. Initial weight was used to establish the blocks. Linear and quadratic polynomials were used to detect the effects of replacing spray-dried plasma protein with spray-dried cheese food.

Results and Discussion

From d 0 to 7 postweaning, ADG and ADFI decreased as cheese food increased (linear, $P < .03$, and .0002, respectively; Table 3). These linear decreases became most apparent in pigs fed diets containing either 12 or 16% cheese food. No differences ($P > .10$) were noted for F/G from d 0 to 7 postweaning.

In phase I (d 0 to 14 postweaning), ADG and ADFI decreased with increasing dietary cheese food (linear, $P < .003$, and .007, respectively). This decrease became most apparent when the cheese food product was included at levels above 4% of the diet. No differences were noted for F/G because of corresponding decreases in ADG and ADFI from d 0 to 14 postweaning.

When all pigs were switched to a common phase II diet (d 14 to 28 postweaning), no differences were noted for ADG, ADFI, and F/G. During phase II, ADFI and ADG tended to be higher for pigs previously fed cheese food levels above 4% during phase I, resulting in similar pig weights at the end of the trial. No differences in growth performance were noted during the overall trial (d 0 to 28 postweaning).

Although growth performance showed a linear decrease in phase I, this decrease was not apparent until cheese food replaced more than 25% of the plasma. This effect is consistent with previous research evaluating alternative protein sources. Plasma appears to be a necessary ingredient to stimulate

optimal growth and feed intake in phase I. However, the exact level required by early-weaned pigs may vary for different production situations. A portion of the spray-dried plasma protein apparently can be replaced by less expensive protein sources. This research indicates that up to 25% of the spray-dried plasma protein can be replaced by spray-dried cheese food without affecting pig performance in phase I. Also, for the overall trial, no performance differences were noted as increasing levels of spray-dried cheese food were fed.

Table 2. Composition of Experimental Diets[a]

	Plasma Protein:Cheese Food, %					
Ingredients, %	5.88:0	4.41:4	2.94:8	1.47:12	0:16	Phase II[b]
Corn	40.10	39.38	38.65	37.92	37.22	56.86
Soybean meal (46.5%)	19.71	19.71	19.71	19.71	19.71	25.86
Plasma protein	5.88	4.41	2.94	1.47	--	--
Cheese food	--	4.00	8.00	12.00	16.00	--
Soybean oil	8.00	6.33	4.66	3.00	1.33	--
Dried whey	20.00	20.00	20.00	20.00	20.00	10.00
Spray dried blood meal	1.75	1.75	1.75	1.75	1.75	2.50
Monocalcium phosphate	1.51	1.41	1.32	1.22	1.12	1.85
Limestone	.99	.94	.89	.84	.78	.85
Antibiotic	1.00	1.00	1.00	1.00	1.00	1.00
L-lysine HCl	.10	.10	.10	.10	.10	.15
DL-methionine	.13	.14	.15	.16	.16	.075
Vit, TM premix	.35	.35	.35	.35	.35	.35
Zinc oxide	.38	.38	.38	.38	.38	.25
Salt	.10	.10	.10	.10	.10	.25
Total	100	100	100	100	100	100

[a]Phase I diets were formulated to contain 1.5% lysine, .42% methionine, .9% Ca, and .8% P.
[b]Phase II diet was formulated to contain 1.35% lysine, .37% methionine, .9% Ca, and .8% P.

Table 3. Influence of Spray-Dried Cheese Food on Starter Pig Performance[a]

	Plasma Protein:Cheese Food, %						P-values ($P <$)	
Item	5.88:0	4.41:4.0	2.94:8.0	1.47:12.0	0:16.0	CV	Linear	Quadratic
d 0 to 7								
ADG, lb	.39	.41	.38	.35	.29	21.8	.03	.20
ADFI, lb	.61	.61	.61	.55	.51	7.8	.0002	.05
F/G	1.67	1.50	1.58	1.61	1.81	21.2	.40	.22
d 0 to 14								
ADG, lb	.63	.62	.56	.57	.50	12.8	.003	.67
ADFI, lb	.72	.70	.65	.62	.59	10.0	.007	.98
F/G	1.12	1.16	1.21	1.17	1.16	9.4	.58	.40
d 14 to 28								
ADG, lb	1.0	1.02	1.05	1.06	1.06	8.7	.19	.68
ADFI, lb	1.80	1.78	1.85	1.85	1.82	5.4	.38	.47
F/G	1.82	1.75	1.80	1.77	1.72	7.9	.32	.80
d 0 to 28								
ADG, lb	.81	.82	.80	.81	.78	8.9	.38	.64
ADFI, lb	1.24	1.23	1.22	1.21	1.20	5.7	.29	.94
F/G	1.47	1.52	1.56	1.55	1.52	7.5	.48	.33
Average pig weight, lb								
d 0	11.09	10.79	10.83	10.79	10.79	2.8	.13	.30
d 14	19.93	19.42	18.65	18.79	18.20	4.7	.003	.60
d 28	33.97	33.72	33.29	33.66	33.43	5.0	.62	.76

[a]A total of 249 pigs (18 ± 3 d; eight or nine pigs/pen) with six replicate pens per treatment.

PERFORMANCE OF WEANLING PIGS FED DIETS CONTAINING VARIOUS LACTOSE SOURCES[1]

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Summary

Two growth trials were conducted to evaluate the effects of replacing the lactose provided by dried whey in the phase II diet with either deproteinized whey or an alternative lactose source, DairyLac 80®. No differences in performance observed among pigs fed diets containing 10% dried whey or deproteinized whey or DairyLac 80®. These trials indicate that deproteinized whey and DairyLac 80® can be used to replace the lactose contained in dried whey for starter pig diets.

(Key Words: Weanling Pigs, Lactose, Deproteinized Whey, DairyLac 80®.)

Introduction

Numerous research reports have validated the necessity of lactose in starter pig diets, and dried whey is one of the most frequently used sources of lactose in phase I and II diets within the swine industry. Growth during phase I has been shown to increase linearly in response to increasing levels of dietary lactose. Research recently has focused on finding suitable alternative lactose sources including deproteinized whey and DairyLac 80®, which contains 80% lactose. Therefore, the objective of these studies was to evaluate the performance of pigs when fed corn-soybean meal-based diets containing dried whey or deproteinized whey (Exp. 1) or dried whey, dried whey and fish meal, or fish meal and DairyLac 80® (Exp. 2).

Procedures

Experiment 1. A total of 70 pigs (initially 11.45 lb and 21 d of age) were used in a 28 d growth trial. Pigs were blocked on the basis of weight and randomly allotted to one of two dietary treatments with five pigs per pen and seven replications (pens) per treatment.

The experimental diets, in meal form, were fed for 28 d postweaning. These diets contained 1.35% lysine, .90% Ca, .80% P, and at least .38% methionine (Table 1). The two dietary treatments consisted of a control diet with 10% dried whey and a second diet containing 8.70% deproteinized whey. The inclusion level of deproteinized whey and subsequent increase in level of spray-dried blood meal provided an equal replacement of the lactose and amino acids provided by the 10% dried whey in the control diet.

Experiment 2. A total of 153 pigs (initially 10.2 lb and 15 d of age) were used in a 28 d growth trial. Pigs were blocked on the basis of weight and randomly allotted to one of three dietary treatments with six, seven, or eight pigs per pen and seven replications (pens) per treatment. Each block had an equal number of pigs/pen.

A common segregated early-weaning (SEW) pelleted diet was fed to all pigs for 7 d postweaning. The common diet contained 1.70% lysine, .90% Ca, .80% P, and at least .48% methionine (Table 2). The phase II

[1]The authors thank Eichman Brothers, St. George, KS for the use of facilities and animals in Experiment 2 and Zepata Protein Inc., Hammond LA and International Ingredient Corp., St. Louis, MO for donating the fishmeal and DairyLac 80® used in Experiment 2.

experimental diets, in meal form, were fed for the remainder of the growth trial. These diets contained 1.35% lysine, .90% Ca, .80% P, and at least .38% methionine (Table 2). The immediate change from a SEW diet to a phase II diet was done to emphasize the quality of the protein in the experimental diets. The three dietary treatments consisted of a control diet with 10% dried whey, a diet containing 10% dried whey and 5% select menhaden fish meal, and a third diet containing 9.00% DairyLac 80® and 6.63% select menhaden fish meal. The inclusion levels of DairyLac 80® and fish meal in the third diet provided an equal replacement of the lactose and amino acids provided by the 10% dried whey in the other diets.

In both experiments, pigs were housed in environmentally controlled nurseries (4 ft × 5 ft pens in Exp. 1 and 5 ft × 5 ft pens in Exp. 2) and allowed ad libitum access to feed and water. Weekly weight gains and feed intakes were measured and used to determine ADG, ADFI, and F/G.

Data were analyzed as a randomized complete block design using the general linear model procedures of SAS. Initial pig weights were used to establish the blocks. In Exp. 2, single degree of freedom contrasts were used to determine the significance of the individual dietary comparisons.

Results and Discussion

Experiment 1. No effect of treatment ($P > .40$) was found on daily gain or on feed intake ($P > .10$) from d 0 to 14 and d 14 to 28. However, for the overall trial (d 0 to 28), pigs fed deproteinized whey tended ($P = .07$) to eat less (1.27 vs 1.38 lb). From d 0 to 14, F/G was improved ($P = .05$) for pigs fed deproteinized whey. Feed efficiency was numerically ($P > .10$) improved for pigs fed deproteinized whey through the study. These data suggest that deproteinized whey is an effective replacement for the lactose provided by dried whey in starter pig diets.

Experiment 2. No differences ($P > .40$) were observed for ADG, ADFI, or F/G throughout the experimental period (Table 4). Pigs fed the diets containing the dried whey and fish meal or DairyLac 80® and fish meal performed equally. Surprisingly, pigs fed the control diet, containing only dried whey, performed as well as the pigs fed the diets containing the specialty proteins.

A drastic decrease in feed efficiency was observed when pigs were changed from an SEW diet to a phase II diet. Consequently, pigs gained faster and converted feed to gain much more efficiently in the first week than in the second week. The sudden diet change was intended to emphasize the quality of the protein in the experimental diets. Also, when dried whey was removed from the diets, it was replaced with specialty proteins (fish meal and blood meal) and alternative lactose sources (deproteinized whey and DairyLac 80®) for an equal replacement of the lactose and amino acids contained in the dried whey. The cost of the alternative lactose sources and added cost of supplementing the amino acids compared to the cost of dried whey is an important consideration when formulating diets to contain these products.

Table 1. Composition of Diets (Exp. 1)[a]

Ingredients, %	Dried Whey	Deproteinized Whey
Corn	52.69	52.39
Soybean meal (46.5%)	26.78	26.74
Dried whey	10.00	----
Deproteinized whey	----	8.70
Soybean oil	3.00	3.00
Spray-dried blood meal	2.50	3.70
Monocalcium phosphate	1.88	2.23
Limestone	1.00	1.06
Antibiotic[b]	1.00	1.00
Premix	.40	.40
Salt	.25	.25
Zinc oxide	.25	.25
L-lysine	.15	.15
DL-methionine	.10	.13
Total	100.00	100.00

[a]Diets were formulated to contain 1.35% lysine, .38% methionine, .90% Ca, and .80% P.
[b]Provided 50g/ton carbadox.

Table 2. Composition of Diets (Exp. 2)

		Phase II[b]		
Ingredients, %	Common SEW Diet[a]	10% Dried Whey	10% Dried Whey and 5% Fish Meal	9% DairyLac 80® and 6.63% Fish Meal
Corn	33.40	48.32	52.44	51.98
Soybean meal (46.5%)	12.73	33.79	25.57	25.57
Dried whey	25.00	10.00	10.00	----
Select menhaden fish meal	6.00	----	5.00	6.63
DairyLac 80®	----	----	----	9.00
Soybean oil	6.00	3.00	3.00	3.00
Spray-dried plasma protein	6.70	----	----	----
Lactose	5.00	----	----	----
Spray-dried blood meal	1.75	----	----	----
Monocalcium phosphate	.76	1.76	1.27	1.15
Limestone	.48	1.02	.62	.57
Antibiotic[c]	1.00	1.00	1.00	1.00
Premix	.40	.40	.40	.40
Salt	.10	.25	.25	.25
Zinc oxide	.38	.25	.25	.25
L-lysine	.15	.15	.15	.15
DL-methionine	.15	.06	.05	.05
Total	100.00	100.00	100.00	100.00

[a]SEW diet was formulated to contain 1.70% lysine, .48% methionine, .90% Ca, and .80% P and was fed from d 0 to 7 postweaning.
[b]Phase II diets were formulated to contain 1.35% lysine, .38% methionine, .90% Ca, and .80% P and were fed from d 7 to 28 postweaning.
[c]Provided 50 g/ton carbadox.

Table 3. Effect of Deproteinized Whey on Weanling Pig Performance (Exp. 1)[a]

	Diet			
Item	Dried Whey	Deproteinized Whey	CV	Probability ($P <$)
d 0 to 14				
ADG, lb	.70	.68	9.75	.71
ADFI, lb	.82	.73	12.14	.13
F/G	1.17	1.08	7.08	.05
d 14 to 28				
ADG, lb	1.20	1.17	8.82	.52
ADFI, lb	1.94	1.82	7.23	.12
F/G	1.62	1.57	11.31	.69
d 0 to 28				
ADG, lb	.95	.92	7.35	.48
ADFI, lb	1.38	1.27	7.76	.07
F/G	1.45	1.38	6.48	.19
Average pig weight, lb				
d 0	11.4	11.5	---	---
d 14	20.9	21.3	9.42	.75
d 28	37.8	37.6	6.52	.91

[a]Means represent a total of 70 pigs (initially 11.45 lb and 21 d of age) with five pigs per pen and seven replicate pens per treatment.

Table 4. Effect of Lactose Source on Starter Pig Performance (Exp. 2)[ab]

					Probability ($P <$)		
Item	10% Dried Whey (1)	10% Dried Whey and 5% Fish Meal (2)	9% DairyLac 80® and 6.63% Fish Meal (3)	CV	1 vs 2	1 vs 3	2 vs 3
d 7 to 14							
ADG, lb	.43	.43	.46	33.19	.97	.62	.65
ADFI, lb	.97	.98	1.05	18.53	.98	.45	.46
F/G	2.40	2.34	2.40	20.10	.82	.98	.80
d 7 to 28							
ADG, lb	.77	.75	.77	24.01	.90	.99	.91
ADFI, lb	1.15	1.15	1.16	19.61	.95	.92	.97
F/G	1.51	1.53	1.56	10.77	.84	.64	.80
Average pig weight, lb							
d 0	10.29	10.28	10.28	---	---	---	---
d 7	13.75	13.33	13.27	16.61	.73	.69	.96
d 14	16.58	16.11	16.52	19.11	.78	.97	.81
d 28	29.45	28.76	29.33	20.38	.83	.97	.86

[a]Means represent a total of 153 pigs (initially 10.2 lb and 15 d of age) with six, seven, or eight pigs per pen and seven replicate pens per treatment.
[b]From d 0 to 7 postweaning, pigs were fed a common diet and ADG, ADFI, and F/G were: .46, .45, and .99, respectively.

EFFECTS OF HIGH OIL CORN AND FAT LEVEL ON GROWTH PERFORMANCE OF NURSERY PIGS

J. R. Bergström, C. J. Samland, J. L. Nelssen, M. D. Tokach, and R. D. Goodband

Summary

Two studies were conducted to evaluate the effects of adding high oil corn to nursery diets as compared to other sources of fat. The results of both studies suggest that addition of fat to the nursery pig diet, regardless of the source, has no significant influence on growth performance until late in the nursery phase.

(Key Words: Weanling Pigs, High Oil Corn, Fat Source.)

Introduction

Recently, a tremendous amount of improvement has occurred in the genetic potential of the pig to produce lean pork. With this improvement comes the challenge of feeding the pig a greater amount of nutrients each day so that it can perform to its genetic potential. Nutrient intake can be limited by the pig's ability to consume feed. To compensate for the performance-limiting effects of feed intake, an interest in the use of feedstuffs with higher nutrient density is increasing in the swine industry. Maintaining the proper balance between nutrients is also important. As the concentration of energy increases, the relative levels of all other nutrients must be adjusted to allow for the proper balance between energy and these nutrients.

Carbohydrates and fats in the diet supply most of the pig's caloric needs. Fats and oils contain about 2.25 times as much metabolizable energy as most of the cereal grains. The addition of fat to swine diets usually will increase the cost of the diet. An improvement in pig performance must be realized in order to offset this increase in diet cost.

High oil corn (HOC) is a type of yellow dent corn that contains more oil and, therefore, more energy than typical corn. High oil corn also contains higher concentrations of lysine and tryptophan. A new challenge for the swine industry is to determine how to best apply these characteristics to the feeding of swine.

Therefore, the objective of the following two trials was to compare the growth performance benefits of feeding nursery pigs a diet containing either no added fat, HOC, or increased levels of energy from various other sources.

Procedures

Experiment 1. One hundred and eighty five pigs were weaned at 20 ± 2 d of age, blocked by weight (initially 12.4 ± 1.0 lb), and placed on a common phase I diet from d 0 to 3 postweaning. This was a pelleted diet containing 5% spray-dried plasma protein, 2.5% select menhaden fish meal, 1.75% spray-dried blood meal, and 20% dried whey. Each treatment had six or seven pigs/pen (depending upon the block) and six pens. On d 3, the pens were allotted to one of five treatments and switched to the phase II experimental diets (Table 1). On d 13, the pigs were switched to phase III experimental diets and remained on the same dietary treatments until the conclusion of the trial on d 34. During phases II and III, the control diets consisted of yellow-dent corn (3.7% fat and .26% lysine) and soybean meal formulated to 1.35 and 1.25% lysine, respectively. In the second treatment, HOC (7.8% fat and .31% lysine) replaced the traditional yellow-dent corn and some of the soybean meal found in the control diet to achieve an equal lysine level. The three additional treatments were obtained by adding either soybean oil,

choice white grease, or poultry fat to the control diet to achieve the same level of fat as the HOC treatment.

The pigs were weighed and feed disappearance was determined on d 3, 13, 20, 27, and 34 postweaning. These data were used to calculate ADG, ADFI, and F/G.

Experiment 2. One hundred and eighty pigs were weaned at 20 ± 2 d of age, blocked by weight (initially 13.13 ± 1.0 lb), and placed on a common phase I diet from d 0 to 4 postweaning. The composition of the phase I diet was the same as in Exp. 1. Each treatment had six pigs/pen and six pens. On d 4, the pigs were allotted to one of five treatments and switched to the phase II experimental diets. On d 14, the pigs were switched to phase III experimental diets and remained on the same dietary treatments until the trial's conclusion on d 35. During phases II and III, the control diets consisted of corn and soybean meal formulated to 1.35 and 1.25% lysine, respectively. In the second treatment, HOC (7.8% fat and .31% lysine) replaced the traditional yellow-dent corn and some of the soybean meal found in the control diet to achieve a similar lysine level. The third treatment consisted of the control diet and added soy oil (2.3% in phase II and 2.6% in phase III) to equal the energy level of the second treatment. The fourth treatment consisted of the HOC treatment plus the level of soy oil found in treatment 3. Treatment 5 was formulated with normal dent corn, but soy oil (4.4% in phase II and 5.0% in phase III) was added to make this diet isocaloric to treatment 4.

The pigs were weighed and feed disappearance was determined, on d 4, 14, 21, 28, and 35 postweaning. These data were used to calculate ADG, ADFI, and F/G.

In both experiments, the pigs were housed in an environmentally controlled nursery in 5 × 5 ft pens, with one self-feeder and a nipple waterer to allow ad libitum access to feed and water.

The data were analyzed as a randomized complete block design, with pen as the experimental unit. Pigs were blocked on the basis of initial weight. Analysis of variance was performed using the GLM procedure of SAS. Day 3 weight and d 4 weight were used as a covariate in the analyses of Exp. 1 and 2, respectively.

Results

Experiment 1. From d 0 to 3 postweaning (when all pigs were fed a common phase I diet), ADG, ADFI, and F/G were .62, .45, and .73, respectively.

From d 3 to 13 postweaning, no differences occurred in ADG (Table 2.). However, pigs fed the control diet had greater (P<.05) ADFI than pigs fed the diet containing poultry fat. Pigs fed the control diet or diets containing soy oil or poultry fat had lower (P<.10) F/G than pigs fed HOC.

For the entire phase III period (d 13 to 34 postweaning), no differences occurred in ADG. However, ADFI was reduced (P<.05) by feeding poultry fat. Also, pigs fed poultry fat had improved (P<.05) F/G when compared to those fed soy oil.

Overall (d 0 to 34 postweaning), neither ADG or F/G were affected by either dietary fat or source. However, ADFI was reduced (P<.05) when pigs were fed poultry fat compared to the other dietary treatments.

Experiment 2. From d 0 to 4 postweaning (when all pigs were fed a common phase I diet), ADG, ADFI, and F/G were .69, .56, and .81, respectively.

During the phase II period (d 4 to 14 postweaning), ADG was improved by feeding regular corn and 2.3% soy oil rather than the control (P=.06), HOC (P<.01), or HOC and 2.3% soy oil (P<.06) diets (Table 3.). Additionally, pigs fed regular corn and 2.3% soy oil had greater (P<.04) ADG than pigs fed HOC. Average daily feed intake was greater (P=.08) for pigs fed regular corn and 2.3% soy oil rather than HOC and 2.3% soy oil. Feed efficiency was improved by feeding either regular corn and 2.3% soy oil (P<.05) or regular corn and 4.4% soy oil (P=.08) rather than HOC.

No differences in ADG or ADFI occurred during the phase III period (d 14 to 35). The numeric differences in ADG and ADFI caused F/G to be improved by feeding regular corn and 2.6% soy oil (P=.10) or HOC and 2.6% soy oil (P<.07) rather than the control diet. Pigs fed HOC or regular corn and 5.0% soy oil had intermediate F/G. In both studies, numerical improvements in ADG and F/G were observed during the last week of phase III for pigs fed added fat.

Overall (d 0 to 35 postweaning), pigs fed regular corn and 2.6% soy oil had greater (P<.05) ADG than pigs fed either the control or HOC diets. No differences in ADFI occurred. However, F/G was improved by feeding either regular corn and 2.6% soy oil (P<.07) or HOC and 2.6% soy oil (P=.06).

Discussion

Several previous trials have demonstrated the limited ability of the nursery pig to efficiently use dietary fat before 5 to 6 weeks of age. Possible explanations include decreased levels of fatty acid binding protein shortly after weaning, impaired digestion because of a fat-induced sloughing of intestinal villi cells, or immature metabolic enzyme systems. As in many studies, our results demonstrate little benefit obtained from feeding any of the various fat sources or levels to nursery pigs until late in the phase III period.

Previous research with older pigs has indicated that the feeding value of HOC is correlated highly with its increased nutrient density (fat and amino acids) compared to normal corn. The tendencies for improved ADG during phase III in Exp. 1 and improved ADG and F/G in Exp. 2 demonstrate the increasing value of HOC as a feedstuff for growing swine.

In conclusion, HOC seems to be more beneficial in late nursery diets than in the initial diets after weaning. These results may not reflect the feeding value of HOC but indicate the limited ability of the nursery pig to effectively utilize fat immediately postweaning.

Table 1. Composition of the Experimental Basal Diets (Exp. 1 and 2)

Ingredient, %	Phase II	Phase III
Corn[ab]	55.98	63.03
Soybean meal (46.5% CP)	26.51	32.37
Dried whey	10.00	-
Spray-dried blood meal	2.50	-
Soybean oil	-	-
Antibiotic[c]	1.00	1.00
Monocalcium phosphate	1.85	1.49
Limestone	1.02	1.11
Zinc oxide (72%)	.25	-
Copper sulfate	-	.08
Vitamin premix	.25	.25
Trace mineral premix	.15	.15
DL-methionine	.10	.03
L-lysine HCl	.15	.15
Salt	.25	.35
Total	100.00	100.00

[a](Exp. 1) In the second treatment, HOC replaced the normal dent corn and a portion of the soybean meal to provide the same level of lysine as the basal diet. Treatment 3 was isocaloric to the HOC treatment and contained soy oil (2.3% in phase II and 2.6% in phase III), which replaced a portion of the normal corn in the basal diet. The amount of soybean meal increased slightly to maintain a constant level of lysine across all treatments. The fourth and fifth treatments consisted of choice white grease and poultry fat, respectively, in place of the soy oil found in the third treatment.
[b](Exp. 2) The second and third treatments were identical to those in Exp. 1. The fourth treatment consisted of the second treatment (high oil corn) with the same level of soy oil as treatment three (2.3% in phase II and 2.6% in phase III). The fifth treatment was made isocaloric to the fourth treatment by including soy oil (4.4% in phase II and 5.0% in phase III) in the basal diet.
[c]Provided 50 g/ton of carbadox.

Table 2. An Evaluation of Various Fat Sources in Nursery Pig Diets and Their Effects on Growth Performance (Exp. 1)[a]

		Added Fat Source[b]				
Item	Control	HOC	Soy Oil	CWG	Poultry Fat	CV
d 3 to 13						
ADG, lb	.76	.69	.73	.71	.70	11.4
ADFI, lb	1.09[c]	1.07[cd]	1.03[cd]	1.06[cd]	1.01[d]	6.5
F/G	1.43[c]	1.56[d]	1.43[c]	1.49[cd]	1.43[c]	7.8
d 13 to 34						
ADG, lb	1.18	1.23	1.14	1.19	1.18	8.1
ADFI, lb	2.08[c]	2.15[c]	2.10[c]	2.08[c]	1.98[d]	4.0
F/G	1.75[cd]	1.75[cd]	1.85[c]	1.75[cd]	1.67[d]	7.0
d 0 to 34						
ADG, lb	1.01	1.02	.98	.99	.99	7.5
ADFI, lb	1.65[c]	1.68[c]	1.64[c]	1.64[c]	1.55[d]	4.0
F/G	1.64	1.64	1.69	1.67	1.56	6.0

[a]One hundred and eighty five weanling pigs were used (initially 12.4 lb and 20 d of age), six or seven pigs/pen and six pens/treatment.
[b]Each of these sources supplied 2.4% added fat.
[c,d,e]Means on the same row with different superscripts differ by ($P<.10$).

Table 3. A Comparison of High Oil Corn and Soy Oil as Fat Sources in Nursery Pig Diets and Their Effects on Growth Performance (Exp. 2)[a]

	Regular Corn Soybean Oil, %			High Oil Corn Soybean Oil, %		
	0	2.3/2.6	4.4/5.0	0	2.3/2.6	
ME, kcal/lb						
Phase II	1,464	1,504	1,541	1,514	1,550	
Item Phase III	1,475	1,520	1,561	1,531	1,573	CV
d 4 to 14						
ADG, lb	.65[bd]	.73[c]	.70[cd]	.62[b]	.66[bd]	8.6
ADFI, lb	.98[bc]	1.02[b]	.99[bc]	.97[bc]	.95[c]	7.2
F/G	1.52[bc]	1.41[c]	1.41[c]	1.56[b]	1.43[bc]	8.3
d 14 to 35						
ADG, lb	1.21	1.23	1.21	1.24	1.24	3.6
ADFI, lb	2.21	2.11	2.13	2.18	2.12	4.9
F/G	1.82[b]	1.72[c]	1.75[bc]	1.75[bc]	1.69[c]	6.0
d 0 to 35						
ADG, lb	.99[b]	1.03[c]	1.00[bc]	.99[b]	1.02[bc]	2.9
ADFI, lb	1.66	1.63	1.62	1.65	1.61	4.7
F/G	1.69[b]	1.59[c]	1.61[bc]	1.67[bc]	1.59[c]	5.0

[a]One hundred and eighty weanling pigs were used (initially 13.13 lb and 20 d of age), six pigs/pen and six pens/treatment. Treatments with added soy oil contained 2.3 and 4.4% soy oil in phase II, and 2.6 and 5.0% soy oil in phase III, respectively.
[b,c,d]Means on the same row with different superscripts differ by ($P<.10$).

AN EVALUATION OF SEVERAL DIET ACIDIFIERS COMMONLY UTILIZED IN PIG STARTER DIETS TO IMPROVE GROWTH PERFORMANCE[1]

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Summary

Early-weaned pigs (weaned at 14 d of age) that are managed in a conventional one-site production system and fed a complex segregated early-weaning diet will benefit from the inclusion of a diet acidifier during the first week. However, the data indicate no benefit from including a diet acidifier in semicomplex diets fed during subsequent growth phases.

(Key Words: Weanling Pigs, Growth Performance, Diet Acidifiers.)

Introduction

The supplementation of diets for weanling pigs with organic acids (citric, formic, fumaric, and propionic acid) has been shown to improve ADG and F/G in many, but not all, studies. The inconsistent results observed may have been due to a number of factors, such as weaning age, health status, diet complexity, degree of stress at weaning, and inclusion rate of the organic acid. Generally, the inclusion of organic acids in starter diets has not been as beneficial when the diets contained high levels of milk products. However, the increased use of spray-dried blood meal and plasma protein to replace a portion of the milk products in nutrient-dense starter diets has renewed the interest in organic acids and their impact on starter pig performance.

Recently, interest has increased in the use of diet acidifiers that contain mixtures of organic and inorganic acids. Such mixtures may enhance the effectiveness of acidification. Thus, acidification of the diet can be accomplished at a lower dietary inclusion level. The purpose of this trial was to evaluate the effectiveness of several of these acidifiers when included in a typical early-weaning feeding regime. The diet acidifiers used in this trial were: Syneracid, Lupro-mix, Digest Acid, and Kemgest.

Procedures

A total of 270 pigs (initially 14 ± 2 d of age and 9.8 ± 1.0 lb) was used in a 28 d growth trial. The pigs were blocked by weight and allotted to one of five acidification treatments, with a total of nine pigs/pen and six pens/treatment. The trial was divided into three phases, an SEW phase (d 0 to 7 postweaning), Transition phase (d 7 to 14 postweaning), and Phase II (d 14 to 28 postweaning). The five treatments were: 1) control (without acid), 2) Syneracid (.35% in the SEW and Transition phases, .225% in phase II), 3) Lupro-mix (.4% in all phases), 4) Digest Acid (.2% in all phases), and 5) Kemgest (.2% in all phases). The inclusion levels used in this trial were based on the suppliers' recommendations.

The SEW basal diet was a corn-soybean meal diet containing 25% dried whey, 7.5% spray-dried plasma protein, 6% select menhaden fish meal, 5% lactose, and 1.75% spray-dried blood meal and was formulated to contain 1.7% lysine .47% methionine, .9% Ca, and .8%

[1]The authors appreciate the assistance provided by Eichman Bros. Farms, St. George, KS, who provided the pigs and facilities used in this study. We also thank the following contributors for their financial support, product donations, and expertise: Roger Stuhr, Stuhr Enterprises, Inc.; Gary Lynch, BASF; Donnie Moran, Agri-America; and Gary Fitzner, Feed Specialties, Inc.

P (Table 1). The Transition basal diet contained 20% dried whey, 2.5% spray-dried plasma protein, 2.5% select menhaden fish meal, 5% lactose, and 2.5% spray-dried blood meal and was formulated to contain 1.5% lysine, .41% methionine, .9% Ca, and .8% P. The Phase II basal diet contained 10% dried whey and 2.5% spray-dried blood meal and was formulated to contain 1.35% lysine, .37% methionine, .9% Ca, and .8% P. Syneracid, Lupro-mix, Digest Acid, and Kemgest each replaced corn starch in the basal diet to provide the four additional treatments.

Pigs were housed in an environmentally controlled nursery in 5 × 5 ft pens. Pens were equipped with one self-feeder and two nipple waterers to provide ad libitum access to feed and water.

The pigs were weighed and feed disappearance was determined on d 7, 14, 21, and 28 postweaning. Average daily gain, ADFI, and F/G were calculated from this information.

The data were analyzed as a randomized complete block design, with pen as the experimental unit. The pigs were blocked on the basis of initial weight. Analysis of variance was performed using the GLM procedure of SAS. All possible individual contrasts were performed using three separate SAS outputs, because no more than four individual contrasts could be run at one time when only four degrees of freedom existed for diet in the model.

Results

From d 0 to 7 postweaning, when pigs were fed an SEW diet, no differences occurred in ADG or ADFI; however, F/G was improved ($P<.05$) by including an acidifier in the diet (Table 2). Although not significant, numeric improvements occurred in ADG when pigs were fed acidified diets, with improvements in ADG ranging from 5% to 16%. Improvements in F/G ranged from 3% to 19% with acid inclusion.

During the Transition (d 7 to 14 postweaning) and Phase II (d 14 to 28 postweaning) periods, no differences in growth performance were observed. Also, for the entire trial period (d 0 to 28 postweaning), growth performance was similar among all of the treatments.

Discussion

The results of this trial are in agreement with much of the data already published concerning the inclusion of acidifiers in starter diets. The improvements in growth performance that resulted from diet acidification during the first week are indicative of the benefits often observed when young pigs are subjected to the stresses of weaning. Weaning often occurs when pigs are 3 to 4 weeks of age, a time when secretion of gastric HCl, as well as pancreatic lipase, amylase, and trypsin, is relatively low. Supplementing starter diets with acidifiers may improve growth performance by increasing digestibility and nutrient and energy retention when pigs are weaned at 3 to 4 weeks of age.

Previous research at Kansas State University demonstrated that adding fumaric acid to a Phase I starter diet (containing 20% dried whey and 10% plasma protein) resulted in tendencies for improved ADG and F/G. In another study, weanling pigs fed a nutrient-dense Phase I diet containing either 1.5% fumaric acid or .4% buffered propionic acid (Luprosil NC or Luprosil salt) had improved ADG and F/G. These two studies demonstrated that the inclusion of an organic acid in a nutrient-dense diet containing 20% dried whey will improve the growth performance of early-weaned pigs.

In this study, the lack of a significant improvement in growth performance after the first week may have been due to the high health status of the pigs. The growth performance obtained in this trial is indicative of the high health status. The benefits of using a diet acidifier often are more evident when pigs are subjected to a disease challenge, and the incidence of diarrhea may be reduced by including an acidifier in the diet.

Also, the complex nutrient-dense diets used in this trial may have reduced the potential for an improved growth response with acidification. Past research at the University of Illinois has demonstrated that diet acidifiers are

not as effective when included in complex diets containing high levels of milk products. Recent research at Oklahoma State University indicates that feeding an acidified diet (Syneracid) will improve growth performance during the first 3 weeks post-weaning. However, the basal diets used were less complex than those in this trial and may have been responsible for the lower growth performance observed by all pigs in that research.

In conclusion, including an acidifier in a complex SEW diet will improve growth performance of the conventionally reared, early-weaned pig. However, when the stresses associated with weaning have been overcome, acidification is not necessary if semicomplex diets are fed during subsequent growth phases.

Table 1. Composition of Diets[a]

Ingredient, %	SEW	Transition	Phase II
Corn	32.18	35.92	55.50
Soybean meal (46.5% CP)	11.76	20.93	25.72
Dried whey	25.00	20.00	10.00
Spray-dried plasma protein	7.50	2.50	-
Spray-dried blood meal	1.75	2.50	2.50
Soybean oil	6.00	5.00	-
Select menhaden fish meal	6.00	2.50	-
Lactose	5.00	5.00	-
Corn starch[b]	1.50	1.50	1.50
Antibiotic[c]	1.00	1.00	1.00
Monocalcium phosphate	.75	1.41	1.88
Limestone	.46	.67	.97
Zinc oxide (72% Zn)	.38	.38	-
Copper sulfate	-	-	.08
Vitamin premix	.25	.25	.25
Trace mineral premix	.15	.15	.15
DL-methionine	.13	.10	.07
L-lysine HCl	.10	.10	.15
Salt	.10	.10	.25
TOTAL	100.00	100.00	100.00
Calculated Analysis, %			
CP	22.85	21.39	20.48
Lysine	1.70	1.50	1.35
Methionine	.47	.41	.37
Ca	.90	.90	.90
P	.80	.80	.80

[a]Pigs were fed the SEW, Transition, and Phase II diets from d 0 to 7, d 7 to 14, and d 14 to 28, respectively.
[b]Syneracid (.35% in the SEW and Transition phases, .225% in phase II), Lupro-mix (.4% in all phases), Digest Acid (.2% in all phases), and Kemgest (.2% in all phases) each replaced corn starch to form the four additional experimental treatments.
[c]Provided 50 g/ton of carbadox.

Table 2. Comparison of Various Acidifiers Commonly Utilized in Pig Starter Diets to Improve Growth Performance[a]

		Dietary Acidifier				
Item	Control	Syneracid	Lupro-Mix	Digest Acid	Kemgest	CV
d 0 to 7						
ADG, lb	.37	.41	.39	.43	.43	16.4
ADFI, lb	.42	.40	.37	.40	.40	9.8
F/G[b]	1.14	.99	.97	.93	.92	16.6
d 7 to 14						
ADG, lb	.64	.57	.64	.66	.62	13.2
ADFI, lb	.79	.79	.82	.86	.82	8.0
F/G	1.25	1.39	1.28	1.32	1.33	10.4
d 14 to 28						
ADG, lb	1.02	1.00	1.00	.99	.99	6.1
ADFI, lb	1.44	1.42	1.41	1.46	1.48	3.9
F/G	1.41	1.43	1.41	1.47	1.49	4.8
d 0 to 28						
ADG, lb	.76	.74	.76	.77	.76	5.1
ADFI, lb	1.02	1.01	1.00	1.04	1.05	4.1
F/G	1.33	1.35	1.33	1.37	1.37	3.4

[a]Two hundred and seventy pigs were used (initially 9.8 lb and 14 d of age), nine pigs/pen, six pens/treatment.
[b]Control vs acidified diets ($P<.05$).

EFFECTS OF SPLIT-NURSING MANAGEMENT ON GROWTH PERFORMANCE IN NURSING PIGS [1]

T. S. Donovan [2] and S. S. Dritz [2]

Summary

We evaluated the effects of split nursing the lightest 50% of pigs per litter or the lightest and heaviest 50% of pigs per litter at birth on growth performance until weaning. We did not observe any effects of split nursing on growth performance in pigs from litter sizes < 9 at birth. Additionally, we did not observe a difference in mean ADG or pig weight at weaning. However, we did observe a reduction in the variation of ADG between litters. The resulting decrease in variation leads to approximately a 55% (1.3 vs 3.0) reduction in pigs weighing less than 8 lb at weaning. We conclude that the greatest economic benefits are derived from split nursing the lightest 50% of pigs from litter sizes

(Key Words: Split Nursing, Colostrum, Lactation, Growth.)

Introduction

Split nursing is defined as removing piglets from the dam for a set period of time to allow uncompetitive suckling for others. Split nursing is a management tool that can be used to decrease the competitiveness for colostrum in large litters. Implementing split nursing allows underprivileged piglets (less than 2 lb) the opportunity for adequate transfer of passive immunoglobulin. If these piglets are able to gain sufficient amounts of immunoglobulin, they will benefit by being more viable and heavier at weaning. Production on a sow farm typically is measured by pigs/sow/year (p/s/y). Measuring (p/s/y) gives no indication of the quality of pigs being produced. Pigs that receive inadequate amounts of immunoglobulin are challenged by disease and unthriftiness. Thus, increasing the amount of immunoglobulin absorbed by piglets will enhance the quality of weaned piglets. More efficient production has led to larger litters with an increased variation in piglet size. This includes more piglets in the less viable category. Variation in weight among litter mates starts at birth and seems to continue to weaning age and often through the nursery and finisher. Limiting weight variation is important for improving the facility's utilization of all-in all-out systems. Our objective was to improve weaned pig quality by decreasing the variation in growth performance of nursing pigs using management methods.

Procedures

Treatment Groups. We used a total of 118 litters, randomly assigned to one three treatment groups:

Control = Control group in which no split nursing was performed.

Light = Removed the heaviest 50% of the litter to allow uncompetitive suckling for the lightest 50%.

All = Removed the heaviest 50% (as in Light group), then removed the lightest 50% to

[1]Appreciation is expressed to Newsham Hybrids USA, Colorado Springs, CO for providing the facilities and animals used in this experiment. A special thank you to Chris Allen for providing technical assistance.

[2]Food Animal Health and Management Center.

allow the same uncompetitive suckling for the heavier pigs.

A sow was assigned randomly to a treatment group before parturition. At the completion of farrowing (expulsion of the placenta), each piglet was weighed and tattooed with an individual ID. The individual pig birth weight, piglet identification, sow identification, parity, gestation length, and farrow date were recorded. The litters that were split nursed were divided by birth weight into the heaviest and lightest 50%. If a litter consisted of an odd number of piglets, the odd piglet was put in the heavier group. The heavy piglets were put in a box next to the crate for 2 hr. After 2 hr, the heavy pigs were placed back into the farrowing crate. For the litters in which the heavier pigs were split suckled, the light pigs were now removed for 2 hr. This allowed the heavier piglets an opportunity for nursing without competition from the lighter pigs. After completing the split nursing, the piglets were left to suckle the sow for 24 hr. The litters then were processed which includes cutting teeth, castrating, cauterizing tails, and injecting with a 3 cc IM iron. Lastly, the piglets were cross-fostered to create even litters of nine to 11 per sow depending on the size of the litters. The piglets were weighed individually again at weaning. Mortality was monitored, with the date and piglet weight at mortality recorded.

Calculations. The standard deviation (STD) for birth weight (BW) and weaning weight were calculated for each litter. Average daily gain (ADG) was calculated for each pig by dividing piglet weight gain by days of lactation. The coefficient of variation (CV) was calculated by taking the STD for each litter divided by average pig weight. The standard normal curves then were obtained using the average and STD for pig weaning weight and ADG.

Statistical Analysis. Data were analyzed as a randomized complete block design in a 2 × 3 factorial arrangement. With the main effects of litter size (less than 9 and 9 or greater pigs born alive) and split nursing treatment (control, light 50% split nursed, light and heavy 50% split nursed). Litter was considered the experimental unit for all response criteria. Analysis of variance was performed using the GLM procedure of SAS with birth weight and lactation days used as a covariates.

Results and Discussion

Preweaning mortality was not affected by treatment (data not shown). Other results are listed in Table 1. Interactions for litter size by split nursing strategy were detected for ADG STD and ADG CV ($P<.09$ and .07, respectively). No significant main effects ($P>.10$) were detected for any of the other response criteria. Interpretation of the values suggests that weaning weights in litters with less than 9 born alive were not affected by the split nursing procedure, whereas a linear improvement ($P<.05$) in the ADG STD and CV occurred for litters with 9 or greater pigs born alive. The distribution of weaning weights shows a shift to the right (Figure 1). This shift for the split-nursed pigs indicates fewer lighter weight pigs at weaning. Occurrence of the shift for both groups of split-nursed pigs suggests less variation among weights of pigs at weaning.

The distribution of the mean pig ADG is depicted in a normal curve in Figure 2. The shifting of the weaning weight was due to decreased variation in ADG for the split-nursed piglets. Split nursing the less viable piglets achieved a more consistent growth performance.

These data suggest that the quality of weaned pigs from split-nursed litters is improved. The decrease in variation of ADG among litters will produce pigs that are more uniform at weaning, possibly reducing the variation in days to market pigs at optimal weight. The decrease in lighter weight pigs limits variation at weaning. An all-in all-out system would benefit by a decreased variation in weight of pigs entering the nursery. A decrease in variation would improve facility utilization by decreasing turnaround time. Improving variation in a group carried throughout the finisher would produce a more uniform, consistent product at market. Further research must be conducted to determine if the benefits of split nursing are maintained to market.

Intestinal absorption of immunoglobulin from colostrum normally ceases by 24 to 36 hr after birth. Small amounts of colostrum in newborn piglets induces intestinal closure, suggesting that piglets must have adequate time to suckle. Therefore, a short but vital period exists when sufficient intake for each pig must be accomplished. The competition among litters of 9 or greater pigs inhibits adequate transfer of immunoglobulin in the lighter weight, less viable piglets. Split nursing decreases the competition and allows the underprivileged pigs an opportunity for colostral intake.

Economic Analysis. This study included 118 litters with a total of 1,193 pigs. We assumed that pigs were sold at weaning and 1,193 pigs were sold. The following market prices per head were assumed: $32 for weaned pigs 9 lb or greater, $25 for pigs 8 lb or greater but less than 9 lb, and $7 for pigs less than 8 lb.

The percentages of pigs 8 lb or greater and 9 lb or greater from a litter size of 9 or greater are listed in Table 2. Using the above prices for the weaned pigs, the litters that were split nursed (light) would have a gross income of $37,500. The litters in which both groups were split nursed (all) would have a gross income of $37,407. The control group that was not split nursed would produce only $36,849 gross income. The difference in income between the light and control groups is $651. These litters were farrowed in a 2-week period. Therefore, the increased income per day is $46.50 (based on 8 litters/day). Subtracting the labor cost (1.5 hr/8 litters @ $10/hr) of implementing the split nursing, the total profit from split nursing is $46.50 - $15 = $31.50/day. The yearly increase in net income from implementing split nursing would be $11,497.50. These calculations are based on a sow herd size of 1800 sows in which split-nursing is practice for only the lightest 50%. We also assumed that approximately 2/3 of the litters will have 9 or greater pigs born alive.

Practical Implementation of Split Nursing. In a production setting, the time-consuming tasks of weighing, tattooing, and record keeping involved in this project would be eliminated. In addition, our data suggest that greater benefits are obtained by split nursing litters with > 8 pigs born alive. The weight of the piglet could be estimated, and the heaviest or largest half of the litter removed. A plastic container that can be disinfected and reused is suggested along with a heat lamp with a clamp or a heat pad. Monitoring the split nursing would be the most time-consuming part of the procedure. Limiting the split-nursing time to 2 hr needs to be watched carefully to prevent hypoglycemia or hypothermia. Small portable timers can be used to remind personnel when piglets need to be returned to the crate. Piglets should be split nursed within 24 hr of birth in order to have sufficient opportunity for immunoglobulin.

In conclusion, split nursing can be used to decrease the variation of average daily gain of pigs while nursing. Split nursing the lightest pigs from litters of 9 or greater resulted in the greatest economic benefit.

Table 1. Influence of Litter Size and Split-Nursing Management Strategy on Growth Performance of Nursing Pigs [a]

	Litter Less than 9			Litter 9 or Greater			S×T[c]	
Item	Control	Light	All[b]	Control	Light	All	P-value (*P*<)	CV
Average, lb								
Weaning weight	12.8	12.2	12.3	11.9	12.0	12.1	.55	11.3
ADG	.51	.47	.48	.46	.46	.47	.52	16.0
Average litter STD, lb								
Birth weight	.63	.69	.58	.61	.61	.68	.18	29.2
Weaning weight	1.9	1.8	1.9	2.1	1.8	2.0	.84	32.7
ADG[d]	.09	.09	.11	.12	.11	.10	.09	34.4
Average coefficient of variation, %								
Birth weight	17.9	19.6	16.8	16.9	17.0	19.1	.21	28.8
Weaning weight	14.7	14.6	16.2	17.3	15.3	16.2	.73	31.6
ADG[d]	17.1	19.8	23.6	26.3	24.1	22.4	.07	36.2

[a]A total of 118 litters was used. Birth weight and lactation days were used as covariates. The average birth weight was 3.6 lb, and average lactation length was 18.2 days.
[b]The split-nursing strategies consisted of control (no split nursing), light (only the lightest 50% of the litter allowed to suckle uncompetitively, and all (both the light and heavy 50% were split nursed). The pigs were allowed to suckle uncompetitively for 2 hr following the birth of the last pigs in the litter.
[c]S × T = litter size < or
[d]Treatment × litter size *P*<.05).

Table 2. Percent of Pigs Greater than or Equal to 8 or 9 lb at Weaning Weight Born to Sows with Litter Sizes of 9 or Greater

	Split-Nursing Treatment		
Pigs, %	Control	Light	All
Greater than or equal to 8 lb	97.0	98.7	98.4
Greater than or equal to 9 lb	91.8	95.4	94.9

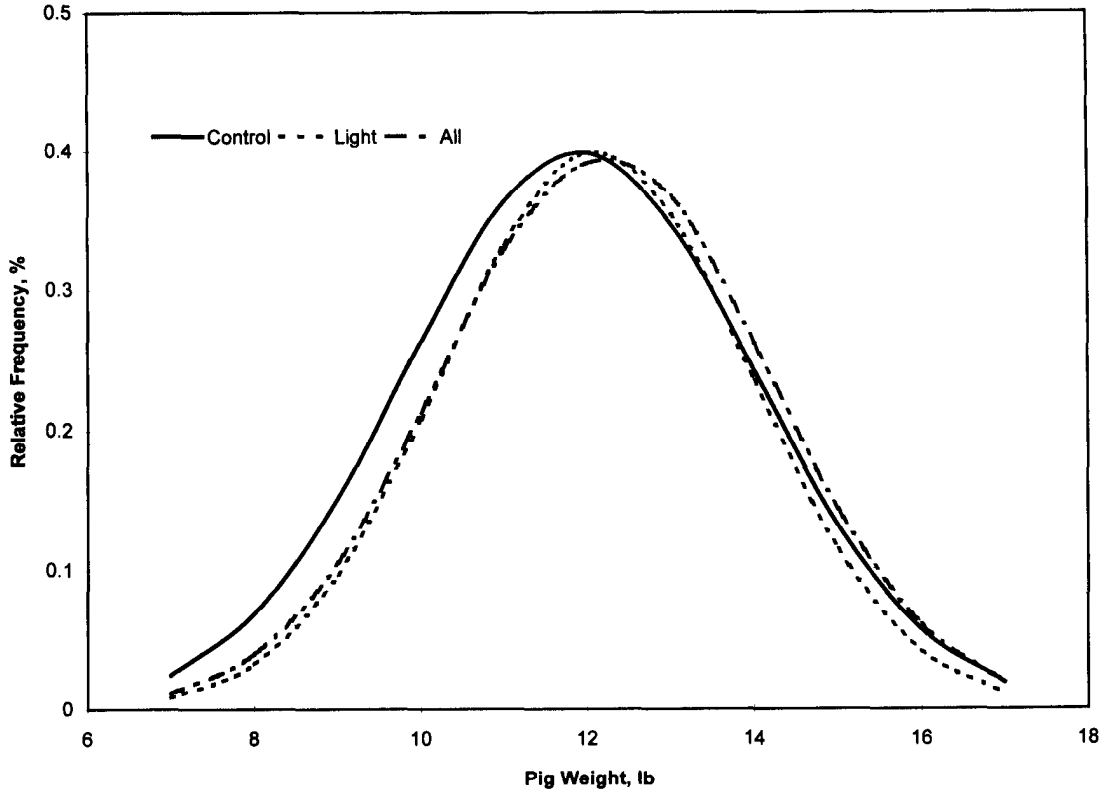

Figure 1. Distribution of Weights of Split-Nursed Pigs at Weaning

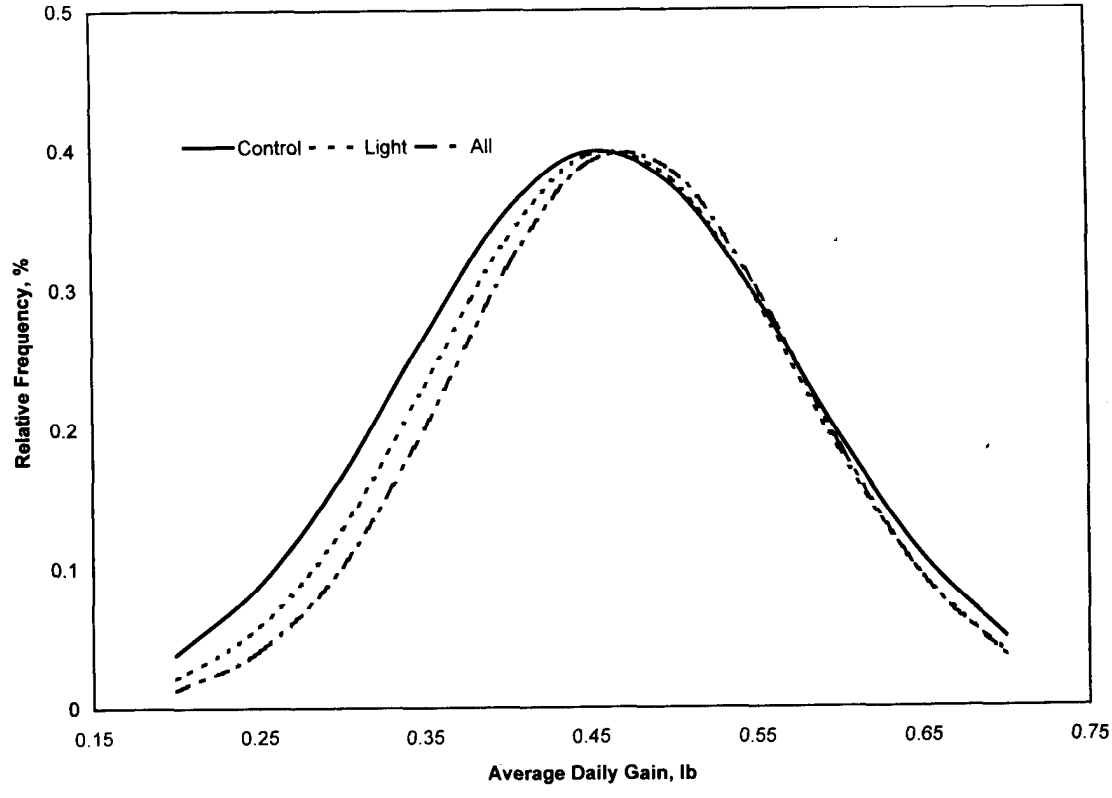

Figure 2. Distributions of ADG of Split-Nursed Pigs during Lactation

THE EFFECTS OF PORCINE REPRODUCTIVE AND RESPIRATORY SYNDROME (PRRS) VACCINATION ON POSTWEANING GROWTH PERFORMANCE [1]

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Summary

We evaluated the effects of a modified-live virus vaccine for PRRS virus on nursery growth performance. The pigs used in this study were obtained from a herd with substandard nursery growth performance attributed to PRRS virus infection. We failed to detect the presence of active circulating field strain virus in either the controls or vaccinated pigs. However, we did detect a strain similar to the vaccine virus strain on d 34 after weaning in the vaccinated pigs. The vaccinated pigs had poorer growth performance from d 7 to 14 after vaccination and were lighter in weight for the remainder of the experiment. Vaccinating uninfected pigs with a modified-live vaccine (RespPRRS™) has a cost in growth performance. Therefore, determining if virus is circulating within the nursery population is necessary before vaccinating.

(Key Words: Porcine Reproductive and Respiratory Syndrome, Nursery Pigs, Vaccination.)

Introduction

Porcine reproductive and respiratory syndrome (PRRS) was first reported in 1987 and has since spread throughout the major pig producing areas of Asia, North America, and Europe. Clinical signs and production losses are different among herds. This study focuses on the respiratory syndrome associated with PRRS virus infection in nursery populations. The most consistent signs observed in recently weaned pigs include respiratory distress, anemia, lethargy, failure to thrive, and decreased feed intake and growth.

Many different strategies have been proposed to manage active PRRS virus infection in nursery populations. Management strategies for controlling PRRS virus infection include nursery depopulation and MCREBEL (Management Changes to Reduce Exposure to Bacteria to Eliminate Losses). Nursery depopulation is most effective after viral transmission in the breeding and finishing populations has been controlled. The goal of these strategies is to stop active virus circulation within the populations that transmit infection to recently weaned pigs. Another tool for control of PRRS virus is vaccination using a modified-live vaccine (RespPRRS™, Boehringer-Ingelheim, St. Joseph, MO). The vaccine is approved for pigs 3 weeks of age or older, with a labelled intramuscular (IM) dose of 2 ml. Our first goal in this study was to assess the growth performance of pigs in an off-site nursery after weaning from a PRRS virus-infected, commercial herd. Our second goal was to study the effects of PRRS vaccination on growth performance.

[1]Appreciation is expressed to Keesecker Agri-Business for supplying the pigs and NOBL Laboratories, Inc., Sioux Center, IA for providing the serologic testing, virus isolation, and strain differentiation.

[2]Food Animal Health and Management Center.

[3]Abilene Animal Hospital, Abilene, KS.

[4]NOBL Laboratories, Inc., Sioux Center, IA.

Procedures

Three hundred eighty unvaccinated pigs 17 to 23 days of age were obtained from a commercial herd with ongoing PRRS-associated infection in weaned pigs. Vaccination at weaning with a modified-live virus vaccine (RespPRRS™) was being conducted as a control strategy on the farm. Previous nursery depopulations and the vaccination program had resulted in unacceptable growth performance.

One day before weaning, 25 sows and their litters were selected randomly. Serum was harvested from the sows and frozen for later analysis. Four pigs from each sow were tagged and designated to be followed by PRRS ELISA. Two pigs from each litter were given even-numbered tags for the vaccination group, whereas the other two representing the control group were given odd-numbered tags. The next day (d 0), these 100 pigs were weaned along with 280 other pigs the same age and transported to the segregated early-weaning nurseries at Kansas State University.

Pigs were housed in one of two environmentally controlled, identical nurseries located a minimum of .8 km from other pig-rearing sites. One hundred ninety pigs were placed in one nursery, including the 50 even-numbered pigs, and 190 pigs including the 50 odd-numbered pigs were placed in another nursery. Animal caretakers were not allowed to be in contact with pigs on any other site for the previous 24 hours before entering the nursery. Pigs were checked, fed, or bled in the control barn first. Once in the treatment barn, caretakers could not return into the control barn for 12 hours.

Pigs were blocked by initial weight (heavy, medium, or light) and placed in pens each containing five pigs initially with weight equalized across pens within blocks. Each pen was 4 ft. x 4 ft. with slotted metal flooring, resulting in a population density of 1 pig per 3.2 sq. ft. A self-feeder and nipple waterer were located in each pen to allow ad libitum consumption of feed and water. Pigs were used simultaneously in a nutrition experiment. On d 15, pigs were reallocated by weight within each barn to one of three blocks (heavy, medium, or light) to be used in a second nutrition experiment. Average pig weight was held constant within barns before and after reallocation. In both nutrition experiments, pigs were fed complete blocks of dietary treatments within each weight block. The pigs were weighed on d 7, 14, 21, 28, 35, and 42, and feed intake was recorded from d 0 to 14 and 21 to 42 to monitor ADG, ADFI, and F/G.

After allocation, prevaccination serum was obtained from the 50 tagged animals in each group and frozen for later analysis. Then the entire population in the control barn was injected with saline and the entire population in the treatment barn was injected with 2 ml IM of a modified-live PRRS virus vaccine (RespPRRS™). Tagged animals were bled on d 14, 35, and 42 after vaccination, and the serum was examined for the presence of antibodies to PRRS virus using an ELISA procedure. Pigs that died were submitted to the KSU Diagnostic Lab for necropsy. Tissues were formalin-fixed and examined for PRRS virus antigen using an immunohistochemical detection procedure.

On d 34, alveolar macrophages were obtained from 29 pigs (14 controls and 15 vaccinates) using alveolar-bronchial lavage. The macrophages were used for virus isolation procedures to detect PRRS virus. Virus isolates from the lavage were examined for similarity to vaccine virus strain using molecular biology techniques.

Data were analyzed as a randomized complete block design with the main effects of vaccination status and dietary treatment. The GLM function of SAS was used to analyze the data. Each pen of pigs was used as an experimental unit. Interactions ($P>.10$) were not detected between dietary treatment and vaccination status. This indicates that the responses to vaccination status and dietary treatment were independent.

Results

Growth Performance. In the first week (d 0 to 7), vaccinated pigs had a slightly higher ADFI compared with control pigs (.38 vs .35, respectively; *P*<.05; Table 1). The vaccinated pigs consumed on average of .03 lb per day more (*P*<.05) than the control group. From d 7 to 14, ADG of the control group was higher (*P*<.01) than that of the vaccinated group (.63 vs .49 lb, respectively). The control group consumed more (*P*<.01) feed than the vaccinated group. Feed efficiency of the control group was better than that of the vaccinated group (*P*<.03; 1.16 vs 1.30, respectively) in this time period. For the d 0 to 14 period, the control group had higher ADG (*P*<.01) and ADFI (*P*<.07) and better F/G (*P*<.05). Average daily gain and F/G did not differ between treatments from d 21 to 42. On d 7, pig weights between treatments were nearly identical. However, on d 14, 21, 28, 35, and 42, pigs in the control group were heavier (*P*<.02) than those in the vaccinated group.

Serology. Sixty percent (15/25) of the sows were seropositive (>.4 S/P) for PRRS virus. All pigs in the control group (50/50) were seronegative on d 35. Seventy-five percent (36/49) of the vaccinated group were seropositive for PRRS virus on d 35.

Virus Isolation in Alveolar Macrophages. Porcine reproductive and respiratory syndrome virus was not detected in the lavage samples from the control group on d 34. However, PRRS virus was detected in 20% (3/15) of the vaccinated group lavage samples examined on d 34. Virus samples from these three pigs were differentiated and found to be similar to RespPRRS™/2332 vaccine strain.

Immunohistochemistry. Two pigs that died from the control barn were submitted for necropsy, one each on days 8 and 10, respectively and formalin-fixed tissues were examined for the presence of PRRS virus antigen. Antigen was not detected by immunohistochemical methods.

Discussion

The pigs used in this study were from a commercial herd experiencing substandard growth performance after weaning. Vaccination with RespPRRS™ was being conducted in this herd at weaning. We do not know whether a field strain of PRRS virus was contributing to the decreased growth performance in the nursery population or if the vaccine itself had negative effects on growth performance.

The pigs housed in the off-site nurseries at KSU from weaning until d 42 proved to be free of field strain PRRS virus. All control pigs were PRRS ELISA negative. Nearly three-fourths of the vaccinated population were PRRS ELISA positive. Antibodies can be detected first by the ELISA at 9 to 13 days after vaccination (> 0.4 S/P ratio), peak 4 to 6 weeks later (2.0 to 4.0 S/P ratio), and are estimated to revert below detectable levels by 4 to 5 months after infection.

Alveolar macrophages collected by lavage of the lungs of infected pigs can be useful for virus isolation. Results with this dependable tool for PRRS diagnosis supported the serology results and allowed the isolated strain to be differentiated. The only strain isolated was one having a genetic profile similar to that of the RespPRRS™/2332 strain, indicating that the antibody response mounted by the vaccinated pigs was to the vaccine and not to a field strain virus. PRRS virus antigen was not found by immunohistochemistry on the formalin-fixed tissues of the necropsied control pigs, providing further supporting evidence that virus was not actively circulating.

Our results reflect a decrease in post-weaning growth performance after vaccination with RespPRRS™. The largest differences in growth performance occurred 7 to 14 days after weaning and vaccination. Average daily gain and ADFI were lower and F/G poorer for vaccinated compared to control pigs during this time period. Pig weights significantly differed by d 14. We found that ADG and F/G did not differ between treatments from days 21 to 42 after infection. However, because of the decrease in performance from d 7 to 14, vaccinated pigs weighed less on d 21, 28, 35, and 42. This indicates that the weight difference was not getting larger and the

vaccinated pigs did not compensate with increased growth performance.

These findings stress the importance of determining the presence of active PRRS virus within nursery populations before vaccination are initiated. Sixty percent of the sows from which the pigs came in this study were PRRS ELISA positive. However, this does not provide evidence of the viral status in the nursery population. Serology coupled with virus isolation in nursery pigs should give practitioners and producers a good idea of what is happening in that population. Our results show that vaccination has a significant influence on growth performance and is not recommended if the nursery is free of circulating field-strain virus.

In conclusion, vaccinating uninfected pigs with a modified-live vaccine (RespPRRS™) has a cost in growth performance. Producers must know if a field-strain virus is circulating within the nursery population before vaccinating. Live vaccine virus was detected on day 34 after vaccination, and the ELISA titer of the dams at weaning was not predictive of PRRS virus infection in the nursery.

Table 1. Influence of a Modified-Live PRRS Vaccine on Growth Performance, Immune Response, and Viral Shedding[a]

Item	Control	Vaccinates	*P*<	CV
d 0 to 7				
ADG, lb	.28	.30	.39	26.8
ADFI, lb	.35	.38	.05	17.0
F/G	1.24	1.28	.54	21.2
d 7 to 14				
ADG, lb	.63	.49	.01	15.0
ADFI, lb	.73	.64	.01	16.4
F/G	1.16	1.30	.03	20.3
d 0 to 14				
ADG, lb	.46	.39	.01	12.0
ADFI, lb	.54	.51	.07	13.9
F/G	1.19	1.29	.05	11.0
d 21 to 42				
ADG, lb	1.11	1.08	.23	8.7
ADFI, lb	2.14	2.05	.04	7.9
F/G	1.95	1.91	.34	8.1
Pig weight, lb				
d 7	14.2	14.3	.40	3.6
d 14	18.6	17.9	.01	4.0
d 21	26.0	25.1	.01	3.1
d 28	33.3	31.5	.01	3.8
d 35	40.4	39.4	.02	4.0
d 42	49.6	47.7	.01	4.9
ELISA results, % >.4				
d 35	0 (0/50)	73 (36/49)	--	--
Lavage results, % Pos VI				
d 34	0 (0/14)	20 (3/16)	--	--

[a]Each number is the mean of 36 pens (five pigs/per pen) from d 0 to 14 after weaning and 30 pens from d 21 to 42 after weaning. Pigs initially averaged 12.2 lb. V accine was administered to pigs in the vaccinated group on the day of weaning (d 0). All VI isolates on d 34 were similar to the vaccine strain (RespPRRS™).

EFFECTS OF ANTIBIOTICS ON SHEDDING OF *SALMONELLA TYPHIMURIUM* IN EXPERIMENTALLY INOCULATED PIGS

D. R. Hyatt [1], J. C. Galland [1], S. S. Dritz [1], J. Nietfeld [2], C. Irwin [1], and C. Davison [1]

Summary

The objective of this experiment was to determine if antibiotics used as feed additives and disease treatment for livestock affect duration of shedding and colonization of tissues with *Salmonella typhimurium* in pigs. No statistically significant difference was detected in duration or amount of shedding of *S. typhimurium* between pigs receiving antibiotics and control pigs. Antibiotics prevented colonization of tissues by *S. typhimurium*. The odds (OR=.02) of isolating *S. typhimurium* in at least one of four tissues examined were significantly less from pigs treated with antibiotics than from control pigs (two-tailed Fisher exact test, *P*=.009).

(Key Words: *Salmonella typhimurium*, Nursery Pigs, Antibiotics.)

Introduction

Antibiotics are used to treat infections in animals and humans and are fed to food animals for growth promotion. These practices may be associated with development of bacteria resistant to antibiotics. Increased antibiotic resistance leads to increased risk to animal and human health. Infections caused by antibiotic-resistant *Salmonella* are increasing and are reasons for public health concern. Thus, obtaining a better understanding of *Salmonella* infections so that antibiotics currently available can be used more effectively is important.

The research described here was designed to determine the effect of subtherapeutic and therapeutic dosages of antibiotics on infection of pigs experimentally inoculated with *Salmonella typhimurium*.

Procedures

Subjects for the study were 18 3-week-old pigs (PIC, C15 x L326), one pig from each of 18 litters. Pigs were assigned randomly to either control or treatment groups, matched by initial body weight and gender. Results of randomization yielded a design balanced on treatment, gender, litter, and body weight within gender. Pigs were housed in a controlled isolation facility in concrete pens, one pig per pen. Each pig had access to feed and water ad libitum. Diets were prepared at the Kansas State University feed mill. After a 7-day acclimation period, all pigs were inoculated intragastrically with 4×10^9 CFU of *S. typhimurium* that was susceptible to the antibiotics used. After inoculation and until completion of the experiment, the treatment group received subtherapeutic levels of neomycin and tetracycline in feed (99.5 mg each /lb of feed) and tetracycline (4.5 mg/lb of body weight) in water. Ceftiofur was administered at therapeutic levels (15.1 mg/lb) to the treatment group on day 2 through day 6 postinoculation. The control group was not given antibiotics as feed or water additives or as treatments for disease.

All pigs were evaluated daily for clinical signs of disease; activity level (normal, lethargic, down); stool consistency (firm, soft,

[1]Food Animal Health and Management Center.
[2]Department of Diagnostic Medicine/Pathobiology.

runny); and intake of feed and water. Body temperature was recorded, and rectal swab and blood samples were collected three times a week from each pig.

Rectal swabs were cultured for *S. typhimurium* using standard microbiological techniques. Amount of shedding was defined as the number of steps required to isolate *S. typhimurium*. If *S. typhimurium* could be isolated by direct swab, the amount of *S. typhimurium* in the sample was given a score of 1, indicating that *S. typhimurium* was easiest to isolate and, therefore, shed in the highest numbers. If *S. typhimurium* was isolated after a 24-h enrichment, the sample was given a score of 2. If further enrichment was required for isolation, the sample was given a score of 3.

At necropsy (day 25 postinoculation), swab samples of ileum, cecum, ileocecal junction, and colon were collected aseptically for bacterial isolation and identification. Four tissue sections (liver, spleen, lymph node, and colon) were cultured after extensive washing and mechanical disruption. Pigs that died before completion of the experiment were necropsied and sampled on the day of death.

Frequency data were tabulated and analyzed by use of EpiInfo. The SAS GLM procedure was used to analyze continuous data.

Results and Discussion

Two pigs from the control group died before the end of the experiment. One pig died of salmonellosis (day 8 postinoculation) and the other died from complications unrelated to the study (day 4). The pig that died on day 8 was necropsied and checked for colonization by swabbing several sites along the intestinal tract. *S. typhimurium* was isolated by direct plating at every portion of the tract that was sampled. No pigs from the treatment group died before the end of the experiment.

All pigs in both groups were shedding *S. typhimurium* on day 3 postinoculation. For the control group, 57% (4/7) of the pigs were shedding on the final day. For the treatment group, 22% (2/9) were shedding on day 25 (Table 1). Excluding the two pigs that died early and the four pigs that were shedding *S. typhimurium* on the final day of the study (and that might have continued to shed if the study was not terminated), the average duration of shedding was 21 days. Average duration of shedding for the treatment group, excluding the two pigs that were shedding *S. typhimurium* on the final day, was 18 days.

S. typhimurium was isolated from tissue swabs of all pigs in at least one site along the intestinal tract. *S. typhimurium* was isolated from four of the seven control pigs (57%) at every site sampled. *S. typhimurium* was isolated from only one of the nine treatment pigs (11%) at every sample site. For the control group, *S. typhimurium* was isolated most in the colon and spiral colon (Table 2). For the treatment group, *S. typhimurium* was isolated most frequently from the cecum, colon, and ileocecal junction. For both groups, *S. typhimurium* was isolated least from swab samples of the jejunum. *S. typhimurium* was isolated from swabs of the jejunum significantly less often from treatment pigs than from control pigs.

In the control group, 86% (6/7) of the pigs were colonized by *S. typhimurium* in at least one of the four tissues that were sampled (Table 1 and Figure 1). One pig from the group that received antibiotics (11%) was colonized by *S. typhimurium* in the spleen (Table 2). *S. typhimurium* was not detected in any of the tissues of the other treatment group pigs. The primary tissue colonized in the control group was the colon (71% or 5/7) and the lymph node was the second most commonly colonized tissue (43% or 3/7). The liver and spleen were both colonized in 14% (1/7) of the pigs in the control group. Although the reason that the colon was the primary tissue colonized might have been surface bacteria, the lack of colonization in the treatment group and the careful washing of all tissues before disruption should have eliminated them.

No differences were detected in the shedding duration or amounts between the treatment or control group (Tables 3 and 4). The failure to detect differences probably was due to the small sample size and the short duration of the experiment. No difference in weight gain was detected between the two

groups. Initial screening of tissues failed to isolate L-form bacteria.

After clinical signs ceased, pigs in both groups continued to shed *S. typhimurium*. The odds of finding *S. typhimurium* in the tissues were significantly (P=.009) lower for pigs given antibiotics at subtherapeutic and therapeutic levels than for the control group. This provides evidence that the use of antibiotics in the treatment group prevented invasion of *S. typhimurium* into tissues. These results have important food safety implications.

Table 1. Percentage of Pigs Shedding on Day 25 and Colonized in at Least One Tissues by *Salmonella typhimurium*

Group	Pigs	Shedding on Day 25	Colonized (at least 1 tissue)
Treated	9	22%[a]	11%[a]
Control	7	57%[a]	86%[b]

[a]No statistical difference ($P \leq .05$) was detected between percents in a column that share the same superscript.

Table 2. Percentage of Pigs from which *Salmonella typhimurium* Was Isolated from Swab Samples of Intestinal Tissue

Group (pigs)	Jejunum	Ileum	Spiral Colon	Cecum	Colon	Ileo-Cecal
Control (8)	75[a]	75[a]	100[a]	88[a]	100[a]	88[a]
Treated (9)	11[b]	22[a]	67[a]	89[a]	89[a]	89[a]

[a]No statistical difference ($P \leq 05$) was detected between percents in a column that share the same superscript.

Table 3. Average Shedding Score (Rounded to Nearest Whole Number) for *Salmonella typhimurium* Isolated from Rectal Swabs

	Days Postinoculation									
Group	3	5	7	11	13	15	18	20	22	25
Control	1[a]	1	1	2	2	2	1	2	1	2
Treated	2[b]	1	1	2	2	2	2	2	2	3[c]

[a]1 = Isolated from direct plate.
[b]2 = Isolated from enrichment.
[c]3 = Isolated from double enrichment.

Table 4. Average Shedding Score (Rounded to Nearest Whole Number) for *Salmonella typhimurium* Isolated from Tissue Sections

Group (pigs)	Ileum	Ileo-Cecal	Cecum	Jejunum	Colon	Spiral Colon
Control (7)	2[a]	2	2	2	2	2
Treated (9)	3[b]	3	3	3	3	2

[a]2 = Isolated from enrichment.
[b]3 = Isolated from double enrichment.

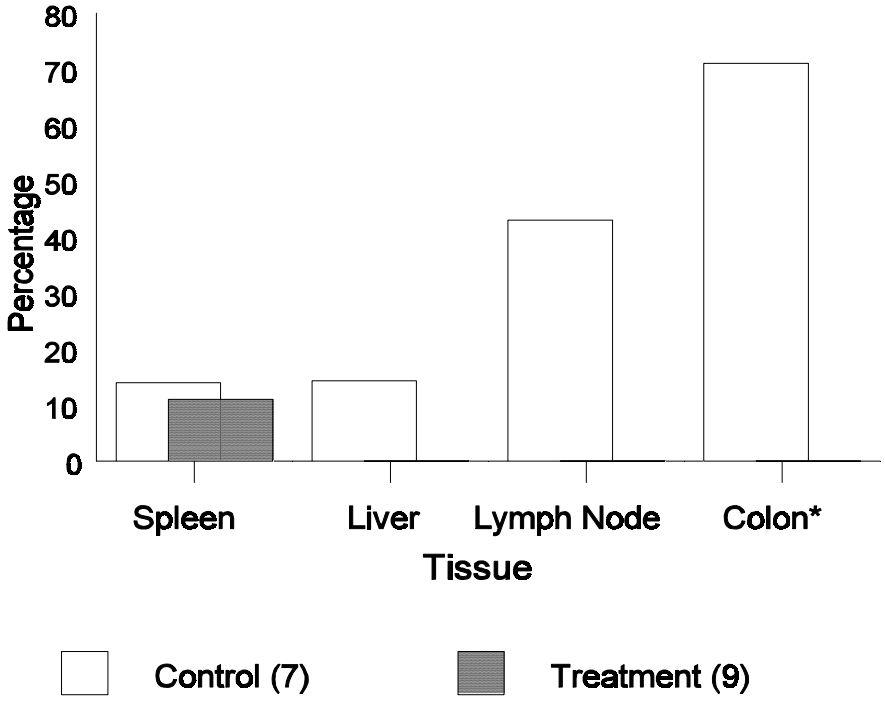

Figure 1. Percent of Pigs in Each Group with *Salmonella typhimurium* Isolated from Four Tissues. Asterisk Indicates Significant ($P \leq .05$) Difference between Control and Treatment Group

INFLUENCE OF A PROBIOTIC/TRACE MINERAL MIXTURE ON GROWTH PERFORMANCE AND *SALMONELLA CHOLERAESUIS* SHEDDING IN NURSERY PIGS [1]

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Summary

We tested a probiotic/trace mineral mixture using a bacterial challenge model in high-health status pigs. We examined the influence of the mixture on growth performance, hematologic parameters, haptoglobin concentration, and *Salmonella choleraesuis* shedding in nursery pigs. A successful model of *S. cholereasuis* challenge was established. However, the probiotic/trace mineral mixture did not influence growth performance, bacterial shedding, or other parameters examined in this experiment.

(Key Words: *Salmonella choleraesuis*, Probiotics, Trace Minerals.)

Introduction

The influences of disease processes on growth performance are difficult to quantify in actual on-farm conditions. Therefore, disease challenge models are employed in carefully controlled environments to quantify the influence of therapeutic agents.

In addition to growth performance benefits, therapeutic agents can be used to decrease the bacterial numbers shed or residing in the gastrointestinal tract. The decreased numbers then result in less contamination of meat products in the packing plant. Currently, probiotics are used in Sweden to reduce *Salmonella* bacterial shedding in chickens and are being tested in cattle to reduce *E. coli* shedding.

Consequently, our objective was to use a bacterial challenge model to determine the influence of a probiotic trace mineral mixture on growth performance, hematologic parameters, haptoglobin concentration, and *Salmonella choleraesuis* shedding in nursery pigs.

Procedures

Sixty-four high-health status pigs (initially 28.7 lb, PIC L326 sires × C15 dams) were obtained from a commercial farm in northeast Kansas and used in three experiments. Neither clinical signs nor laboratory evidence of *S. choleraesuis* infection had been observed on this farm. In addition, neither clinical signs nor laboratory evidence of any other enteric diseases had been observed in the group of pigs from which the experimental pigs were obtained. Pigs were housed in an environmentally controlled isolation facility in which the initial temperature (75ÞF) was reduced by 2ÞF each week. Each pen contained a self-feeder and a nipple waterer to provide ad libitum access to feed and water.

Experiment 1. Experiment 1 was a 35-day assay. Pigs were allotted by initial weight, with gender equalized across treatments within blocks to polyethylene pens (4 × 5 ft) with slotted plastic flooring, using four pigs per pen and eight replicate pens.

Pigs were fed either a control diet or a diet containing probiotic/trace minerals for the 35 d trial (Table 1). All diets were formulated to contain 1.25% lysine, .345% methionine, .80% Ca, and .70% P. On day 14, all pigs were

[1]Appreciation is expressed to Porter Livestock Products, Nichols, IA for partial financial support.

[2]Food Animal Health and Management Center.

challenged by oral gavage with 8.7×10^9 cfu of *S. choleraesuis* bacteria after being held of f-feed for 6 hours. The *S. choleraesuis* isolate was obtained from the liver and spleen of a pig submitted to the Kansas Veterinary Diagnostic Laboratory. The challenge dose had been determined to decrease growth rate by approximately 16% and induce clinical signs of *S. choleraesuis* infection in a previous pilot study. Prior to challenge, fecal swabs were taken from one pig per pen and cultured for *S. choleraesuis*; no *S. choleraesuis* was isolated. Fecal swabs were obtained from all pigs on d 24 and 31 and cultured for *S. choleraesuis*.

Pig weights and feed consumption were determined weekly to calculate ADG, ADFI, and F/G. On d 17, 24, and 31, serum and whole blood samples were collected from each pig and analyzed for haptoglobin, white blood cell, red blood cell, hemoglobin, and mean corpuscular hemoglobin (MCHC) concentrations, as well as hemotocrit percentage, mean corpuscular volume (MCV), and mean corpuscular hemoglobin (MCH).

Experiment 2. Twenty-eight of the pigs fed the control diets in experiment 1 were reallotted by weight, with gender equalized across treatments within blocks to polyethylene pens (4 × 5 ft) with slotted plastic flooring, using two pigs per pen and seven replicate pens. Experiment 2 was an 18-day growth assay. Pigs were housed in an environmentally controlled isolation facility in which the temperature was maintained at 65þF. Each pen contained a self-feeder and a nipple waterer to provide ad libitum access to feed and water.

Pigs were fed either the control diet or a diet containing probiotic/trace minerals; both contained carbadox (25 g/ton; Table 1). An antibiotic sensitivity had been performed previously and indicated that the *S. choleraesuis* isolate used in this experiment was sensitive to carbadox. All diets were formulated to contain 1.25% lysine, .345% methionine, .80% Ca, and .70% P.

Pig weights and feed consumption were determined to calculate ADG, ADFI, and F/G.

Experiment 3. Twenty-eight of the pigs fed the diets containing the probiotic/trace mineral mixture in Experiment 1 were reallotted by weight, with gender equalized across treatments within blocks to solid-floor concrete pens (6 × 8 ft) with solid concrete pen dividers, using three or four pigs per pen and four replicate pens. Pigs were housed in an isolation facility in which a thermoneutral environment was maintained. Experiment 3 was an 18-day growth assay.

Pigs were fed either a control diet or a diet containing carbadox (25 g/ton). Both diets contained the probiotic/trace mineral mixture (Table 1). Both diets were formulated to contain 1.25% lysine, .345% methionine, .80% Ca, and .70% P.

Pig weights and feed consumption were determined to calculate ADG, ADFI, and F/G.

Statistical Analysis. Data were analyzed according to the GLM procedures of SAS as a randomized complete block design with initial body weight used to establish each block. Haptoglobin concentrations and hematology parameters were analyzed using a repeated measures ANOVA. Pen was used as the experimental unit for all statistical analysis.

Results and Discussion

Experiment 1. During the d 0 to 14 period, no differences were detected in growth performance (Table 2). One pig died during this period. Subsequent bacteriological and histological examinations indicated that the pig died from a bacterial menigitis caused by *Streptococcus suis*.

The *Salmonella* challenge model used in this experiment was successful in establishing clinical signs and fecal shedding of *S. cholereasuis* (Table 3). However, no differences in the prevalence of shedding occurred between the two treatment groups. Further evidence of clinical disease was the decreased growth performance from d 14 to 35 of the experiment. However, again no differences occurred between treatments.

Three pigs (two on the control diet and one on the probiotic/trace mineral diet) died during the day 14 to 35 period. Subsequent bacteriological and histological examinations indicated that they died from a bacterial septicemia caused by *S. cholereasuis.*

Haptoglobin and white blood cell concentrations were elevated in both treatment groups, with no difference between groups (normal values are <15 mg/dL and 11 to 22 × 10^3/µL for haptoglobin and white blood cells, respectively; Table 4). Elevated haptoglobin and white blood cell count are indicative of an infectious disease. All other hematology parameters were within normal limits, with no differences between treatments.

Experiments 2 and 3. Growth performance was excellent in both experiments (Tables 5 and 6). However, neither the probiotic/trace mineral nor carbadox had an influence on growth performance. One pig in the carbadox group in experiment 3 died on d 17 of the experiment.

In conclusion, a successful model of *S. cholereasuis* challenge was established. However, probiotic/trace mineral mixture did not influence growth performance, bacterial shedding, or other parameters examined in this experiment.

Table 1. Diet Composition, (%) As-Fed

			Experiment 2		Experiment 3	
	Experiment 1		Carbadox		PBTM	
Ingredient, lb	Control	PBTM[a]	Control	PBTM	Control	Carbadox
Corn	60.02	60.02	59.52	59.52	59.52	59.52
Soybean meal (46.5% CP)	32.53	32.53	32.53	32.53	32.53	32.53
Soy oil	3.00	3.00	3.00	3.00	3.00	3.00
Monocal (21% P)	1.53	1.53	1.53	1.53	1.53	1.53
Limestone	1.09	1.09	1.09	1.09	1.09	1.09
Salt	.35	.35	.35	.35	.35	.35
KSU swine vitamin premix	.25	.25	.25	.25	.25	.25
KSU swine trace mineral	.15	.15	.15	.15	.15	.15
Lysine	.15	.15	.15	.15	.15	.15
Methionine	.025	.025	.025	.025	.025	.025
Medication[b]	--	--	.50	.50	--	.50
Belly Buster	--	.50	--	.50	.50	.50
Iron Vite	--	.40	--	.40	.40	.40
Corn Starch	.90	--	.90	--	.50	--
Total	100.00	100.00 2000.00	100.00 2000- .00	100.00 2000.00	100.00 000.00	100.00 2000.00

[a]PBTM = Probiotic/trace mineral mixture (Belly Buster P and Iron V ite, Porter Livestock Products, Nichols, IA.
[b]Provided 25 g/ton carbadox (Mecadox, Pfizer).

Table 2. Experiment 1 Growth Performance[a]

Item	Control 1	PBTM	CV
d 0 to 14			
ADG, lb	.92	.82	12.0
ADFI, lb	1.90	1.84	6.7
F/G	2.14	2.24	15.2
d 14 to 35			
ADG, lb	1.07	1.00	19.7
ADFI, lb	2.23	2.12	8.7
F/G	2.09	2.25	20.3
d 0 to 35			
ADG, lb	1.01	.93	11.2
ADFI, lb	2.09	2.00	5.6
F/G	2.09	2.20	8.0
d 14 to 21			
ADG, lb	.34	.41	134.5
ADFI, lb	1.24	1.38	17.4
F/G	3.84	4.25	161.7

[a]Each number is the mean of eight replicate pens (four pigs per pen with a mean initial weight of 28.7 lb). Pigs were orally challenged with 8.7×10^{9} cfu of *Salmonella choleraesuis* bacteria 14 days after the beginning of the test period. Pigs were fed the diets for 35 days. No significant differences were detected ($P>.15$).

Table 3. Recovery of *Salmonella choleraesuis* from Fecal Swabs in Experiment 1[a]

Culture Date	Control 1	PBTM
Day 24	7/31 (23%)[b]	8/31 (26%)
Day 31	13/31 (42%)	10/30 (33%)

[a]Pigs were challenged orally with 8.7×10^{9} cfu of *Salmonella choleraesuis* bacteria 14 days after the beginning of the test period.
[b]Number pigs positive / Number of pigs cultured (Percentage).

Table 4. Haptoglobin Concentration and Hematology Parameters in Experiment 1

Item	Control 1	PBTM	*P*<	CV
Haptoglobin, g/dL	97.3	91.9	.32	26.6
White blood cell count, $\times 10^3/\mu L$	30.2	29.9	.83	14.3
Red blood cell count, $\times 10^6/\mu L$	7.6	6.3	.24	50.7
Hemoglobin, g/dL	11.4	10.9	.09	3.1
Hematocrit, %	34.2	32.8	.10	3.5
MCV, *f*L	52.4	52.2	.70	1.4
MCH, pg	17.4	17.3	.65	1.4
MCHC, g/dL	32.5	33.1	.41	7.3

[a]Each number is the mean of eight replicate pens (four pigs per pen with a mean initial weight of 28.7 lb). Pigs were challenged orally with 8.7×10^9 cfu of *Salmonella choleraesuis* bacteria 14 days after the beginning of the test period. Pigs were fed the diets for 35 days.

Table 5. Experiment 2 Growth Performance (Pigs Fed the Control Diet in Experiment 1)[a]

	Carbadox		
Item	Control 2	PBTM	CV
ADG, lb	1.80	1.75	6.1
ADFI, lb	3.77	3.67	11.3
F/G	2.08	2.10	7.9

[a]Each number is the mean of seven replicate pens (two pigs per pen with a mean initial weight of 62.1 lb). Pigs were challenged orally with 8.7×10^{9} cfu of *Salmonella choleraesuis* bacteria 21 days before the beginning of the test period. Pigs were fed the diets for 18 days. No significant differences were detected ($P>.15$).

Table 6. Experiment 3 Growth Performance (Pigs Fed the Probiotic/Trace Mineral Mixture in Experiment 1)[a]

	PBTM		
Item	Control 3	Carbadox	CV
ADG, lb	1.85	1.75	4.4
ADFI, lb	3.63	3.56	4.2
F/G	1.97	2.05	6.9

[a]Each number is the mean of four replicate pens (three or four pigs per pen with a mean initial weight of 62.5 lb). Pigs were challenged orally with 8.7×10^{9} cfu of *Salmonella choleraesuis* bacteria 21 days before the beginning of the test period. Pigs were fed the diets for 18 days. One pig from the carbadox group died on d 17. No significant dif ferences were detected ($P>.20$).

OMITTING VITAMIN AND TRACE MINERAL PREMIXES, AND(OR) REDUCING INORGANIC PHOSPHORUS DURING LATE FINISHING DID NOT AFFECT GROWTH PERFORMANCE, CARCASS TRAITS, OR MUSCLE QUALITY

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Summary

Omitting the vitamin and trace mineral premixes and(or) adding 2/3 less supplemental inorganic phosphorus source (from .55% down to .40% total P) to diets during late finishing (191 to 265 lb) had no effect on growth performance, carcass characteristics, or muscle quality in high-lean pigs. Thus, this concept can be used to decrease the cost of feeding terminal-cross pigs to heavy weights, while decreasing excretion of minerals from intensive swine operations.

(Key Words: Finishing Pigs, Vitamins, Minerals, Phosphorus, Muscle Quality.)

Introduction

It generally is recognized that as pigs increase in age and weight, nutrient needs (as a percentage of the diet) decrease. It also is well established that nutrients in excess of those needed for maintenance and production are excreted from the body. Thus, feeding diets with excess nutrients does nothing for the pig, increases cost of production, and potentially contributes to environmental pollution. Therefore, nutritionists and producers should take advantage of technologies such as the multiple diets used in phase-feeding regimens to meet nutrient needs with minimum nutrient excesses. This philosophy has special significance in view of the extremely heavy slaughter weights now so common in the U.S.

In last year's KSU Swine Day Report, we presented data from two experiments designed to determine the effects of omitting vitamin and(or) trace mineral premixes and decreasing the supplemental inorganic phosphorus (P) in diets for pigs during late finishing (i.e., from 200 lb to a slaughter weight of 250 lb). In those experiments, we observed no negative effects on growth performance, carcass leanness, or muscle quality from our rather drastic reductions in vitamin and mineral fortification. Thus, we designed a third experiment, reported herein, to verify last year's results and to combine the most favorable treatments from those previous two experiments.

Procedures

A total of 160 pigs, with an average initial body wt of 191 lb, was used in a 30-d experiment. Crossbred pigs of PIC origin (326 boars x C15 sows) were blocked by weight and allocated to dietary treatments based on ancestry. Each treatment used 10 pigs per pen and four pens.

The pigs were housed in 6-ft × 16-ft pens, with concrete (50% solid and 50% slatted) flooring, in a modified open-front barn. Each pen was equipped with a two-hole feeder and nipple waterer to provide ad libitum access to feed and water.

The control diet was corn-soybean meal based and formulated to .70% lysine, .65% Ca, and .55% P (Table 1). Other treatments were achieved by omitting the vitamin and trace mineral premixes, 2/3 of the monocalcium phosphate and vitamin and trace mineral premixes, and 2/3 of the monocalcium phosphate. The diets were fed in meal form.

Pigs and feeders were weighed at the beginning and end of the experiment to allow calculation of ADG, ADFI, and F/G. When pigs in the heaviest pen in a weight block averaged 260 lb, the entire block was slaughtered at a commercial plant. Hot carcass weight, 10th rib backfat thickness, and longissimus muscle depth were recorded. The next day (during fabrication of the carcasses), loins were collected and the longissimus

muscle was scored for color, firmness, and marbling according to NPPC (1991) guidelines. Chops from the 10th rib location were cut 1-in. thick; placed on an absorbent pad in a styrofoam tray; wrapped with polyvinylchloride film; and displayed for 15 d (36°F with 150 foot candles deluxe, warm-white, fluorescent lighting). A Minolta CR-200 spectrocolorimeter was used to measure meat lightness (Hunter L value) at d 0, 5, 10, and 15. Water loss was determined after letting 1-in. chops (from the 10th rib location) thaw for 24h at 31°F. After roasting to an internal temperature of 160°F, cooking water loss and Instron™ shear force (tenderness) were determined.

Prior to statistical analyses, dressing percentage, 10th rib fat thickness, fat-free lean index, and longissimus muscle depth and area were adjusted by using slaughter weight as a covariable. All data were analyzed using the GLM procedure of SAS and orthogonal contrasts to separate treatment means.

Results and Discussion

Average daily gain was not affected by treatment ($P>.15$), but pigs fed diets without the vitamin and trace mineral premixes tended to eat more feed ($P<.07$). The similar ADG with greater ADFI resulted in pigs fed the diet without premixes having worse F/G than pigs fed the diet with 2/3 of the monocalcium phosphate omitted ($P<.02$). However, this likely was a chance effect, because omitting both the vitamin/trace mineral premixes and 2/3 of the monocalcium phosphate resulted in a F/G value no different than that for pigs fed the positive control (i.e., 3.29). This is in accordance with results from the previous experiments, where no negative effects on growth performance were observed from omitting the vitamin/trace mineral premixes and most of the monocalcium phosphate.

Carcass characteristics generally were not influenced by the dietary treatment, but there was a trend ($P<.06$) for greater backfat thickness (from .79 to .83 in) when vitamin/trace mineral premixes were omitted. This trend should cause concern, but it should also be remembered that the largest loin eye areas (at least numerically) were for pigs fed the control diet and the diet with the combination of no vitamin/trace mineral premixes and reduced P addition. Also, in last year's experiments, we were unable to detect any differences in carcass leanness when the vitamin and trace mineral premixes were omitted and the inorganic P was reduced by 2/3.

Subjective scores for color and firmness of the longissimus muscle were not affected by treatment ($P>.15$). However, marbling was greatest for pigs fed diets without the vitamin/trace mineral premixes or with reduced addition of monocalcium phosphate. Again, it seems likely that this is chance effect because omitting the vitamin/trace mineral premixes and 2/3 of the monocalcium phosphate gave the same mean marbling score as for pigs fed the control diet. Objective measurements (Hunter L values) of color were not affected by treatment ($P>.15$). Cooked meat tenderness and thawing loss also were not affected by treatment ($P>.15$). However, water loss during cooking tended ($P<.06$) to be greater in the control treatment.

In conclusion, omitting the vitamin and trace mineral premixes and reducing the inorganic P addition to supply .40% total P can improve profitability of swine operations feeding terminal-market high-lean pigs to heavy slaughter weights. Additionally, the reduced mineral content of these diets will result in less excretion in urine and feces and improve the environmental friendliness of swine production units.

Table 1. Diet Composition

		Ingredients Omitted[a]		
Ingredients, %	Control	VIT & TM	2/3 of MCP	VIT & TM & 2/3 of MCP
Corn	83.82	84.07	84.77	85.01
Soybean meal (46.5% CP)	12.37	12.37	12.29	12.30
Soybean oil	1.00	1.00	1.00	1.00
Monocalcium phosphate (21% P)	1.12	1.12	.37	.37
Limestone	.94	.94	.82	.82
Salt	.30	.30	.30	.30
Vitamin premix	.15	-	.15	-
Trace mineral premix	.10	-	.10	-
Lysine-HCl	.15	.15	.15	.15
Antibiotic[b]	.05	.05	.05	.05
Total	100.00	100.00	100.00	100.00
Calculated analysis				
Lysine, %	.70	.70	.70	.70
Ca, %	.65	.65	.47	.47
Total P, %	.55	.55	.40	.40
Available P, %	.29	.29	.14	.14

[a]VIT & TM = vitamin and trace mineral premixes; MCP = monocalcium phosphate.
[b]Provided 40 g/ton tylosin.

Table 2. Effects of Omitting the Vitamin and Trace Mineral Premixes (PMXs) and(or) Reducing the Supplemental Monocalcium Phosphate (MCP) Additions for Diets during Late Finishing on Growth Performance, Carcass Characteristics, and Muscle Quality of High-Lean Pigs[a]

	Ingredients Omitted from Diet					Contrasts[b]		
Item	Control	PMXs	2/3 MCP	PMXs & 2/3 MCP	SEM	1	2	3
ADG, lb	2.29	2.22	2.22	2.22	.10	-[i]	-	-
ADFI, lb	7.54	7.48	7.13	7.30	.16	.13	-	.07
Feed/gain	3.29	3.37	3.21	3.29	.09	-	-	.02
Dressing percentage	74.1	74.7	74.2	74.8	.7	-	-	-
10th rib fat thickness, in.	.79	.85	.83	.83	.03	.06	-	-
10th rib loin eye area, sq. in.	6.9	6.4	6.7	6.9	.2	-	.14	-
Fat-free lean index, %[c]	48.7	48.0	48.4	48.3	.4	.07	-	-
Longissimus muscle color[d]	2.6	2.7	2.6	2.6	.1	-	-	-
Longissimus muscle firmness[e]	2.5	2.5	2.5	2.4	.1	-	-	-
Longissimus muscle marbling[f]	2.2	2.5	2.4	2.2	.2	.07	.02	-
Longissimus muscle lightness[g]								
After 0 d of display	52.2	52.2	52.3	52.2	.9	-	-	-
After 5 d of display	53.4	53.2	52.8	53.3	1.0	-	-	-
After 10 d of display	54.2	52.7	54.1	54.7	1.3	-	-	-
After 15 d of display	52.9	51.1	51.9	52.5	.7	-	-	-
Cooked meat tenderness, lb[h]	2.5	2.5	2.5	2.6	.2	-	-	-
Thawing water loss, %	2.2	2.1	2.1	2.3	.4	-	-	-
Cooking water loss, %	25.6	22.7	22.7	23.3	2.1	.06	-	-

[a]A total of 160 pigs (10 pigs/pen and four pens/treatment) with an avg initial wt of 191 lb and an avg final wt of 265 lb.

[b]Contrasts were: 1) control vs other treatments, 2) PMXs or 2/3 MCP vs PMXs and 2/3 MCP, and 3) PMXs vs 2/3 MCP.

[c]Equation used was (NPPC, 1994): fat-free lean index = 51.537 + (.035 × hot carcass wt) – (12.26 × off-midline backfat thickness).

[d]Scored on a scale of 1 = pale pinkish grey to 5 = dark purplish red (NPPC, 1991).

[e]Scored on a scale of 1 = very soft and watery to 5 = very firm and dry (NPPC, 1991).

[f]Scored on a scale of 1 = practically devoid to 5 = moderately abundant (NPPC, 1991).

[g]Minolta CR-200 spectrocolorimeter values (lightness is Hunter L value). An acceptable range is 50 to 55, which is equal to NPPC scores of 2 to 3 (NPPC, 1991).

[h]Instron™ shear force values, kg.

[i]Dashes indicate $P>.15$.

REMOVING VITAMIN AND TRACE MINERAL PREMIXES FROM FINISHER DIETS (154 TO 247 LB) DID NOT AFFECT GROWTH PERFORMANCE, CARCASS CHARACTERISTICS, OR MEAT QUALITY

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Summary

Average daily gain; ADFI; F/G; dressing percentage; tenth rib fat thickness and depth; and color, firmness, and marbling of the longissimus muscle were not influenced by omitting the vitamin and(or) trace mineral premixes from diets during finishing (154 to 247 lb). Thus, omitting vitamin and trace mineral premixes can decrease diet costs without decreasing performance or meat quality of high-lean pigs.

(Key Words: Finishing Pigs, Vitamins, Minerals, Meat Quality, Growth.)

Introduction

Feed represents 60 to 70% of the total cost of producing a market hog. Although vitamin and trace mineral premixes make up only a small part of the total feed, their withdrawal from diets for the finishing period will reduce production costs significantly.

In last year's KSU Swine Day Report, we suggested that the KSU vitamin and trace mineral premixes could be omitted during late finishing (200 to 250 lb) to reduce cost of gain without decreasing growth performance, carcass merit, or muscle quality. Therefore, the objective of the experiment reported herein was to determine if longer-term (150 to 250 lb) deletion of vitamin and(or) trace mineral premixes affects growth performance, carcass leanness, or muscle quality in finishing pigs.

Procedures

A total of 80 finishing barrows (initial wt of 154 lb) was blocked by weight and allocated to pens based on ancestry. Each treatment had two pigs (PIC Line 326 boars × C15 sows) per pen and 10 pens. Treatments were: 1) corn-soybean meal-based control with KSU vitamin and trace mineral premixes; 2) diet 1 with the vitamin premix omitted; 3) diet 1 with the trace mineral premix omitted; and 4) diet 1 with the vitamin and trace mineral premixes omitted. The diets were formulated to .7% lysine, .65% Ca, and .55% P (Table 1). The pigs were housed in an environmentally controlled finishing barn with 4 ft × 4 ft pens and totally slatted floors. The pens were equipped with a single-hole feeder and nipple waterer to allow ad libitum consumption of feed and water. Drip coolers were activated when temperatures exceeded 80°F. Pigs and feeders were weighed at the initiation and conclusion of the growth assay to allow calculation of ADG, ADFI, and F/G.

When the pigs in the heaviest pen of a weight block reached an average of 250 lb, the entire block was slaughtered. Two blocks reached the ending weight on d 40 and two blocks on d 49 of the experiment. The pigs were killed at a commercial slaughtered plant to collect carcass measurements. Tenth rib fat thickness was measured 2 in. off-midline using a Fat-O-Meter™ probe and adjusted to skin-on fat thickness by adding .1 to the probe reading. Dressing percentage was calculated with hot carcass weight as a percentage of slaughter weight. Color, firmness, and marbling of the longissimus muscle were determined according to NPPC (1991) guidelines. Additionally, chops from the 10th rib location were cut 1 in. thick, placed on an absorbent pad in a styrofoam tray, and overwrapped with polyvinylchloride film. Measurements of longissimus muscle color were determined at d 0 (before display) and after 3, 5, 10, and 15 d of continuous (24 h/d) display at 36°F under

150 foot candle deluxe, warm-white, fluorescent lighting. A Minolta spectrocolorimeter was used to measure meat lightness at d 0, 3, 5, 10, and 15. Water-holding capacity of the longissimus muscle was determined using the Carver press method. Thaw loss was determined as loss in weight after thawing the longissimus muscle at 2°F for 24 hr. The chops were cooked to an internal temperatures of 160°F. Warner-Bratzler shear force was determined using an Instron instrument.

Data were analyzed as a randomized complete block design with orthogonal contrasts used to separate treatment means. Hot carcass weight, dressing percentage, last rib backfat thickness, and longissimus muscle depth were analyzed with slaughter weight as a covariable. Pen was the experimental unit for all analyses.

Results and Discussion

From 154 to 247 lb, ADG, ADFI, and F/G were not influenced ($P>.15$) by dietary treatment. Dressing percentage; 10th rib fat thickness; fat free lean index; muscle depth; and subjective scores for color, firmness, and marbling of the longissimus muscle also were not affected by dietary treatment ($P>.11$).

Objective color determinations (Minolta spectrocolorimeter) at d 0 (before display) and d 5 suggested that pigs fed the diet without vitamins had lighter muscle than pigs fed the diet without the trace minerals ($P<.05$), but color for all treatments was considered well within normal ranges. Also, the rate of change for meat color at d 3, 5, 10, and 15 was similar for all treatments. Thus, withdrawal of the vitamin and(or) trace mineral premixes had no effect on pork muscle color stability during display.

Water-holding capacity was not affected by dietary treatment ($P>.38$), but pigs fed the diet without vitamins had lower Warner- Bratzler shear force than pigs fed the diet without trace minerals ($P<.02$). Thaw loss was not affected by dietary treatment ($P>.48$), and cooking loss for pigs fed the control diet actually was increased compared to pigs fed diets without the vitamin and(or) trace mineral premixes ($P<.01$).

In conclusion, additional research is needed to determine the effects of omitting the vitamin and (or) trace mineral premixes during the finishing phase on such response criteria as immune function and nutrient content of pork tissue. However, for the time being, cost of gain can be decreased by omitting these premixes during the finishing phase (154 to 247 lb). Also, omitting these premixes did not result in fat carcasses with poor meat color/quality, and the differences that were observed for the criteria measured were small and inconsistent.

Table 1. Diet Composition, %[a]

		Premix Omitted		
Ingredient, %	Control	Vitamin	Mineral	Vitamin & Mineral
Corn	83.82	83.99	83.93	84.10
Soybean meal (46.5% CP)	12.37	12.35	12.36	12.34
Soybean oil	1.00	1.00	1.00	1.00
Monocalcium phosphate (21% P)	1.12	1.12	1.12	1.12
Limestone	.94	.94	.94	.94
Salt	.30	.30	.30	.30
Vitamin premix	.15	--	.15	--
Trace mineral premix	.10	.10	--	--
Lysine-HCl	.15	.15	.15	.15
Antibiotic[b]	.05	.05	.05	.05

[a]All diets were formulated to .70% lysine, .65% Ca, and .55% P.
[b]Supplied 40 g/ton tylosin.

Table 2. Effects of Omitting Vitamin and Trace Mineral Premixes on Growth Performance in Finishing Pigs[a]

		Premix Omitted				Contrasts[b]		
Item	Control	Vitamin	Mineral	Vitamin & Mineral	CV	1	2	3
154 to 247 lb								
ADG, lb	2.10	2.11	2.07	2.16	7.1	1.00	.49	.41
ADFI, lb	6.89	6.95	6.49	6.87	9.3	.45	.35	.57
F/G	3.28	3.29	3.14	3.18	8.8	.43	.14	.97

[a]A total of 80 pigs (two pigs/pen and 10 pens/treatment) with an avg initial wt of 154 lb and an avg final wt of 247 lb.
[b]Contrasts were: 1) control vs other treatments; 2) omitting vitamins vs minerals; and 3) omitting vitamins or minerals vs omitting both.

Table 3. Effects of Omitting Vitamin and Trace Mineral Premixes on Carcass Characteristics and Meat Quality in Finishing Pigs[a]

		Premix Omitted				Contrasts[b]		
Item	Control	Vitamin	Mineral	Vitamin & Mineral	CV	1	2	3
Dressing percentage	73.9	74.8	73.7	72.4	3.9	.80	.40	.11
10th rib fat thickness, in.	.88	.94	.90	1.03	22.2	.35	.71	.21
Fat free lean index, %[c]	49.22	48.81	49.03	48.75	2.3	.41	.67	.70
Muscle depth, in	2.19	2.15	2.18	2.16	8.5	.79	.78	.96
Longissimus muscle area, in.	6.0	6.3	6.5	6.4	11.3	.15	.57	.84
Longissimus muscle color[d]	2.5	2.6	2.6	2.5	.1	.66	.72	.53
Longissimus muscle firmness[e]	2.5	2.6	2.5	2.6	.1	.35	.45	1.00
Longissimus muscle marbling[f]	2.2	2.1	2.4	2.0	.1	.63	.25	.12
Longissimus muscle lightness[g]								
0 d of display	54.9	55.1	53.4	54.1	.6	.28	.05	.90
3 d of display	55.3	55.1	53.3	53.6	.8	.18	.11	.49
5 d of display	55.7	56.2	54.0	55.0	.7	.41	.03	.86
10 d of display	55.9	56.4	54.4	55.3	.9	.58	.12	.96
15 d of display	55.3	55.8	53.7	55.0	1.0	.70	.15	.87
Water-holding capacity[h]	.45	.47	.47	.46	15.2	.38	.97	.68
Cooked meat tenderness[i]	6.4	5.7	7.1	6.0	18.9	.59	.02	.26
Thaw loss, %	1.3	1.3	1.1	1.4	44.3	.66	.67	.48
Cooking loss, %	27.7	25.0	24.6	22.9	14.4	.01	.83	.18

[a]A total of 80 pigs (two pigs/pen and 10 pens/treatment) with an average initial weight of 154 lb and an avg final wt of 247 lb.
[b]Contrasts were: 1) control vs other treatments; 2) omitting vitamins vs minerals; and 3) omitting vitamins or minerals vs omitting both.
[c]Equation (NPPC, 1991) was: fat free lean index = 51.537 + (.035 × hot carcass wt) - (12.26 × off-midline backfat thickness).
[d]Scored on a scale of 1 = pale pinkish-gray to 5 = dark purplish-red (NPPC, 1991).
[e]Scored on a scale of 1 = very soft and watery to 5 = very firm and dry (NPPC, 1991).
[f]Scored on a scale of 1 = practically devoid to 5 = moderately abundant (NPPC, 1991).
[g]Minolta CR-200 spectrocolorimeter values (lightness is Hunter L value).
[h]Expressed as a ratio of meat film area to total area (i.e., muscle/(fluid + muscle area)); a smaller value represented greater water-holding capacity.
[i]Instron™ shear force value, lb.

EFFECT OF DIETARY L-CARNITINE ON GROWTH, CARCASS CHARACTERISTICS, AND METABOLISM OF SWINE [1]

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Summary

Thirty six Yorkshire gilts (initially 123 lb BW) were used to investigate the effect of dietary carnitine on growth performance, carcass characteristics, fatty acid oxidation, and enzyme kinetics. Dietary carnitine reduced fat deposition in favor of protein deposition, stimulated fatty acid oxidation, induced the expression of pyruvate carboxylase, increased the capacity of pyruvate carboxylase flux, and decreased the capacity of branch chain keto-dehydrogenase.

(Key Words: Carnitine, Feed Efficiency, Carcass.)

Introduction

The primary role of carnitine in intermediary metabolism is to transport long chain fatty acids across the mitochondrial membrane into the mitochondrial matrix, where they are broken down through β-oxidation. Results from Kansas State University has shown that feeding L-carnitine to pigs during the growing-finishing phase resulted in small increases in longissimus muscle area and decreases in backfat thickness and lipid accretion rates. However, the mode of action by which carnitine elicits these responses has not been investigated in swine. Therefore, the objective of our study was to evaluate the influence of dietary carnitine on growth performance, carcass characteristics, fatty acid oxidation rates, and enzyme kinetics in finishing swine.

Procedures

Animals. All research was conducted at Oklahoma State University, Stillwater, OK. Thirty-six Yorkshire gilts (initially 123 lb BW) were blocked by weight and sire group in a randomized complete block design. Three pigs were housed per pen (7 ft × 8 ft) in an environmentally regulated finishing barn with total slatted concrete flooring. There were four replicate pens per treatment. Each pen contained a single-hole self-feeder and a nipple waterer to provide ad libitum access to feed and water. Pig weights and feed disappearance were recorded every 14 d to determine ADG, ADFI, and F/G.

A basal diet based on corn and soybean meal (Table 1), was formulated to contain .85% lysine and 2.5% soy oil and was fed in meal form. L-carnitine replaced corn to provide added dietary carnitine levels of 50 and 125 ppm. All other nutrients either met or exceeded NRC (1988) estimates for pigs between 110 and 240 lb.

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[1]We thank Brenda de Rodas, Leroy Kimbrel, Tom Gardner, Kim Brock, Tim Cash, John Bergstrom, and Shaban Coribec for technical assistance and data collection. Appreciation is expressed to Lonza Inc., Fair Lawn, NJ for partial financial support and for the L-carnitine used in this experiment.

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Table 1. Diet Composition[a]

Ingredient	Percent
Corn[b]	73.80
Soybean meal, (48% CP)	21.32
Soybean oil	2.50
Dicalcium phosphate, (18% P)	.85
Limestone	.78
Salt	.35
Copper sulfate	.10
Antibiotic[c]	.05
Vitamin and mineral premix	.25
Total	100.00

[a]Formulated to contain .85% lysine, and .60% Ca and .50% P.
[b]L-carnitine replaced corn to provide dietary

Carcass Characteristics. Food was withheld from pigs for 18 to 24 hrs prior to slaughter, after which all pigs were slaughtered and standard carcass measurements were recorded. The heart, liver, kidney, and kidney fat were removed from each carcass following slaughter and weighed. Three samples per muscle (25 to 50 g) were taken from the longissimus muscle (a three rib sample taken between the 9th and 11th rib), the biceps femoris and semitendinosus muscles of the ham, and the liver. After the liver and muscles were dissected, they were ground and subsampled for proximate analysis and measurement of tissue carnitine and free amino acid concentrations.

Blood Samples. Blood samples were collected via vena cava puncture between 1 and 2 h after pigs were removed from pens. Plasma was harvested and stored until analysis for plasma carnitine, IGF-1, IGF-2, insulin, and other blood metabolites.

Isolation of Mitochondria. As the gilts were slaughtered, a 5 to 10 g sample of liver and muscle was excised and mitochondria were isolated by centrifugation. The sample was taken from the semitendinosus muscle from the ham.

Isolation of Hepatocytes. A 20 to 30 g sample of the liver was excised and used to isolate hepatocytes by collagenase digestion. Viability of the hepatocytes was assessed by exclusion of trypan blue and was routinely higher than 95%. Protein content of the hepatocyte suspension was determined by the biuret method, using bovine albumin as the standard.

Palmitate Oxidation in Isolated Mitochondria. Oxidation of fatty acids was assayed using [1-^{14}C] palmitate. The sum of radioactivity from CO_2 trapped in a center well and radioactivity in the acid-soluble fraction of a reaction mixture was used to calculate the oxidation of palmitate.

Pyruvate Carboxyase Flux in Isolated Mitochondria. Pyruvate carboxylase flux was assayed by measuring pyruvate-dependent incorporation of [^{14}C] $KHCO_3$ into acid-stable radiolabeled products during 10 min of incubation at 98.6°F.

Branch Chain Keto-Dehydrogenase Flux in Isolated Liver Mitochondria. Flux through branch chain keto-dehydrogenase was assayed in the same reaction mixture used for measuring pyruvate carboxylase flux except [1-^{14}C]Na isocaproate was used in place of pyruvate and $KHCO_3$ was used instead of [^{14}C]$KHCO_3$.

Pyruvate Carboxylase Activity in Particle-Free Extracts of Liver Mitochondria. Particle-free extracts of mitochondria were prepared by homogenizing mitochondria (~20 mg protein) in 1 mL of detergent solution containing: deoxycholate (0.1%), Tris buffer (0.1 mol/L, pH 7.2), and glutathione (1 mmol/L). Enzymatic activity was assayed by coupling with excess malate dehydrogenase and spectrophotometric measurement of the resultant pyruvate-dependent oxidation of NADH at 339 nm during 5 min incubation at 77°F.

Branch Chain Keto-Dehydrogenase Flux in Isolated Muscle Mitochondria. Flux through branch chain keto-dehydrogenase in muscle mitochondria was assayed as described for liver mitochondria.

Palmitate Oxidation in Isolated Hepatocytes. Palmitate oxidation by hepatocytes was assayed similar to palmitate oxidation with mitochondria (see above).

Protein Synthesis in Isolated Hepatocytes. Protein synthesis was assayed by measuring incorporation of [^{35}S]methionine into TCA precipitate.

Statistical Analysis. The pen was the experimental unit for analyses of performance and carcass data, and the pig was the experimental unit for analyses of liver and muscle assays. Means were separated using linear and quadratic polynomials. Carcass data and organ weights were analyzed using cold carcass weight as a covariate.

Results and Discussion

Increasing dietary L-carnitine increased carnitine concentrations found in plasma, liver, longissimus muscle, and bicep femoris muscle (linear, $P<.01$; Table 3). This indicates increased biological availability of carnitine within the body. Despite increased concentrations of carnitine in plasma, liver, and muscle tissues in response to dietary carnitine supplements, adding L-carnitine at levels up to 125 ppm had no effect on growth performance ($P>.10$; Table 3). However, supplemental L-carnitine reduced 10th and average backfat thickness (linear, $P<.10$ and $P<.05$, respectively) and increased percentage lean and muscle (linear, $P<.05$); Table 3), which suggests that providing L-carnitine reduces fat accretion. Also, visual scores for carcass muscling, longissimus marbling, and firmness were not affected ($P>.10$) by dietary treatment (Table 3). However, increasing L-carnitine increased visual scores for longissimus color (quadratic, $P<.05$).

The second objective of our study was to evaluate a metabolic model to determined carnitine's influence on intermediary metabolism in finishing swine. This metabolic model anticipated that added dietary L-carnitine could promote the breakdown of fatty acids, thereby increasing the rate of acetyl CoA formation and thus, the energy charge (ATP/ADP ratio) of the cell. By increasing the breakdown of fatty acids, the activity of enzymes such as pyruvate carboxylase (rate-limiting enzyme in gluconeogenesis) and branch chain keto-dehydrogenase (rate-limiting enzyme in branch chain amino acid breakdown) also should be altered. Activation of pyruvate carboxylase should favor gluconeogenesis and the use of carbon chains of pyruvate for the production of amino acids. Also, enhanced fatty acid oxidation should inhibit branch chain keto-dehydrogenase by elevating concentrations of acetyl CoA, NADH, and ATP and, thereby, reducing the breakdown of branch chain amino acids. In turn, this should reduce the breakdown of other amino acids and ultimately promote protein synthesis.

Palmitate oxidation in isolated liver mitochondria (linear, $P<.01$) and hepatocytes (linear, $P<.01$) was increased in carnitine-fed pigs (Table 4 and 5). This clearly demonstrates that carnitine increases breakdown of fatty acids. These results are consistent with the reduction in backfat thickness in pigs fed L-carnitine.

Flux through pyruvate carboxylase in mitochondria (linear, $P<.01$) and pyruvate carboxylase activity (linear, $P<.01$) in liver mitochondria extract was increased for pigs fed added dietary L-carnitine (Table 4). Although neither the concentration of acetyl CoA or the energy charge (ATP/ADP ratios) were measured in this study, we could speculate that the increase in pyruvate carboxylase flux was caused by these effectors.

Flux through branch chain keto-dehydrogenase in liver (linear, $P<.01$) and muscle (linear, $P<.01$) mitochondria was reduced in pigs fed increasing L-carnitine (Table 4.). As in the case of pyruvate carboxylase flux, we could hypothesize that increased concentrations of acetyl CoA, NADH, and ATP from carnitine's influence on β-oxidation were responsible for the inhibitory effect on branch chain keto-dehydrogenase flux. By enhancing fatty acid breakdown, branch chain keto-dehydrogenase flux should be inhibited by elevations of acetyl CoA, NADH, and ATP levels, thereby, reducing the breakdown of branch chain amino acids.

Increasing dietary L-carnitine increased the content of some amino acids in liver and muscle tissues (Tables 6, 7, and 8). Among these amino acids, glutamine; proline; and the branch chain amino acids (leucine, isoleucine, and valine) were elevated consistently. Because the branch chain keto-dehydrogenase flux was inhibited, we would expect increases in the contents of branch chain amino acid, which were increased consistently. Other amino acids that were increased included: aspartic acid, threonine, cysteine, methionine, tyrosine, phenylalanine, histidine, and lysine. Most of these are essential amino acids and cannot be synthesized in vivo but possibly can be spared.

Increased protein synthesis (linear, $P<.01$; Table 5) in the isolated hepatocytes of pigs fed increasing L-carnitine and an increase in percentage muscle are consistent with the effect that branch chain amino acids have on protein synthesis. Therefore, these results indicate that dietary carnitine reduced fat deposition in favor of protein deposition in finishing gilts. However, more research is needed to document the effect L-carnitine has on amino acid metabolism.

Increasing dietary L-carnitine increased insulin (linear, $P<.05$) concentrations taken after a 1 hr fast. Also, albumin and lactate dehydrogenase concentrations were decreased (linear, $P<.01$) by increasing levels of dietary L-carnitine. This is the first research to show these effects on insulin and blood metabolites from L-carnitine. Current research is ongoing to validate these responses.

In summary, dietary carnitine reduced fat deposition in favor of protein deposition, stimulated fatty acid oxidation, and positively influenced amino acid metabolism. Because of carnitine's role in fat and amino acid metabolism, research is being conducted to determine if carnitine can be used to spare dietary energy and amino acids. This possibly could allow producers to reduce diet cost and still obtain added benefits in carcass merits. Results from this experiment provide evidence of carnitine's role in intermediary metabolism and insight into the different mechanisms involved with its utilization.

Table 2. Tissue Carnitine Concentrations Found in Liver, Longissimus Muscle, Biceps Femoris, and Plasma[a]

	L-Carnitine, ppm			
Item	0	50	125	CV
Whole tissue, nmol/g				
Liver[b]	93.4	123.9	155.1	28.5
Longissimus muscle[b]	864.6	1316.5	1569.4	13.5
Biceps femoris[b]	838.7	1239.8	1640.2	9.8
Plasma Carnitine, μM/L				
Total[b]	6.2	10.7	14.3	26.3
Free[b]	5.0	8.4	12.0	27.9
Esters[c]	1.2	2.3	2.2	61.6

[a]A total of 24 pigs, eight pigs/treatment.
[b]Linear effect of dietary L-carnitine ($P<.01$).
[c]Linear effect of dietary L-carnitine ($P<.10$).

Table 3. Performance and Carcass Characteristics of Pigs Fed L-Carnitine from 123 to 267 lb[a]

	Added Carnitine, ppm			
Item	0	50	125	CV
Growth performance				
ADG, lb	1.96	2.01	1.94	6.2
ADFI, lb	6.26	6.45	6.17	5.8
F/G	3.20	3.22	3.17	6.3
Carcass characteristics				
Live wt, lb	267	264	260	3.2
Dressing percentage	75.51	74.53	74.62	3.0
Average BF, in[b]	1.20	1.16	1.14	9.7
10th rib BF, in[c]	.95	.88	.85	15.7
Longissimus muscle, in^2	5.78	5.87	6.31	12.0
Percentage lean[cd]	50.03	50.91	52.08	4.2
Percentage muscle[ce]	54.19	54.86	55.48	4.6
Organ weights				
Liver, g	1680	1666	1710	12.7
Heart, g	411	419	388	16.2
Kidney, g	378	370	353	12.1
Kidney fat, g	1160	1114	1044	23.9
Quality				
Muscle score[f]	2.40	2.64	2.68	17.8
Color[gh]	2.64	3.00	2.75	15.8
Firmness	3.18	3.07	2.92	19.8
Marbling	2.59	2.63	2.50	47.2

[a]A total of 36 pigs, three pigs/pen, four replicate pens/treatment.
[b]Linear effect of dietary L-carnitine ($P<.10$).
[c]Linear effect of dietary L-carnitine ($P<.05$).
[d]Percentage lean was calculated from NPPC (1991) equation for percentage lean with 5% fat.
[e]Percentage muscle was calculated from NPPC (1991) equation for percentage muscle with 10% fat.
[f]Carcasses were evaluated on a 3-point scale ranging from thin muscling (1) to extremely thick muscling (3).
[g]Quadratic effect of dietary L-carnitine ($P<.05$).
[h]Loins were evaluated on a 5-point scale according to NPPC (1991) procedures with 1=light and 5=dark.

Table 4. Effect of Dietary L-Carnitine on Palmitate Oxidation, Pyruvate Carboxylase, and Branch Chain Keto-Dehydrogenase in Liver Mitochondria; Branch Chain Keto-Dehydrogenase in Muscle Mitochondria; and Pyruvate Carboxylase Activity in Liver Extracts[a]

	L-Carnitine, ppm			
Item	0	50	125	CV
Liver mitochondria				
Palmitate oxidation, nmol/mg protein/hr[b]	10.6	11.9	15.3	13.8
Pyruvate carboxylase flux, nmol/mg protein/hr[b]	20.4	30.9	44.2	16.5
Branch chain keto-dehydrogenase flux, nmol/mg protein/hr[bc]	82.2	60.4	54.1	13.2
Muscle mitochondria				
Branch chain keto-dehydrogenase flux, nmol/mg protein/hr[bcd]	108.8	110.1	86.5	9.2
Liver mitochondria extract				
Pyruvate carboxylase activity, nmol product/mg protein/min[bc]	.09	.15	.26	17.2

[a]A total of 24 pigs, eight pigs/treatment.
[b]Linear effect of dietary L-carnitine ($P<.01$).
[c]Quadratic effect of dietary L-carnitine ($P<.10$).
[d]Quadratic effect of dietary L-carnitine ($P<.01$).

Table 5. Effect of L-Carnitine on Palmitate Oxidation and Protein Synthesis in Isolated Hepatocytes[a]

	L-Carnitine, ppm			
Item	0	50	125	CV
Palmitate oxidation, nmol/mg protein/hr[b]	.94	1.56	2.38	24.8
Protein synthesis, nmol/mg protein/hr[b]	.95	1.25	1.75	10.0

[a]A total of 24 pigs, eight pigs/treatment.
[b]Linear effect of dietary L-carnitine ($P<.01$).

Table 6. Amino Acid Concentrations in Longissimus Muscle (Samples from 9th, 10th and 11th rib)[a]

	L-Carnitine, ppm			
Item, μmol/g	0	50	125	CV
Aspartic acid[b]	7.09	7.49	7.70	7.0
Threonine[c]	3.44	3.66	3.77	7.7
Glutamic acid[c]	10.99	11.89	12.12	8.9
Proline[c]	2.82	2.99	3.16	10.2
Alanine[b]	4.38	4.60	4.73	6.3
Cysteine[c]	.90	.98	.97	6.4
Valine	3.90	4.11	4.10	7.4
Methionine[c]	2.15	2.35	2.36	7.3
Isoleucine	3.59	3.82	3.79	7.8
Leucine[b]	6.26	6.66	6.80	6.2
Tyrosine[b]	2.74	2.94	2.98	6.5
Phenylalanine[b]	3.15	3.37	3.42	5.6
Histidine[cd]	3.37	3.69	3.66	8.4
Lysine[c]	6.89	7.31	7.49	6.8
Arginine[c]	5.01	5.31	5.42	6.9
Tryptophan[c]	.95	1.07	1.05	8.6

[a]A total of 24 pigs, eight pigs/treatment.
[bc]Linear effect of dietary L-carnitine ($P<.05$, $P<.10$, respectively).
[d]Quadratic effect of dietary L-carnitine ($P<.10$)

Table 7. Amino Acid Concentrations Found in Biceps Femoris Muscle[a]

	L-Carnitine, ppm			
Item, μmol/g	0	50	125	CV
Aspartic acid	5.86	6.13	6.13	8.0
Threonine	2.69	2.93	2.83	9.7
Glutamic acid	8.27	9.76	9.67	18.8
Proline	2.63	2.62	2.69	45.5
Alanine	3.64	3.86	3.93	9.1
Cysteine	1.17	.79	.77	71.3
Valine[b]	2.86	3.26	3.21	17.0
Methionine	1.96	1.85	1.85	20.9
Isoleucine[c]	2.72	3.13	3.19	10.1
Leucine[b]	4.82	5.42	5.45	10.8
Tyrosine	2.65	2.35	2.37	29.9
Phenylalanine[d]	2.55	2.72	2.78	7.5
Histidine	2.29	2.81	2.76	21.5
Lysine[d]	4.83	5.95	6.02	21.8
Arginine	4.48	4.39	4.48	11.6
Tryptophan	1.28	.81	.86	77.9

[a]A total of 24 pigs, eight pigs/treatment.
[bcd]Linear effect of dietary L-carnitine ($P<.05$, $P<.01$, $P<.10$, respectively).

Table 8. Amino Acid Concentrations Found in Liver Tissue[a]

	L-Carnitine, ppm			
Item, μmol/g	0	50	125	CV
Aspartic acid[b]	5.73	5.99	6.08	4.9
Threonine[c]	2.83	2.92	3.01	4.5
Serine[c]	2.49	2.68	2.88	8.1
Glutamic acid[c]	6.99	7.42	7.88	6.1
Proline[c]	2.78	2.92	3.10	7.1
Alanine[d]	3.66	4.03	4.08	6.5
Cysteine[b]	1.24	1.29	1.29	8.1
Valine	4.06	4.22	4.12	6.9
Methionine[c]	1.46	1.51	1.56	4.0
Isoleucine	3.01	3.06	3.08	6.3
Leucine[b]	6.08	6.46	6.52	6.0
Tyrosine	2.56	2.61	2.64	4.5
Phenylalanine	3.40	3.54	3.54	5.8
Histidine	1.86	1.95	1.90	9.8
Lysine	5.14	5.30	5.32	5.1
Arginine	3.92	4.02	4.06	4.6
Tryptophan	.89	.90	.93	9.9

[a]A total of 24 pigs, eight pigs/treatment.
[bcd]Linear effect of dietary L-carnitine ($P<.05$, $P<.01$, $P<.10$, respectively).

Table 9. Effect of L-Carnitine on IGF-1, IGF-2, IGF1:IGF2 Ratio, Insulin Concentration, and Blood Metabolites after Pigs Were Removed from Feed for at Least One Hour[a]

	L-Carnitine, ppm			
Item	0	50	125	CV
IGF-1, ng/mL	66.8	72.98	57.64	30.2
IGF-2, ng/mL	139.33	146.39	133.16	12.5
IGF1:IGF2	.47	.50	.43	20.9
Insulin, ng/mL[bd]	.39	.60	.59	27.0
Cholesterol, mg/dL	82.38	86.88	82.73	12.5
Glucose, mg/dL	75.57	81.12	81.69	24.4
Albumin, mg/dL[b]	3.48	3.44	3.05	10.9
Blood urea nitrogen, mg/dL	15.60	15.54	14.34	19.3
Creatine, mg/dL	1.61	1.63	1.54	10.3
Triglycerides, mg/dL	41.99	48.50	42.64	49.8
Lactate dehydrogenase, ug/mL[ce]	1121.7	600.3	670.8	28.9
Aspartate aminotransferase, ug/mL	68.67	35.87	48.30	76.1
Alanine aminotransferase, ug/mL	42.47	42.38	47.23	34.4

[a]Data represents six to eight pigs/treatment.
[bc]Linear effect of dietary L-carnitine ($P<.05$, $P<.01$, respectively).
[de]Quadratic effect of dietary L-carnitine ($P<.10$, $P<.01$, respectively).

THE EFFECTS OF SUPPLEMENTING GROWING-FINISHING PIG DIETS WITH CARNITINE AND(OR) CHROMIUM ON GROWTH AND CARCASS CHARACTERISTICS [1]

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Summary

Eighty crossbred gilts (initially 83 lb) were used to examine the effects of 50 ppm carnitine and(or) 200 ppb chromium from chromium nicotinate on growth performance and carcass characteristics. In this trial, adding carnitine and(or) chromium to the diets of high-lean growth finishing gilts did not increase carcass leanness. However, the combination of carnitine and chromium improved the color characteristics of the longissimus muscle.

(Key Words: Feed Efficiency, Carnitine, Chromium.)

Introduction

Research at Kansas State University has tested several carcass modifiers to examine their effects on growing-finishing pig performance and carcass characteristics. In the past, both carnitine and chromium were tested with medium-lean growth potential pigs. The results of these studies indicated that adding both carnitine and chromium to growing-finishing pig diets decreased backfat thicknesses and increased carcass leanness. Researchers at Louisiana State University showed dramatic improvements in leanness with the addition of chromium, from chromium nicolinate, to growing-finishing pig diets. Therefore, our objective was to examine the possible interactive effects of carnitine and chromium, from chromium nicotinate, on growth performance and carcass characteristics of growing-finishing pigs.

Procedures

Eighty crossbred gilts (PIC L326 × C15; initially 83 lb) were used in a growth assay. Carnitine (0 or 50 ppm) and chromium (0 or 200 ppb), from chromium nicotinate, were used in a 2 × 2 factorial arrangement. Pigs were blocked by weight and ancestry in 10 randomized complete blocks. The corn-soybean meal-based experimental diets (Table 1) were fed in two phases: growing (83 to 145 lb) and finishing (145 to 240 lb). The growing diets were formulated to contain 1.0% lysine, .75% Ca, and .65% P. The finishing diets were formulated to contain .80% lysine, .65% Ca, and .55% P. All diets contained .1% L-lysine HCl.

The study was conducted in an environmentally controlled finishing barn with two pigs in each 4 ft × 4 ft totally slatted pen. The pens contained a single hole self-feeder and a nipple waterer to allow pigs ad libitum access to feed and water. Drip coolers were activated when temperatures exceeded 80°F, cycling on for 3 out of every 15 min. Pigs and feeders were weighed every 14 days to calculate ADG, ADFI, and F/G. When mean weight in a pen reached 240 lb, pigs were slaughtered to collect standard carcass measurements. Visual analysis of the longissimus muscle was conducted with procedures developed by the National Pork Producers Council for color, marbling, moisture, and firmness. In addition, color was analyzed objectively with Minolta colorspectrometry to determine Hunter L*, a*, and b* values.

[1]The authors acknowledge Lonza, Inc., Fair Lawn, NJ, for partial financial support of this trial.

[2]Lonza, Inc., Fair Lawn, NJ.

Data from this trial were analyzed with the GLM procedure of SAS. The statistical model included the main and interactive effects of carnitine and chromium.

Results and Discussion

In this study, carnitine and(or) chromium did not affect growth performance of high-lean growth potential gilts (Table 2).

When pigs were slaughtered at 240 lb, no differences were detected for tenth rib backfat depth; last rib fat thickness; or average backfat thickness (average of first rib, last rib, and last lumbar vertebra backfat thicknesses; Table 3). Longissimus muscle area, percentage lean, and percentage muscle, in high-lean growth gilts were not affected by the addition of carnitine and(or) chromium to the diet.

An interaction occurred between carnitine and chromium for color ($P<.05$) and firmness ($P<.10$). Adding carnitine or chromium separately did not affect the color or firmness of pork compared with pigs fed the control diet. However, pork from pigs fed the combination of carnitine and chromium was darker and firmer. This indicates that feeding the combination of carnitine and chromium may improve the color and firmness of pork longissimus muscle.

Instrumental analysis of the longissimus muscle also revealed a carnitine × chromium interaction for Hunter L* (measure of light to dark color) and a* values (measure of redness) and saturation index (measure of vividness or intensity, $P<.10$). This means that adding both carnitine and chromium produced longissimus muscle that was darker, redder, and more intensely colored than adding either carnitine or chromium alone. When chromium and carnitine were added separately, color and firmness scores were not different than those for muscle from pigs fed the control diet.

In conclusion, feeding carnitine and(or) chromium did not influence growth, leanness, or muscling of the high-lean growth gilts used in this trial. However, adding carnitine and chromium in combination improved the color characteristics of longissimus muscle. The improvement in color may not justify the addition of these compounds without an improvement in leanness. Although our previous research with both carnitine and chromium showed improvement in leanness of pigs with lower lean growth potentials, further evaluation is needed to understand why a similar response was not observed in this study.

Table 1. Diet Composition[a]

Ingredient, %	Grower (80 to 145 lb)	Finisher (145 to 240 lb)
Corn	79.08	71.70
Soybean meal, 46.5%	15.53	22.53
Soybean oil	2.50	2.50
Monocalcium phosphate	1.09	1.46
Limestone	.90	.91
Salt	.35	.35
Vitamin premix	.20	.20
Trace mineral premix	.15	.15
L-lysine HCl	.15	.15
Antibiotic[b]	.05	.05
Premix[c]	---	---
Total	100.00	100.00

[a]Grower diets were formulated to 1.0% lysine, .75% Ca, and .65% P; Finisher diets were formulated to .80% lysine, .65% Ca, and .55% P.
[b]Provided 40 g/ton tylosin.
[c]Premix contained either .1 lb L-carnitine and(or) 1.36 g of chromium nicotinate to achieve experimental levels of carnitine or chromium.

Table 2. The Effects of Carnitine and(or) Growth Performance of Growing-Finishing Pigs[ab]

Item	Control	Carnitine	Chromium	Carnitine + Chromium	CV
Grower, 80 to 145 lb					
ADG, lb	2.19	2.18	2.16	2.16	6.7
ADFI, lb	4.98	5.19	4.98	5.01	8.1
F/G	2.28	2.37	2.31	2.33	7.0
Finisher, 145 to 240 lb					
ADG, lb	2.04	2.08	2.02	2.02	8.9
ADFI, lb	6.29	6.48	6.06	6.32	9.5
F/G	3.11	3.11	3.00	3.13	9.2
Overall, 80 to 240 lb					
ADG, lb	2.09	2.13	2.08	2.07	7.2
ADFI, lb	5.77	5.81	5.62	5.77	5.9
F/G	2.77	2.72	2.71	2.79	4.8

[a]Means derived from 79 gilts (initially 83 lb) housed at two per pen with ten replicate pens per treatment. Carnitine was fed at 50 ppm, and chromium from chromium nicotinate was fed at 200 ppb.
[b]No significant difference ($P>.10$).

Table 3. The Effects of Carnitine and(or) Chromium on Carcass Characteristics[a]

Item	Control	Carnitine	Chromium	Carnitine + Chromium	CV
Backfat					
First rib, in	1.42	1.37	1.41	1.43	
Tenth rib, in	.80	.76	.78	.82	25.7
Last rib, in	.78	.79	.82	.79	13.9
Last lumbar, in	.70	.68	.72	.73	19.6
Average, in[b]	.97	.96	1.00	.97	12.0
LMA, in^2	6.86	7.07	6.96	6.82	10.6
Lean, %[c]	54.13	54.47	55.03	54.16	3.4
Muscle, %[d]	56.83	56.99	57.46	56.84	6.0
Dressing percent	73.78	74.24	74.15	73.81	2.6
Visual color[eh]	2.39	2.29	2.22	2.66	20.6
Firmness[ei]	2.44	2.26	2.35	2.62	21.8
Marbling[eh]	2.09	1.81	1.93	2.32	29.6
Hunter L*[fi]	54.00	54.43	54.76	52.07	7.4
Hunter a*[fi]	10.84	10.80	9.66	11.31	17.9
Hunter b*[f]	7.96	7.67	7.15	7.78	2.4
Hue angle[fij]	53.93	50.00	54.90	48.27	20.2
Saturation index[fh]	13.48	13.29	12.06	13.76	18.7
A:B ratio[fj]	1.39	1.47	1.40	1.49	13.6

[a]Means derived from 79 pigs slaughtered at 240 lb with 15 or 16 pigs per treatment. Hot carcass weight was used covarate in the statistical analysis.
[b]AVGBF calculated as the average of first rib, last rib, and last lumbar fat depths.
[c]Lean percent was derived from NPPC equations for carcasses with 5% fat.
[d]Muscle percent was derived from NPPC equations for carcasses with 10% fat.
[e]Scores of 1 to 5: 2 = grayish pink, traces to slight, or soft and watery; 3 = reddish pink, small to modest, or slightly firm and moist; and 4 = purplish red, moderate to slightly abundant, or firm and moderately dry.
[f]Means derived from three readings per loin. Measure of dark to light (Hunter L*), redness (Hunter a*), yellowness (Hunter b*), vividness or intensity (saturation index), or red to orange (Hue angle).
[gh]Carnitine × chromium effect ($P<.05$, and .10, respectively).
[i]Chromium effect ($P<.05$).
[j]Carnitine effect ($P<.07$).

EFFECTS OF FAT AND SODIUM BICARBONATE ON GROWTH PERFORMANCE AND STOMACH MORPHOLOGY IN FINISHING PIGS

S. P. Sorrell, J. D. Hancock, I. H. Kim, R. H. Hines, G. A. Kennedy, and L. L. Burnham

Summary

Pigs fed diets with soybean oil consumed less feed; grew more efficiently; and had greater last-rib backfat thickness, keratosis, and ulceration in their stomachs than pigs fed diets without soybean oil. Pigs fed diets with $NaHCO_3$ tended to eat more feed and had numerically greater ADG, but feed/gain and carcass measurements were not affected. $NaHCO_3$ decreased ulceration scores only for pigs fed diets without added fat.

(Key Words: Finishing Pigs, Fat, Sodium Bicarbonate, Ulcers.)

Introduction

Swine production in the United States has become very intensive. With this intensive production have come major changes in genetics; sometimes crowded pens; advanced feed processing procedures (e.g., fine grinding, pelleting, extruding, and expanding); and diet modifications (e.g., high fat) to maximize efficiency of gain. All of these factors have been implicated as contributors to the development of stomach lesions in finishing pigs. The resulting loss in growth performance and even death of afflicted pigs has prompted widespread investigation of methods to decrease the incidence and severity of stomach lesions.

Especially in the southeastern United States, anecdotal reports link crowded pens and high-fat diets with increased incidence of stomach lesions in pigs. In previous research here at KSU (1993 Swine Day Report), we observed that inclusion of 1% $NaHCO_3$ in simple corn-soy-based diets tended to reduce severity of gastric lesions in finishing pigs. Thus, the objective of the experiment reported herein was to determine the effects of fat on growth performance and stomach lesions in finishing pigs and to evaluate $NaHCO_3$ as a modifying influence in development of stomach lesions for pigs fed diets with added fat.

Procedures

Two hundred and forty crossbred pigs were allotted to 16 pens with 15 pigs per pen (6 ft^2/pig). Each pens was equipped with a self-feeder and nipple waterer to allowed ad libitum consumption of feed and water. The experiment was conducted as a 2 × 2 factorial with main effects of fat (none vs 6% added) and $NaHCO_3$ (none vs 1% added).

All pigs (Hampshire × Yorkshire × Duroc × Chester White crossbreds) were fed a corn-soybean meal-based diet formulated to .65% calcium and .55% phosphorus (Table 1). Lysine concentrations were .65% for the diets without added fat and .70% for the diets with added fat. The pigs were allotted to treatments on the basis of initial weight (avg of 100 lb), sex (eight barrows and seven gilts in each pen), and ancestry. The pigs were housed in a modified open-front building with half slatted and half solid, concrete floors.

The pigs were slaughtered when the average weight in the heaviest pen of a weight block reached 250 lb. At slaughter, carcass data were obtained, and the esophageal regions of the stomachs were scored for keratosis and ulceration. Response criteria were ADG, ADFI, G/F, backfat thickness, dressing percentage, FFLI, and scores for keratosis and ulceration in the stomach.

All data were analyzed as a randomized complete block design (initial weight as the

blocking term) using the GLM procedure of SAS and with a 2 × 2 factorial arrangement of treatments. Pen was the experimental unit for all analyses.

Results and Discussions

No interactions ($P>.15$) occurred among the main effects of fat and $NaHCO_3$ for any of the growth or carcass data (Table 2). However, pigs fed diets with soybean oil consumed less feed and were more efficient than pigs fed diets without soybean oil ($P<.001$). These data are in agreement with numerous other reports that adding fat increases energy density of diets, reduces voluntary feed intake, and improves efficiency of growth. Pigs fed the fat-added diet had 1% greater dressing percentage ($P<.002$), but also had .08 in. more last rib fat thickness ($P<.006$).

The pigs ate more of the diets with 1% $NaHCO_3$ ($P<.06$), but rate and efficiency of gain were not affected ($P>.12$). Adding $NaHCO_3$ to the diets did not affect carcass characteristics ($P>.15$).

Pigs fed soybean oil had greater keratinization ($P<.07$) and ulceration ($P<.05$) scores than pigs fed no soybean oil. Adding $NaHCO_3$ decreased ulceration scores, but only for pigs fed diets without added fat (fat × $NaHCO_3$ interaction, $P<.01$). This response was actually the opposite of what was expected, i.e., that fat additions might aggravate stomach tissues and that $NaHCO_3$ could be of greatest benefit in those situations. To the contrary, lesion scores were actually slightly greater for pigs fed $NaHCO_3$ in the fat-added diets.

In conclusion, our data suggested that soybean oil enhanced growth performance but increased stomach keratosis and ulceration. Feeding $NaHCO_3$ did not affect growth performance (with only a trend for greater feed consumption) or carcass characteristics and prevented adverse changes in stomach morphology only for pigs fed diets without soybean oil.

Table 1. Diet Composition[a]

Ingredient, %	No Soy Oil and No $NaHCO_3$	1% $NaHCO_3$	6% Soy Oil	1% $NaHCO_3$ & 6% Soy Oil
Corn	82.8	81.6	77.0	75.9
Soybean meal	14.6	14.8	14.2	14.3
Soy oil	-	-	6.0	6.0
$NaHCO_3$	-	1.0	-	1.0
Vit, Min, Antibio[b]	2.6	2.6	2.7	2.7
Lysine HCl	-	-	.1	.1
Calculated analysis				
Lys, %	.65	.65	.70	.70
ME, kcal/lb	1,508	1,492	1,611	1,595

[a]Formulated to .65% Ca and .55% P.
[b]Supplied 40 g/ton tylosin.

Table 2. Effects of Fat and Sodium Bicarbonate on Growth Performance, Carcass Characteristics, and Stomach Morphology in Finishing Pigs [a]

Item	No Soy Oil & No $NaHCO_3$	1% $NaHCO_3$	6% Soy Oil	1% $NAHCO_3$ & 6% Soy Oil	CV	Contrasts 1	2	3
ADG, lb	1.85	1.93	1.87	1.91	3.7	-[e]	.12	-
ADFI, lb	5.86	6.10	5.54	5.64	2.7	.001	.06	-
F/G	3.18	3.17	2.96	2.96	3.0	.001	-	-
Backfat, in	1.14	1.15	1.24	1.20	3.7	.006	-	-
HCW, lb	186	186	189	189	.74	.002	-	-
Dressing, %	74.8	74.6	75.9	76.0	.8	.002	-	-
FFLI, %	47.1	46.9	46.2	46.6	.8	.01	-	-
Keratosis [c]	1.39	1.45	1.62	1.54	43	.07	-	-
Ulceration [d]	.72	.33	.66	.88	139	.05	-	.01

[a]A total of 240 pigs (avg initial wt of 100 lb) were used.
[b]Contrasts were: 1) fat vs no fat; 2) $NaHCO_3$ vs no $NaHCO_3$; and 3) fat × $NaHCO_3$ interaction.
[c]The scoring system was: 0 = normal; 1 = mild; 2 = moderate; and 3 = severe keratosis.
[d]The scoring system was: 0 = normal; 1 = mild; 2 = moderate; and 3 = severe ulceration.
[e]Dashes indicate $P>.15$.

THE USE OF REAL-TIME ULTRASOUND TO MODEL THE GROWTH PERFORMANCE AND LYSINE REQUIREMENTS OF GROWING-FINISHING PIGS ON COMMERCIAL FARMS

J. W. Smith, II, M. D. Tokach, A. P. Schinckel [1], S. S. Dritz, J. L. Nelssen, and R. D. Goodband

Summary

Eighty pigs, 40 barrows and 40 gilts, on two commercial finishing operations were used to model growth and accretion rates. Major differences were observed between the two farms. This analysis indicates that real-time ultrasound can be used to develop lean and lipid accretion curves for formulating farm-specific diets that optimize lean growth performance in commercial operations

(Key Words: Ultrasound, Growth, Modeling, Performance.)

Introduction

Currently, swine nutritionists formulate diets based upon estimates of lean accretion, lipid accretion, and protein requirements determined in controlled settings on university or company research facilities. However, implementing these recommendations on individual farms is difficult because of the differences in feed intake, disease status, stocking density, management, and a plethora of other factors. Researchers at Purdue University have developed models to determine the growth and accretion rates of pigs. However, this technique has not been tested in commercial operations. Therefore, this study was designed to evaluate whether real-time ultrasound could be used to model the growth performance and lysine requirements of growing-finishing pigs on commercial farms.

Procedures

Eighty pigs (40 barrows and 40 gilts) on two commercial farms were used. Pigs were tagged, weighed, and scanned within 1 week of placement in the finishing facility. Subsequently, pigs were weighed and scanned every 3 weeks until all pigs in the facility were marketed. Pigs used in the study were marketed as a group to remove biases caused by fast growth rate of individual pigs.

Growth and real-time ultrasound data were used to determine growth, protein, and lean accretion curves based on models developed at Purdue University. Metabolizable energy requirement curves were determined by the following equation:

$$\begin{aligned}\text{Metabolizable Energy Requirement} = \\ (.4 \times \text{Empty Body Protein}^{.78}) + \\ (.4 \times \text{Protein Accretion}) + \\ (10.53 \times \text{Protein Accretion}) + \\ (12.64 \times \text{Lipid Accretion})\end{aligned}$$

This equation estimates the feed intake in Mcal needed to meet the pigs energy needs based upon its growth and composition. Metabolizable energy requirement is then divided by the energy content of the diet to determine the estimated daily feed requirement.

Lysine requirements for each gender of pig on each farm was determined by estimating the maintenance lysine requirement and the lysine requirement for lean growth.

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Adjusting for the digestibility and efficiency of lysine utilization allows determination of the total lysine requirement. For this analysis, maintenance lysine requirement was estimated by :

$$\text{Maintenance Lysine Requirement} = .036 \times \text{Body Weight}^{.75}$$

Lysine requirement for lean-gain was estimated by:

$$\text{Lysine Requirement for Lean-Gain} = (.066 \times \text{Body Weight}) \div .65$$

where .066 is the lysine content of muscle, and .65 is the efficiency of lysine utilization. T otal lysine requirement was determined by:

$$\text{Total Lysine Requirement} = (\text{Maintenance Lysine Requirement} + \text{Lysine Requirement for Lean-Gain}) \div .80$$

where .80 is the digestibility of lysine.

Results and Discussion

Growth rates were greater for pigs on Farm 1 than pigs on Farm 2 (Figure 1). As expected, barrows grew faster than gilts on the respective farms. The most striking observation was the drastic decrease in growth rate of the barrows on Farm 1 after reaching a peak of 2 lb/d at 145 lb body weight. As will be discussed later , this has a major impact upon the lysine requirements of these pigs. Typically, growth rate for finishing pigs is determined by dividing total weight gain by the numbers of days in the facility . If this were plotted on Figure 1, it would appear as a straight line across the graph and would not account for the dynamics of pig growth. T o illustrate this concept, we will examine the performance to the barrows on Farm 1. These pigs were fed for 117 days, beginning at 56 lb and ending at 266 lb, resulting in an ADG of 1.79. This would be considered excellent performance by most producers. However , this masks the fact that the growth rate of these barrows decreased dramatically after the midpoint of the finishing phase.

Body composition, as determined by real-time ultrasound, is presented as empty body protein and empty body lipid accretion. The protein accretion curves (Figure 2) are similar to the average daily gain curves. However , the protein accretion for barrows on Farm 1 does not fall below that of pigs on Farm 2. indicating that although their growth decreases, the composition of their growth is still better than that of the pigs on Farm 2. The shape of the two barrow protein accretion curves is similar; however, the gilts from Farm 2 do not mimic the protein gain of the gilts from Farm 1. Normally, lean-gain for a commercial operation is established by determining initial lean and carcass lean from NPPC equations and packer carcass performance sheets and dividing lean-gain by days on feed. As with ADG, this gives a single mean for the entire growing-finishing period. By using real-time ultrasound to determine actual daily lean-gain, producers can better assess the quality of their genetics and more importantly can visualize how feeding pigs to heavier weights affects their growth and composition.

Lipid accretion (Figure 3) increased for all pigs as weight increased. The decreasing slope of the lipid accretion of the barrows from Farm 1 beginning at 180 lb is surprising. However , this is primarily a function of overall growth performance. These barrows dramatically decreased growth rate during this period. The barrows from Farm 2, in addition to having the lowest protein deposition rate, had the greatest lipid accretion rate.

The estimated daily feed requirement (Figure 4) was determined from the accretion rates and body compositions of the pigs. Estimated daily feed requirements, as expected, increased as the weight of the pigs increases. It is important to note that this is not daily feed intake. The estimated daily feed requirement is the estimated feed needed to sustain the pig's growth and composition. The daily feed intake may be greater because of feed wastage, variations in protein and energy utilization, and environment.

Total lysine needs (Figure 5) in g/d were determined based upon lean composition and accretion. The lysine needs of the pig follows that of lean accretion. Simply stated, the greater the lean accretion, the greater the lysine

requirement. Surprisingly, the lysine requirement of any of the pigs did not reach 20 g/d or even 18 g/d. Typically, lysine requirements are determined by feeding several levels of lysine and then using feed disappearance data, transformed to daily lysine requirement. This method yields a greater requirement because of the factors affecting feed disappearance. The pig actually may be consuming 18 g/d, but with wastage factored in, 20 g/d may be leaving the feeder.

Total lysine needs were determined on a percentage of diet (Figure 6) by dividing the lysine requirement by the estimated daily feed requirement. Based upon this analysis, Farm 2 is overfeeding lysine especially in the late finishing phase. As expected, the pigs on Farm 1 have a greater lysine requirement as a percentage of the diet.

Implications

Progressive pork producers are demanding diet formulations that are designed specifically for their operations. However, without the use of real-time ultrasound and this type of analysis, nutritionists cannot estimate the dynamics of the growth performance of pigs on a specific operation. Unless an analysis like this is adapted, diets will continue to be formulated for the average and, in most cases, will not meet the specific requirements for the operation.

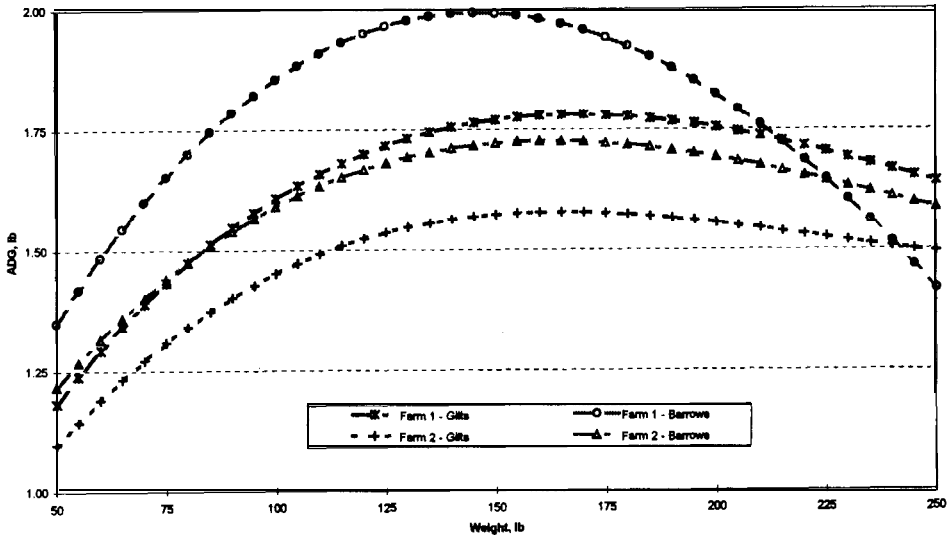

Figure 1. Modeled Average Daily Gain for Barrows and Gilts

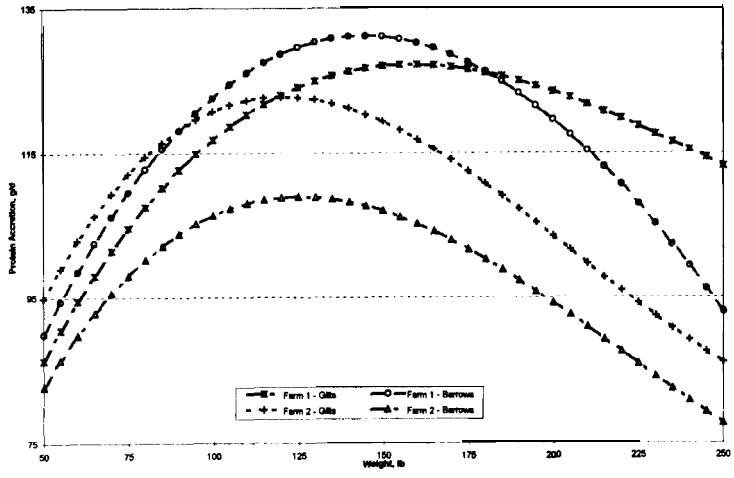

Figure 2. Modeled Empty Body Protein Accretion for Barrows and Gilts

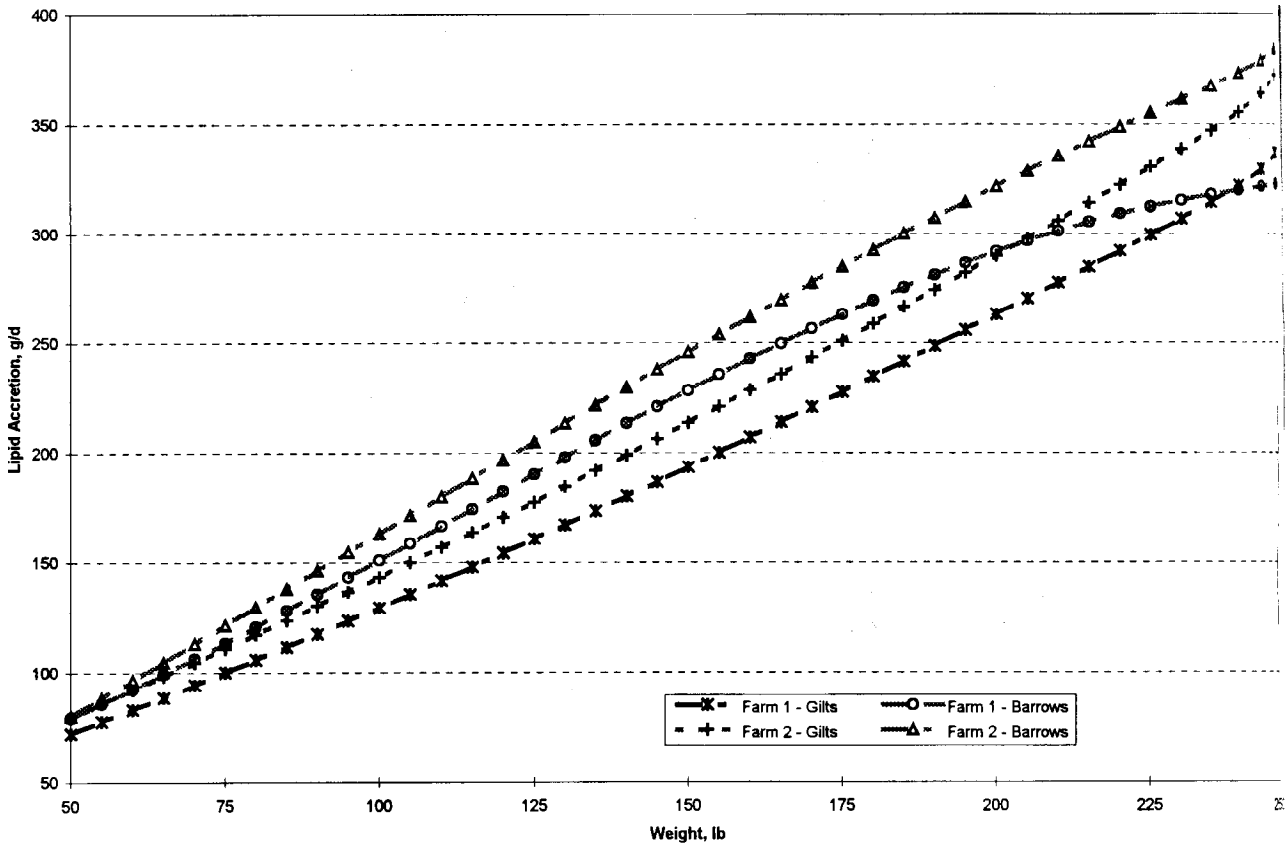

Figure 3. Modeled Empty Body Lipid Accretion for Barrows and Gilts

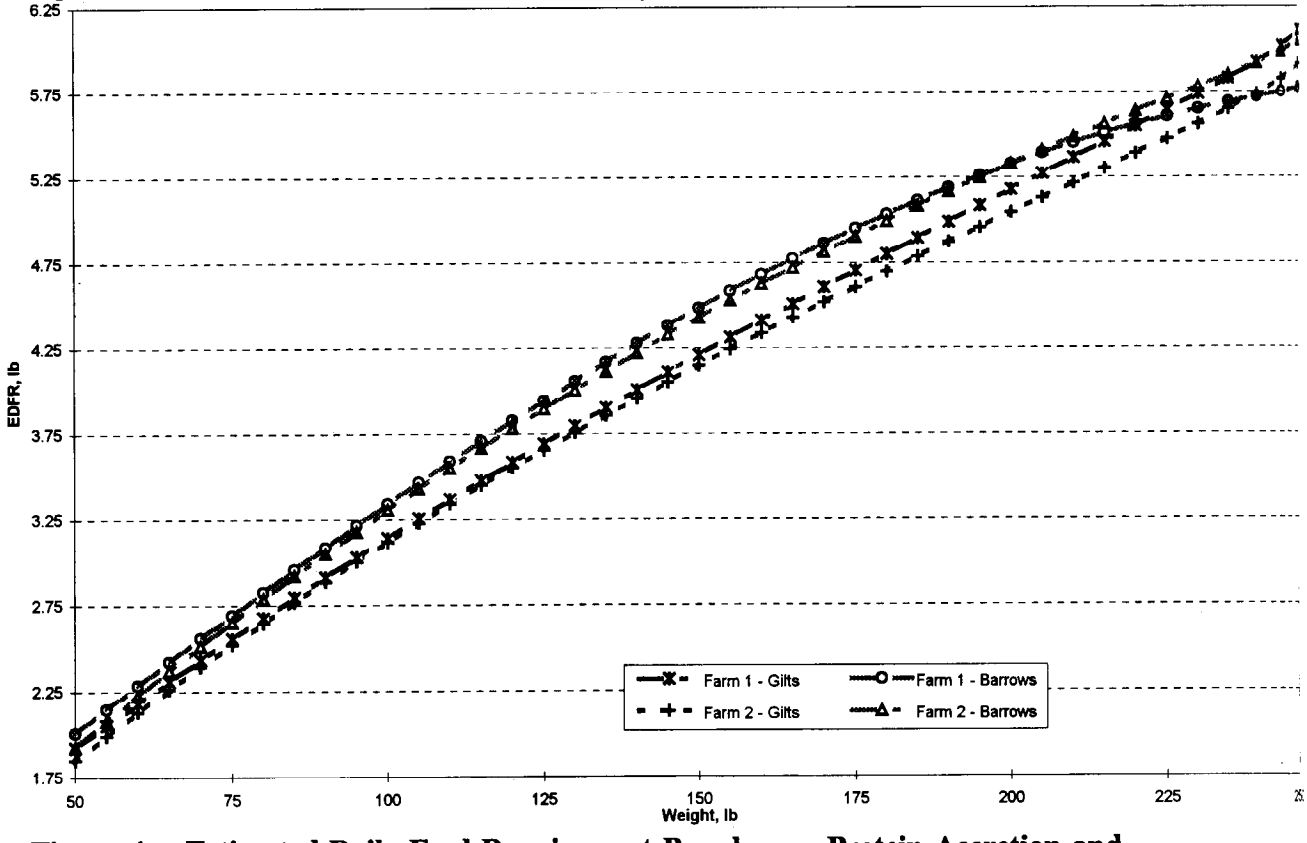

Figure 4. Estimated Daily Feed Requirement Based upon Protein Accretion and Maintenance

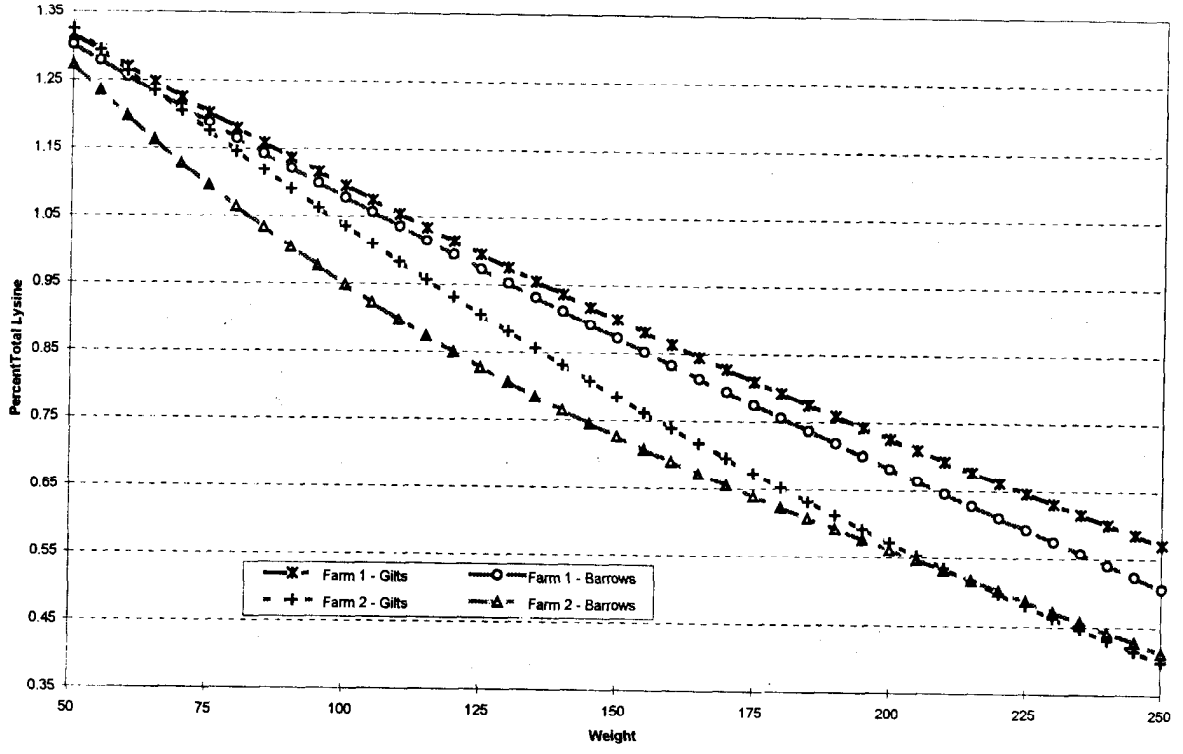

Figure 5. Total Lysine Needs Based upon Modeled Protein Accretion

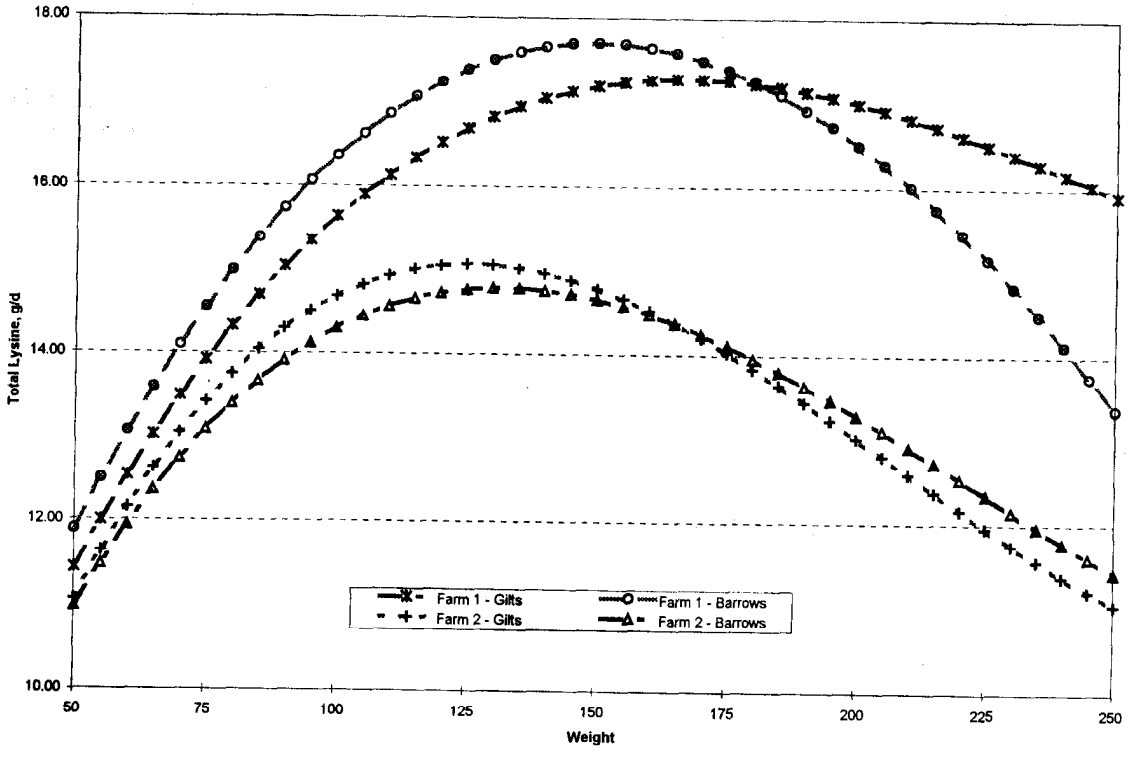

Figure 6. Percent Dietary Lysine Based upon Modeled Protein Accretion and Estimated Daily Feed Requirement

Swine Day 1996

INFLUENCE OF LYSINE CONCENTRATION ON GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF FINISHING PIGS[1]

S. S. Dritz[2], R. D. Goodband, M. D. Tokach, and J. L. Nelssen

Summary

We used a total of 11,653 pigs to examine the influence of a lysine phase-feeding regimen on growth performance and carcass characteristics in finishing pigs. We found that the lysine regimen did not affect ADG. Also, the low-lysine regimen was adequate for maximizing growth performance and carcass characteristics of barrows. However, the low-lysine regimen was inadequate to optimize feed efficiency in gilts. Further analysis indicated that the largest differences in feed efficiency were for the 115 to 160 lb period in gilts. Later in the growth period, feed efficiency of gilts was similar across dietary lysine regimens.

(Key Words: Lysine Requirement, Finishing Pigs.)

Introduction

Research from the University of Illinois suggests that the dietary lysine requirement for maximizing loin eye area and minimizing carcass backfat is considerably lower than the concentration fed to pigs in many production systems. These lower concentrations result in lower diet cost per ton and will decrease feed cost per lb of gain, if feed efficiency is not affected. However, reduction in diet cost should not be the only criterion for decision making in pork production. Improvements in feed efficiency or carcass lean content can result in improvements in economic returns, if higher-cost diets are fed. Our objective was to examine the effect of lysine phase-feeding regimens on growth performance and carcass characteristics of finishing pigs raised under commercial production conditions.

Procedures

A total of 11,653 high-health status pigs (PIC Terminal Crosses) derived from a segregated early-weaning production system was used. Pigs were housed in 1,200-head barns. Each barn had one or two rooms. Each room contained pigs with a maximum age spread of 1 week. Also, each room was filled with pigs from a single sow farm. Each room was managed on an all in, all out basis. The finishing barns were fully slatted, curtain sided, and all of similar design with each pen containing approximately 25 pigs. Pigs were allowed ad libitum access to feed and water.

Gilts and barrows were housed separately on each side of the room with a separate feed line and bulk bin providing feed for each side of the room. A group of barrows and a group of gilts were housed in each room. Both genders were fed either a high- or a low-lysine regimen, with three rooms per regimen. Gilts and barrows were fed the high- and low-lysine regimens, respectively, in three barns. In the three remaining barns, gilts and barrows were fed the low- and high-lysine regimens, respectively. All treatment combinations were represented to allow for

[1]Appreciation is expressed to members of the Pipestone Production System, Pipestone, MN for use of animals and facilities and assistance in data collection. We also thank Marty Heintz for technical assistance.

[2]Food Animal Health and Management Center.

the detection of treatment differences within barn and negating the barn to barn variation. Therefore, each half room was considered an experimental unit. All pigs were marketed to a single packer, and the trial was conducted from May, 1995 through February, 1996.

All diets fed were corn-soybean meal based and formulated to achieve the desired lysine concentrations by altering the corn and soybean meal ratio without the use of lysine HCl. Examples of the diet composition for the 1.00 and .50% lysine diets are listed in Table 1. Lysine concentrations of the diets used to make up the high- or low-lysine phase-feeding regimens are listed in Table 2. The high-lysine regimen was similar to the regimen the producers were feeding at the beginning of the experiment. The low-lysine regimen concentrations for the diets fed from 115 lb to market were determined by using the following regression equations at the average weight for each phase.

Barrow Dietary Lysine, % =
1.0300 - .002 x Weight, lb

Gilt Dietary Lysine, % =
1.14035 - .0236 x Weight, lb

We derived these equations from experiments performed at the University of Illinois. The first diet contained 1.15 or 1.10% lysine for the gilts and barrows, respectively, and was fed from the time pigs were placed in the barns until they weighed approximately 115 lb. The amount of the first diet fed per half room was determined using the KSU feed budget. Pigs then were fed 133, 132, and 177 lb per pig of the 115 to 160, 160 to 200, and the 200 to 250 lb diets, respectively. The pigs then were fed the 250 to Mkt diet until market. A random sampling of three pens per half room was weighed and the feed in the bins was inventoried just prior to the day that the diet for the next phase was to be delivered. The mean pig weight of the three pens was averaged and used as an indicator of the average pig weight on the day of feed inventory. The intermediate weights and feed inventory were used to calculate cumulative feed intake vs body weight curves.

Data were analyzed as a randomized complete block design in a 2 x 2 factorial arrangement with the main effects of lysine regimen (high or low) and gender (barrow or gilt). Half room was considered the experimental unit for all response criteria. Analysis of variance was performed using the GLM procedure of SAS with initial weight used as a covariate.

Results and Discussion

Gender by diet interactions ($P < .02$) were observed for ADFI, F/G, backfat, and lean percentage. The barrows fed the low-lysine regimen had lower ADFI and similar ADG resulting in better feed efficiency when compared to those fed the high-lysine regimen. Similarly, backfat was lower and lean percentage was higher for barrows fed the low-lysine regimen compared to the high-lysine regimen. Conversely, gilts fed the high-lysine regimen had lower ADFI, better feed efficiency, less backfat, and a higher lean percentage compared to gilts fed the low-lysine regimen. Average daily gain was similar across dietary lysine regimen but higher for gilts than barrows. Loin depth was greater for gilts compared to barrows and for pigs fed the high- compared to low-lysine regimen, regardless of gender.

A further analysis of feed efficiency is presented in Figures 1 and 2. Pig weight vs. cumulative feed intake is plotted and a trend line fit to the data for each lysine phase-feeding regimen. Therefore, if feed efficiency is improved as weight increases, cumulative feed intake will be lower.

A comparison of the cumulative feed intakes for barrows fed the high- and low-lysine regimens is presented in Figure 1. The fitted curves are similar for barrows fed the two regimens, whereas the means listed in Table 3 indicate a significant difference. We offer two explanations for this seemingly contradictory data. The first is that the difference between lysine regimens did not occur until very late in the growth period. Therefore, the fitted line is influenced only by relatively few data points, and the fitted trend line would not diverge between the two

treatments. The second explanation is that, although the differences in market weight were not significant (Table 3), barrows fed the high-lysine regimen had heavier market weight compared to those fed the low-lysine regimen. Nevertheless, both explanations indicate that the low-lysine regimen was adequate to optimize feed efficiency.

Similar curves are presented in Figure 2. for the gilts. In contrast to the curves for barrows, the two gilt curves diverge early in the growth phase. This indicates that during the 115 to 160 lb period, the low-lysine regimen was inadequate to optimize feed efficiency. However, in the later phases, the slopes of the lines are similar, indicating that the feed efficiency from 160 lb to market was similar for gilts fed the high- and low-lysine regimen. This analysis indicates the importance of examining the curves over the growth period as opposed to means.

In conclusion, these results indicate that under commercial production conditions, the low-lysine regimen was adequate for barrows but inadequate for gilts during the early finishing phase to optimize growth performance and carcass characteristics.

Table 1. Diet Composition, % (As-Fed)[a]

	Dietary Lysine, %	
Ingredient	1.00	.50
Corn	67.225	85.765
Soybean meal, 46.5% CP	27.63	12.14
Fat, choice white grease	3.00	--
Limestone	.84	.80
Monocalcium phosphate, 21% P	.63	.62
Salt	.35	.35
Vitamin premix	.1	.1
Trace mineral premix	.15	.15
Copper sulfate	.075	.075

[a]The corn:soybean meal ratio was adjusted to provide the dietary lysine levels used in the various weight ranges.

Table 2. Dietary Lysine Concentrations (High and Low Regimens), %[a]

	Barrows		Gilts	
Phase, lb	High	Low	High	Low
Entry to 115	1.00	1.00	1.15	1.15
115 to 160	.95	.75	1.00	.82
160 to 200	.80	.67	.90	.72
200 to 250	.70	.58	.80	.61
250 to Mkt	.60	.50	.70	.52

[a]Diets fed from entry to 115 lb, 115 to 160 lb, and 160 to 200, contained 4%, 3%, and 2% added fat, respectively.

Table 3. Influence of Lysine Phase-Feeding Regimen (High or Low) on Growth Performance and Carcass Characteristics

	Barrows		Gilts		Gender × Diet	
Item	High	Low	Low	High	$P<$	CV
ADG, lb[b]	1.72	1.70	1.63	1.65	.99	4.4
ADFI, lb	5.32[d]	5.10[e]	4.92[e]	4.66[f]	.01	3.8
F/G	3.11[d]	3.01[e]	3.02[e]	2.82[f]	.01	3.1
Back fat, in	.75[d]	.71[e]	.65[g]	.61[f]	.02	5.9
Loin depth, in[c]	2.17	2.12	2.19	2.24	.95	3.1
Lean, %	53.8[d]	54.3[e]	55.3[g]	56.1[f]	.01	1.0
Market weight, lb	261.5	253.0	254.8	251.2	.17	4.1

[a]Each number is the mean of six half-barns housing 300 to 600 pigs. A total of 11,653 pigs was used. Initial weight (60.7 lb) was used as a covariate.
[b]Main effect of gender ($P<.04$).
[c]Main effect of gender ($P<.02$) and lysine regimen ($P<.07$).
[d,e,f,g]Means lacking a common superscript differ ($P<.05$).

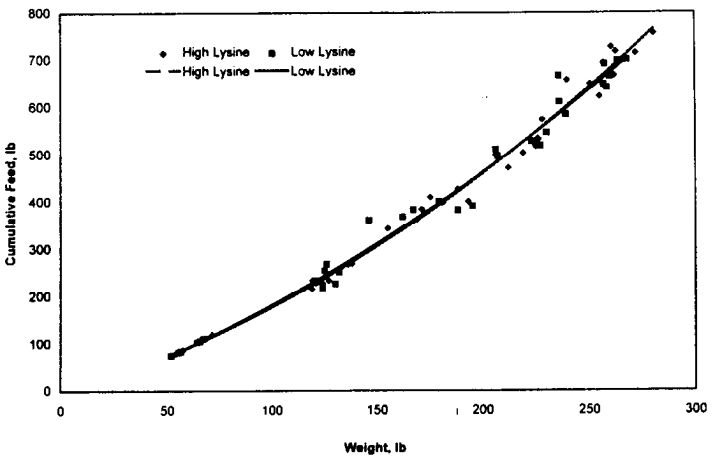

Figure 1. Effect of Lysine Phase-Feeding Regimen on Cumulative Feed Intake of Barrows

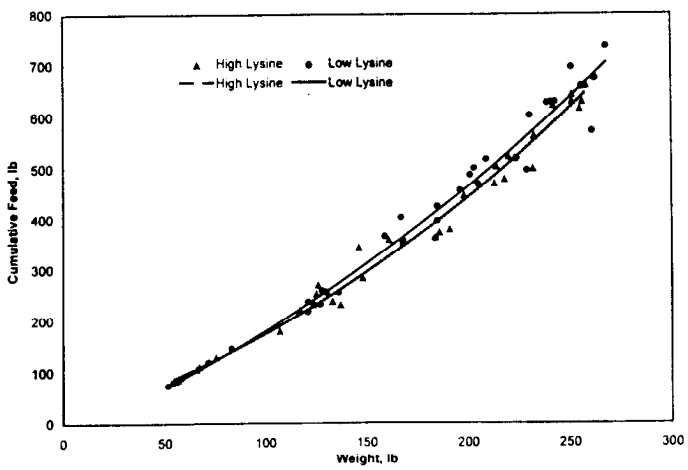

Figure 2. Effect of Lysine Phase-Feeding Regimen on Cumulative Feed Intake of Gilts

DIETARY LYSINE REQUIREMENT FOR OPTIMAL GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF LATE FINISHING GILTS

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Summary

In Exp. 1, increasing dietary lysine from .40% to .70% linearly improved ADG, F/G, 10th rib fat depth, and percentage lean in finishing gilts from 200 to 250 lb. Increasing dietary lysine also tended to improve longissimus muscle area. Results from Exp. 2 indicate no improvement in growth or carcass performance of gilts fed greater than .60% lysine. The combined results of Exp. 1 and 2 indicate that finishing gilts from 200 to 250 lb requires between .60% to .70% (18 to 20 g/d) dietary lysine to maximize both growth performance and carcass characteristics.

(Key Words: Finishing Pigs, Lysine, Lean Growth.)

Introduction

Increased selection for lean tissue growth has resulted in increased dietary lysine requirements. However, as lean growth rate declines, the need for high dietary lysine levels diminishes. With this in mind, phase-feeding regimens to optimize dietary lysine and reduce costs associated with overfeeding nutrients throughout specific growth stages have been developed. Previous research (1993 KSU Swine Day Report of Progress) suggests that gilts with a high-lean growth potential required 26 g/d of lysine from 160 to 230 lb. These gilts were littermates to terminal sire boars and had a higher lean tissue accretion potential than many terminal-cross market gilts. Additionally, growth modeling has suggested that the lysine requirement as a percentage of the diet for late-finishing gilts decreases rapidly after 200 lb as lean growth slows and body mass is increased primarily through fat and bone accretion. Therefore, our objective was to determine the lysine requirement for optimal growth performance and lean tissue accretion in terminal-cross finishing gilts from 200 to 250 lb.

Procedures

Two experiments using 230 gilts (PIC 326 × C-22) were conducted to determine the lysine requirement of finishing gilts from 200 to 250 lb. Treatments were arranged in a randomized complete block design with seven or eight gilts per pen and five or four replications per treatment (Exp. 1 and Exp. 2, respectively). Pigs were blocked by weight at an average initial weight of 93 lb (Exp. 1) or 85 lb (Exp. 2).

All gilts were fed by weight in three phases from 100 to 250 lb. Pigs were weighed every 2 weeks, and diet changes were made when average block weights reached their specified values. All diets were corn-soybean meal based, with different lysine concentrations provided by adjusting the level of soybean meal in each diet. All gilts were fed a diet containing 1.0% total lysine from 100 to 150 lb. The gilts then were switched to a common diet with .80% total lysine from 150 to 200 lb body weight. When the average block weight of 200 lb was reached, all gilts within a block were switched to experimental treatments containing dietary lysine levels of .40%, .55%, and .70% (Exp. 1) or .60%, .70%, .80%, and .90% (Exp. 2). All diets contained .65% Ca and .55% P and were formulated to meet or exceed all digestible amino acid recommendations, with the exception of lysine(Table 1).

Table 1. Composition of Basal Diets with 1.0, .8, .4, and .6% Lysine[a]

	100 to 150 lb	150 to 200 lb	200 to 250 lb[b]	200 to 250 lb[c]
Item, %	1.0	.8	.4	.6
Corn	69.4	77.3	91.6	84.2
Soybean meal (46.5%)	27.5	20.2	5.7	12.9
Monocalcium phosphate	1.33	1.03	.99	1.09
Limestone	1.10	.73	.95	.99
Salt	.35	.35	.35	.35
Vitamin premix	.20	.20	.20	.20
Trace mineral premix	.15	.15	.15	.15
Medication[d]	.05	.05	.05	.125

[a]Each diet was formulated to contain .65% Ca and .55% P.
[b]Exp. 1 diets contained an additional 5.4% and 10.8% soybean meal to create the .55% and .70% diets, respectively.
[c]Exp. 2 diets contained an additional 3.7%, 7.3% and 10.9% soybean meal to create the .70%, .80% and .90% diets, respectively.
[d]Provided 100 g per ton tylosin.

All gilts were housed in a modified open-front building with natural and mechanical ventilation. Drip coolers were activated when ambient temperatures exceeded 80°F. Each pen measured 6 × 16 ft with 50% solid and 50% slatted flooring. Each pen contained a two-hole lidded dry feeder and a single nipple waterer allowing ad libitum access to feed and water. Pig and feeder weights were recorded at approximately 2-week intervals when estimated block weights of 200, 225, and 250 lb. were reached to determine ADG, ADFI, and F/G. Feed was withheld for 1 hour during the initial and final weigh periods before pigs were bled via jugular venapuncture to determine plasma urea nitrogen values (PUN). At an estimated block weight of 250 lb (Exp. 1) or estimated block weights of 200, 225, and 250 lb (Exp. 2), each pig was scanned ultrasonically at the last lumbar position to determine 10th rib fat depth, longissimus muscle area, and calculated lean percentage.

All data were analyzed using general linear models procedures. Data were analyzed as a randomized complete block design with diet as the main effect. Pigs were blocked by initial weight with pen as the experimental unit. Linear and quadratic polynomials were used to determine the effects of dietary lysine levels.

Results and Discussion

In Exp. 1, increasing dietary lysine from .40% to .70% improved ADG and F/G from 200 to 225 lb (linear, $P<.04$). Average daily gain, ADFI, and F/G tended to improve but showed no statistical difference ($P>.05$) from 225 to 250 lb. Increasing dietary lysine from .40% to .70% (11 to 20 g/d) linearly improved ADG, F/G, 10th rib backfat (BF), and carcass lean percentage from 200 to 250 lb (linear, $P<.05$; Table 2). Pigs fed .70% lysine had 20% better ADG and F/G overall than pigs fed the .40% dietary lysine level, with no effect observed for ADFI during the entire trial. Plasma urea nitrogen values increased with increasing lysine (linear, $P<.001$) for each growth period.

In Exp. 2, increasing dietary lysine from .60% to .90% (18 to 26 g/d) had no effect on either growth performance (Table 3) or carcass characteristics (Table 4; linear, $P<.15$). No trends were observed in growth and carcass performance for any of the weight periods.

These results tend to agree with previous research using high lean gilts at Kansas State University. Previous research at KSU indicated that terminal market gilts with a high lean growth potential require 26 g/d of lysine up to 200 lb. However, from 200 to 250 lb these gilts tended to have decreased lean tissue accretion and increased fat depths with increasing levels of lysine. The results of these experiments indicate the total dietary lysine level necessary to optimize growth performance and carcass characteristics for high lean finishing gilts from 200 to 250 lb. is approximately .60% (18 g/d). Although results from Exp. 1 indicate a linear improvement in performance with lysine levels up to .70% (19.8 g/d), PUN values (Exp. 1) indicate the lysine requirement is being met between .55% and .70% lysine. Additionally, these gilts had lower ADFI than the gilts in Exp. 2, resulting in a lower g/d of lysine intake at .70% total lysine. The results from Exp. 2 indicate effects on both growth performance and carcass characteristics plateau above 18 g/d or .60% total lysine. Therefore, based on the results of these experiments, the total dietary lysine requirement for optimal lean growth in gilts from 200 to 250 lb. appears to be between .60 and .70% (18 to 20 g/d) total lysine.

Table 2. Effects of Lysine on Growth Performance and Carcass Characteristics of Late Finishing Gilts (Exp. 1)[a]

	Dietary Lysine, %				Lysine *P*<	
Item	0.4	0.55	0.7	CV	Linear	Quadratic
200 to 225 lb						
ADG, lb	1.57	1.77	1.87	13.07	.07	.68
ADFI, lb	7.04	6.74	6.73	7.69	.38	.65
F/G	4.61	3.86	3.60	16.68	..05	.53
PUN, mg/dl	10.16	11.31	12.76	6.99	.0009	.74
Lysine g/d	12.8	16.8	21.4	7.44	.0001	.74
225 to 250 lb						
ADG, lb	1.70	1.94	2.07	18.07	.13	.79
ADFI, lb	6.81	6.53	6.57	7.62	.48	.57
F/G	4.20	3.42	3.19	22.48	.08	.55
Lysine g/d	12.4	16.3	20.9	10.20	.0001	.73
Overall						
ADG, lb	1.64	1.85	1.97	11.42	.04	.65
ADFI, lb	6.21	6.06	6.22	6.38	.96	.51
F/G	3.83	3.28	3.18	10.42	.02	.27
Lysine g/d	11.3	15.1	19.8	7.05	.0001	.55
PUN, mg/dl	12.39	12.78	15.51	13.36	.03	.27
BF, in.	.94	.88	.81	7.59	.05	.74
LMA, in^2	5.65	5.97	5.93	2.77	.07	.09
% Lean	49.75	51.01	51.63	1.22	.01	.42

[a]A total of 105 gilts (PIC C15 × 326) with an average initial weight of 200 lb. were used in a randomized complete block design with seven gilts/pen and five replicate pens/treatment.

Table 3. Effects of Lysine on Growth Performance of Late Finishing Gilts (Exp. 2)[a]

	Dietary Lysine, %					Lysine *P*<	
Item	.60	.70	.80	.90	CV	Linear	Quadratic
200 to 225 lb							
ADG, lb	1.70	1.77	1.71	1.73	9.28	.91	.78
ADFI, lb	6.58	6.55	6.37	6.58	6.27	.84	.57
F/G	3.87	3.70	3.73	3.80	9.07	.72	.40
Lysine g/d	17.9	20.8	23.1	26.9	7.68	.0001	.62
225 to 250 lb							
ADG, lb	1.75	1.70	1.81	1.75	8.0	.72	.98
ADFI, lb	6.73	6.80	6.88	6.57	5.21	.63	.30
F/G	3.85	4.00	3.80	3.75	4.28	.16	.26
Lysine g/d	18.3	21.6	25.0	26.9	4.47	.0001	.19
Overall							
ADG, lb	1.72	1.72	1.76	1.74	8.18	.74	.90
ADFI, lb	6.64	6.64	6.59	6.48	4.29	.43	.72
F/G	3.86	3.86	3.76	3.75	5.66	.21	.88
Lysine g/d	18.1	21.1	23.9	26.5	4.18	.0001	.64

[a]A total of 125 gilts (PIC C15 × 326) with an average initial weight of 200 lb was used in a randomized complete block design with eight gilts/pen and four replicate pens/treatment.

Table 4. Effects of Lysine on Carcass Characteristics of Late Finishing Gilts (Exp. 2)[a]

	Dietary Lysine, %					Lysine *P*<	
Item	.6	.7	.8	.9	CV	Linear	Quadratic
200 lb							
BF, in.	.68	.68	.72	.68	8.72	.63	.50
LMA, in^2	5.41	5.25	5.43	5.23	7.89	.70	.92
% Lean	54.28	54.07	53.78	53.52	3.05	.50	.98
PUN, mg/dl	11.29	13.10	14.24	15.73	6.58	.0001	.72
225 lb							
BF, in.	.78	.77	.77	.73	8.06	.28	.51
LMA, in^2	5.87	5.84	5.87	5.70	3.67	.35	.53
% Lean	53.26	53.20	53.24	53.27	2.28	.98	.94
PUN, mg/dl	12.52	13.76	15.31	16.15	5.21	.0001	.61
250 lb							
BF, in.	.89	.85	.91	.84	7.30	.62	.57
LMA, in^2	6.48	6.35	6.49	6.32	6.37	.71	.91
% Lean	52.73	52.66	52.41	52.66	2.59	.88	.82
PUN, mg/dl	13.88	15.62	15.37	16.67	8.89	.01	.50

[a]A total of 125 gilts (PIC C15 × 326) with an average initial weight of 200 lb was used in a randomized complete block design with eight gilts/pen and four replicate pens/treatment. Carcass measurements were calculated from scanned values.

EVALUATION OF THE TOTAL SULFUR AMINO ACID REQUIREMENT OF FINISHING PIGS [1]

J. A. Loughmiller, R. D. Goodband, M. D. Tokach, J. L. Nelssen, J. W. Smith II, and J. R. Bergstrom

Summary

Sixty four gilts (initially 120 lb) were used to evaluate the effects of increasing total sulfur amino acid (TSAA):lysine ratios on growth performance and carcass characteristics. Diets included two levels of lysine (.55% and .70% total lysine) and three TSAA:lysine ratios (60, 65, and 70% of lysine) arranged in a 2 × 3 factorial. A tendency for a lysine × TSAA interaction was observed for ADG and ADFI. Increasing TSAA:lysine ratio decreased ADG and ADFI in pigs fed .55% lysine; however, ADG and ADFI were increased in pigs fed .70% lysine and 65% TSAA:lysine. Pigs fed .70% lysine had improved ADG, F/G and 10th rib fat depth compared to those fed .55% lysine. However, no effects were observed with increasing TSAA:lysine ratios. These results suggest that the TSAA requirement of finishing pigs is not greater than 60% of total lysine.

(Key Words: Finishing Pigs, Methionine, Amino Acids.)

Introduction

Methionine and cystine are used mainly for gut tissue maintenance and as substrates in several biological functions. Thus, the TSAA requirement increases only moderately as the pig grows. Because of this moderately increasing need for TSAAs and the decreasing need for lysine, it is hypothesized that the TSAA:lysine ratio should increase with increasing age of the pig. However, little conclusive data exists to confirm this hypothesis. Therefore, the objective of this experiment was to evaluate the TSAA requirement of finishing pigs and determine if it changes relative to lysine.

Procedures

A total of 64 gilts (PIC 326 × C-15; initially 120 lb) was used in a 64 d growth assay. Gilts were blocked by initial weight in a randomized complete block design using a 2 × 3 factorial arrangement. Each treatment had two gilts per pen (5 ft × 5 ft) and six pens. Pigs were housed in an environmentally controlled building with totally slatted flooring. Pigs had access to a nipple waterer and a single-hole feeder providing ad libitum access to both water and feed. Pig weights and feed disappearance were measured every 21 d to determine ADG, ADFI, and F/G. Blood samples were taken via jugular venapuncture on d 21 and at trial conclusion to evaluate plasma urea nitrogen (PUN). Ultrasonic images of 10th rib fat depth and longissimus muscle area were taken by a certified technician at the conclusion of the trial to calculate final carcass composition.

All diets were grain sorghum-soybean meal based with added synthetic L-lysine HCl, L-threonine, and DL-methionine (Table 1). The high lysine diets were formulated to contain .70% total (.56% apparent digestible) lysine with methionine at 30% of total lysine and TSAA at 60, 65, or 70% of total lysine. Low lysine diets were formulated to contain .55% total (.44% apparent digestible) lysine and TSAA:lysine ratios identical to those of the high lysine treatments. All diets were formulated to make lysine and/or cystine the first limiting amino acid with DL-methionine

[1]The authors thank Degussa, Inc. of Kennesaw, GA for partial funding of this experiment.

added in place of cornstarch to provide the TSAA:lysine ratios of 60, 65, and 70%. An 80% transulfation efficiency was calculated into diet formulation compensating for conversion of methionine to cystine. All other amino acid levels except cystine were based on ideal amino acid patterns from the University of Illinois (Table 2). All dietary treatments contained .60% Ca and .50% P, and all other nutrients either met or exceeded current recommendations for high-lean growth potential, finishing pigs.

Table 1. Basal Diet Composition[a]

	Total Dietary Lysine	
Ingredient, %	.70%	.55%
Grain sorghum	84.36	92.34
Soybean meal 46.5%	12.87	4.66
Monocalcium phosphate	.86	1.00
Limestone	1.01	.99
Salt	.35	.35
Vitamin premix	.15	.15
Trace mineral premix	.10	.10
L-lysine HCl	.15	.25
L-threonine	.02	.05
Cornstarch[b]	.08	.06
Medication	.05	.05
Total	100.00	100.00

Data were analyzed as a randomized complete block design in a 2 × 3 factorial arrangement. General linear model procedures were used to conduct the analysis of variance. Linear and quadratic regression polynomials were used to detect the influence of increasing the TSAA:lysine ratio.

Results and Discussion

An improvement in performance was observed for all response criteria except ADFI and longissimus muscle area for pigs fed .70% lysine compared with those fed .55% lysine. A tendency for a lysine × TSAA interaction ($P<.10$) was observed for ADG and ADFI. Pigs fed the .70% lysine had increasing ADG and ADFI up to the 65% TSAA:lysine ratio, whereas pigs fed .55% lysine had decreasing ADG and ADFI as TSAA:lysine ratios increased. However, increasing the ratio above 60% of lysine had no ($P>.05$) effects upon any of the growth, blood, or carcass response criteria evaluated. Longissimus muscle area was not affected ($P>.05$) by either increasing lysine or TSAA:lysine ratios but did tend to be higher for gilts fed the high lysine diet. Tenth rib fat depth was decreased in pigs fed .70% lysine ($P<.03$), but increasing the TSAA ratio had no effect on backfat depth. Plasma urea nitrogen (PUN) concentrations were lower in pigs fed .55% lysine compared with those fed .70% lysine ($P<.01$), but did not differ between TSAA:lysine ratios. The increased PUN concentration for gilts fed the .70% lysine diets compared to gilts fed the .55% lysine diets was caused by feeding a higher level of dietary CP.

Table 2. Total and Apparent Digestible Amino Acid Composition of Basal Diets[a]

	.70% Lysine		.55% Lysine	
Item, %	Total	(dig.)	Total	(dig.)
Lysine	.70	.56	.55	.44
Threonine	.49	.35	.39	.28
Tryptophan	.17	.12	.12	.08
Methionine	.21	.19	.18	.15
Cystine	.22	.16	.15	.13
Methionine + Cystine	.43	.35	.33	.28
Isoleucine	.65	.56	.51	.44
Valine	.62	.48	.51	.40

The results of this experiment suggest that the TSAA:lysine ratio may have been overestimated in the past. No improvements ($P<.05$) in any response criteria were noted with increasing TSAA:lysine ratios. However, a numerical increase in ADG was observed for pigs fed the 65% TSAA:lysine ratio compared to the 60% TSAA:lysine ratio at .70% lysine. The trend for an interaction of ADG and ADFI as the TSAA:lysine ratio increased above 60% indicates that TSAA levels above 60% relative to

lysine can inhibit optimal growth when low lysine (.55%) diets are fed. The lack of improvement in feed efficiency provides further evidence that the optimal TSAA:lysine ratio was less than 60% in this trial. This experiment also indicates that gilts with a high-lean potential require dietary lysine levels greater than .55% total lysine (17 g/d total lysine)

to maintain optimal lean gain. This result is consistent with previous research conducted to determine the lysine requirement of high-lean potential gilts.

In conclusion, no effect ($P<.05$) was seen for overall growth performance and carcass characteristics with increased levels of TSAA relative to lysine. A positive lysine effect ($P<.05$) was seen for ADG, F/G, longissimus muscle area, and 10th rib fat depth. Further research is needed to determine the TSAA requirement of high-lean growth pigs.

Table 3. Effects of Increasing Total Sulfur Amino Acids (TSAA, 60, 65, and 70%) Relative to Lysine on Growing-Finishing Pig Growth Performance[a]

							Probabilities ($P<$)			
	.70% Lysine			.55% Lysine				TSAA		
Item	60%	65%	70%	60%	65%	70%	CV	Linear	Quadratic	Lysine
Overall										
ADG, lb[b]	1.86	1.96	1.97	1.83	1.81	1.68	7.6	.65	.32	.002
ADFI, lb[b]	6.35	6.73	6.86	6.95	6.94	6.53	7.0	.81	.34	.34
F/G	3.42	3.44	3.49	3.78	3.90	3.90	5.7	.28	.79	.001
10th rib BF	.98	1.04	1.05	1.15	1.12	1.17	12.3	.47	.87	.03
LMA, in^2	5.96	5.77	5.84	5.76	5.44	5.51	11.1	.49	.47	.28
Lysine, g/d	20.2	21.4	21.8	17.4	17.3	16.3	6.9	.59	.35	.001
TSAA, g/d	6.1	7.3	8.7	5.0	6.0	6.5	7.3	.0001	.68	.001
PUN, mg/dl	9.2	9.3	9.3	5.6	5.4	6.0	17.1	.64	.76	.001

[a]A total of 64 pigs (two pigs/pen and six pens/treatment) with an initial average body weight of 120 lb and an average final body weight of 238 lb.
[b]Lysine × TSAA interaction ($P<.10$).

DIETARY TOTAL SULFUR AMINO ACID REQUIREMENT FOR OPTIMAL GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS IN FINISHING GILTS [1]

J. A. Loughmiller, M. D. Tokach, R. D. Goodband, J. L. Nelssen, E. C. Titgemeyer, I. H. Kim, J. R. Bergstrom, and J. W. Smith II

Summary

Finishing gilts (initially 163 lb) were fed .58% total lysine (.50% apparent digestible) and total sulfur amino acid (TSAA) concentrations of .26, .285, .31, .335, and .36% (.225 to .325% apparent digestible). These values represent TSAA: lysine ratios of 45, 50, 55, 60, and 65%. Results suggest a linear decrease in ADG and ADFI along with poorer F/G with increasing TSAA levels. However, gilts fed .285% TSAA (50% of lysine) had the best ADG and F/G. No effect was observed on any carcass criteria. Based on the results of this study, the TSAA requirement is not greater than .285% total (.25% apparent digestible) or approximately 50% of the lysine requirement.

(Key Words: Finishing Pigs, Growth, Total Sulfur Amino Acids.)

Introduction

Previous research at KSU indicated that the TSAA requirement of finishing gilts is not greater than 60% of lysine. Because methionine and cystine are used mainly for tissue maintenance and as substrate precursors, previous researchers have hypothesized that the requirement should increase as the pig ages and its maintenance requirement increases. Growth models have agreed with this hypothesis and indicate that the TSAA requirement for older pigs should be greater than that for younger pigs. However, empirical data have been unable to conclusively define the finishing pig's TSAA requirement. Because discrepancies still exist in TSAA recommendations for finishing pigs, our objective was to determine the TSAA requirement of finishing gilts.

Procedures

Eighty gilts (PIC 326 × C-22; initially 163 lb) were used in a 36-d growth trial to determine the effects of increasing TSAA levels on growth performance and carcass characteristics. All gilts were fed a corn-soybean meal grower diet from 50 to 160 lb that was formulated to exceed all current nutrient recommendations. Gilts were blocked by weight and assigned randomly by initial weight to one of five dietary treatments in a randomized complete block design. Experimental diets consisted of .26, .285, .31, .335, and .36% total dietary TSAA (.225, .25, .275, .30, and .325% apparent digestible) with corresponding TSAA ratios relative to apparent digestible lysine of: 45%, 50%, 55%, 60%, and 65%. The TSAA levels were obtained by substituting increasing levels of L-methionine for cornstarch. L-methionine was supplied to meet both the methionine and cystine fractions of the TSAA requirement. An 80% transsulfation efficiency for conversion of methionine to cystine was allowed in diet formulation. To ensure that TSAA were the only limiting amino acids, all others were maintained at or above ratios relative to lysine as suggested by the University of Illinois (Table 1). Grain sorghum, cornstarch, and L-methionine levels varied as the TSAA:lysine ratios increased, and all diets contained 0.65% Ca and 0.55% P (Table 2).

[1]The authors thank Degussa, Inc. of Kennesaw, GA for partial funding of this experiment.

Table 1. Basal Diet Amino Acid Analysis

Item, %	Total	Apparent Digestible
Lysine	.58	.50
Threonine	.41	.33
L-methionine[a]	.14	.13
Methionine + Cystine	.26	.23
Tryptophan	.12	.10
Valine	.60	.49
Isoleucine	.36	.30

Table 2. Basal Diet Composition[a]

Ingredient	Percent
Grain sorghum	64.64
Cornstarch	18.16
Sucrose	2.50
Soybean meal, 46.5% CP	3.00
Soybean oil	5.00
Blood meal	2.00
Monocalcium phosphate	1.64
Limestone	.82
Salt	.35
Choline chloride	.04
Vitamin premix	.25
Trace mineral premix	.15
L-methionine	.002
L-threonine	.111
L-lysine HCl	.202

Each pen (5 ft × 5 ft slatted pens) contained two pigs and they were allowed ad libitum access to both feed and water from a single-hole dry feeder and one nipple waterer per pen. Pigs were housed in an environmentally controlled building with a constant temperature of 70° F, and manure was removed daily via mechanical pit scrapers. Pigs and feeders were weighed and pigs were scanned ultrasonically on d 0, d 18, and d 36 to measure growth performance and determine calculated body composition.

All data were analyzed as a randomized complete block design with pen as experimental unit. The data analysis was performed using general linear model procedures. Polynomial regression was used to determine linear and quadratic effects of TSAA concentration on pig performance.

Results and Discussion

From d 0 to 36, increasing TSAA concentrations tended to decrease ADG (linear, $P<.06$) and worsen F/G ($P<.03$). No effect was observed for ADFI or carcass composition during any growth period. However, gilts fed .285% TSAA (50% of lysine) had the best ADG and F/G.

These results indicate that the requirement for TSAA relative to lysine has been overestimated. Previous research with high-lean finishing gilts (1994 KSU Swine Day Report of Progress) indicated that optimal growth performance and carcass characteristics were achieved when methionine was less than 22% of apparent digestible lysine. Although that is lower than the current University of Illinois ideal amino acid pattern for TSAAs, it agrees with our current research, assuming that methionine constitutes 45% of the TSAA requirement. Methionine then is estimated to be 23% of lysine, and the excess methionine is converted to cystine. Therefore, based upon the results of this experiment, the dietary TSAA requirement for optimal growth performance and carcass characteristics is no greater than .285% (.25% apparent digestible TSAA), which is approximately 50% TSAA relative to apparent digestible lysine.

Table 3. Effects of Total Sulfur Amino Acid Concentration upon Finishing Pig Growth Performance and Carcass Characteristics[a]

	Apparent Digestible TSAA, %[b]						Probability *P*<	
Item,	.225%	.25%	.275%	.30%	.325%	CV	Linear	Quadratic
d 0 to 36								
ADG, lb	1.76	1.97	1.67	1.68	1.63	15.03	.06	.55
ADFI, lb	5.47	5.70	5.29	5.39	5.34	10.20	.37	.97
F/G	3.12	2.92	3.18	3.34	3.29	9.53	.03	.65
10th rib BF, in.	.94	.98	.94	.92	.96	15.07	.93	.95
LMA, in^2	5.73	5.63	5.89	5.49	6.03	9.44	.48	.40
% Lean	51.01	50.34	51.51	50.50	51.73	4.84	.57	.62

[a]A total of 80 gilts (PIC 326 × C-22; initial weight 163 lb.) were used in a randomized complete block design.
[b]L-methionine was used to create TSAA levels of 45, 50, 55, 60, and 65% of apparent digestible lysine.

DIETARY METHIONINE REQUIREMENT FOR OPTIMAL GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS IN FINISHING GILTS [1]

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Summary

In Exp. 1, increasing dietary methionine from .12 to .22% (.10 to .20% apparent digestible methionine) in diets containing excess cystine had no effect on ADG, ADFI, 10th rib fat depth, and longissimus muscle area in finishing gilts from 130 to 190 lb. However, increasing dietary methionine tended to linearly improve feed efficiency. In Exp. 2, increasing dietary methionine from .11 to .17% (.10 to .15% apparent digestible methionine) in diets containing excess cystine resulted in linear improvements in ADG, ADFI, and F/G in finishing gilts from 160 to 230 lb. Quadratic improvements were observed for F/G. No effect was seen on 10th rib fat depth. These data suggest that finishing gilts fed .58% total lysine (.50% apparent digestible lysine) require approximately .14% (3.3 g/d) total methionine or .125 %, (2.9 g/d) apparent digestible methionine.

(Key Words: Growth, Methionine, Finishing Pigs.)

Introduction

Amino acid requirements of high-lean growth potential pigs has received considerable attention recently because of their increased protein accretion potential. With an increased dietary lysine requirement for the high-lean growth gilt, the potential exists for adjusting other amino acid requirements. High health status, coupled with better nutritional and environmental management in the early finishing period, also can affect the nutritional needs of market pigs.

Methionine generally is considered to be the third or fourth limiting amino acid in typical corn- or milo-soybean meal diets. University of Illinois recommendations indicate that the finishing pig's methionine requirement should be 30% of lysine, with a total sulfur amino acid requirement at 65% of lysine. However, research reported in the previous article (p. 133) indicates that the total sulfur amino acid requirement of the finishing pig is no greater that 50% of lysine. With this lower estimate, the methionine requirement of finishing pigs may be different than previously estimated. Therefore, the objective of these experiments was to determine the methionine requirement of finishing gilts fed diets containing adequate cystine.

Procedures

Experiment 1. Eighty gilts (PIC 326 × C-22; initially 136 lb) were used in a 24-d growth trial to determine the effects of increasing dietary methionine on growth performance and carcass traits. All gilts were fed a corn-soybean meal grower diet from 50 to 130 lb that was formulated to exceed all current nutrient recommendations. The gilts then were allotted randomly by initial weight to one of five dietary treatments in a randomized complete block design. Experimental diets consisted of: .116%, .141%, .166%, .191%, and .216% total methionine (0.1%, 0.125%, 0.15%, 0.175%, and 0.2% apparent digestible methionine). Cystine was maintained at levels exceeding the amount of methionine in each

[1]The authors thank Degussa, Inc. of Kennesaw, GA and Extru-tech, Inc. of Sabetha, KS for partial funding of these experiments and supplying the extruded starch used in Exp. 1.

diet. To ensure that methionine was the only limiting amino acid, all others were maintained at or above ratios relative to lysine as suggested by the University of Illinois (Table 1). Extruded cornstarch was the major ingredient, and methionine was substituted for equal amounts of cornstarch to make the dietary treatments. Soybean meal (17.86%), soybean oil (5%), glutamate (1%), and choline chloride 60% (0.15%) were identical among treatments, and calcium and phosphorus were 0.65% and 0.55%, respectively (Table 2).

Table 1. Basal Diet Amino Acid Composition (Exp. 1)

Item, %	Total	App. Dig.	Analyzed Total
Lysine	.60	.50	.53
Threonine	.42	.35	.37
Methionine[a]	.12	.10	.12
Cystine	.18	.15	.18
Methionine + Cystine	.30	.25	.30
Tryptophan	.14	.11	.13
Valine	.41	.36	.38

Table 2. Basal Diet Composition (Exp. 1)

Ingredient	Percent
Extruded corn starch	72.58
Soybean meal, 46.5% CP	17.86
Soybean oil	5.00
Monocalcium phosphate	2.07
Limestone	.58
Salt	.35
Trace mineral premix	.15
Vitamin premix	.25
Choline chloride	.15
L-lysine HCl	.054
L-threonine	.082
L-tryptophan	.028
L-cysteine	.050
DL-methionine[b]	--
L-glutamate	1.00
Medication[c]	.125
Total	100.00

[a]Diets were formulated to contain .65% Ca and .55% P.

Pigs were housed two per pen (5 ft × 5 ft with slatted flooring). They were allowed ad libitum access to both feed and water from a single-hole dry bulk feeder and one nipple waterer per pen. They were enclosed in an environmentally controlled building with a constant temperature of 70°F, and manure was removed daily via mechanical pit scrapers. Pigs and feeders were weighed on d 0 and 24 to calculate ADG, ADFI, and F/G. Each pig was scanned ultrasonically both on day 0 and at day 24 by a certified technician to estimate 10th rib fat depth and longissimus muscle area.

Experiment 2. A total of 105 gilts (PIC 326 × C-22; initial weight 159 lb) was used in a 34-d growth trial to determine the effects of increasing dietary methionine on growth performance and carcass characteristics. All gilts

were fed a corn-soybean meal grower diet from 50 to 160 lb that was formulated to exceed all current nutrient recommendations. Gilts were blocked by weight and randomly assigned by initial weight to one of three dietary treatments in a randomized complete block design. Experimental diets consisted of .11, .14, and .17% total methionine (.10, .125, and .15% apparent digestible methionine). Experimental treatments were created by substituting increasing levels of L-methionine for equal parts of cornstarch. Cystine was maintained at 130% of the highest methionine treatment to ensure that methionine was the only limiting sulfur amino acid. All others were maintained at or above ratios relative to lysine as suggested by the University of Illinois (Table 3). Soybean meal (3%), sucrose (10%), soybean oil (5%), glutamate (1%), and choline chloride 60% (.14%) were identical among treatments, and calcium and phosphorus were .65% and .55%, respectively. Grain sorghum, cornstarch, and L-methionine levels varied as dietary methionine levels increased (Table 4).

Table 3. Basal Diet Amino Acid Composition[a] (Exp. 2)

Item, %	Total	Apparent Digestible
Lysine	.56	.50
Threonine	.40	.33
Methionine	.11	.10
Cystine	.22	.20
Methionine + Cystine	.33	.30
Tryptophan	.12	.10
Valine	.51	.45
Isoleucine	.34	.30

[a]Experimental treatments were made by substituting

Table 4. Basal Diet Composition[a] (Exp. 2)

Ingredient	Percent
Grain sorghum	48.31
Cornstarch	26.53
Sucrose	10.00
Soybean meal, 46.5% CP	3.00
Soybean oil	5.00
Blood meal	2.00
Monocalcium phosphate	1.86
Limestone	.73
Salt	.35
Choline chloride	.14
Vitamin premix	.25
Trace mineral premix	.15
L-methionine	--
L-cysteine	.118
L-threonine	.139
L-lysine HCl	.229

Pigs were housed in a modified open-front building with natural and mechanical ventilation. Drip coolers were activated when ambient temperatures exceeded 80°F. Each pen measured 6 × 16 ft with 50% solid and 50% slatted flooring. Each pen contained a two-hole dry feeder and a single nipple waterer allowing ad libitum access to feed and water. Pig and feeder weights were recorded on d 0, 19, and 34 to calculate ADG, ADFI, and F/G. On d 34 three pigs were selected randomly from each pen and was scanned ultrasonically at the last lumbar position to determine 10th rib fat depth.

All data were analyzed as a randomized complete block design with pen as the experimental unit, using general linear model procedures. Orthogonal contrasts were used to determine linear and quadratic effects of dietary methionine level on pig performance.

Results and Discussion

Experiment 1. From 130 to 190 lb, increasing methionine levels above .12% (.10% apparent digestible methionine) had no effect ($P>.05$) upon any of the growth performance and carcass characteristics measured, but F/G tended to improve with increasing methionine levels (linear, $P<.07$; Table 5). No linear or quadratic effects ($P>.05$) were noted for ADG, ADFI, 10th rib fat depth, and longissimus muscle area (LMA) as a result of increasing dietary methionine.

Experiment 2. From 160 to 225 lb, increasing dietary methionine from .11 to .17% (.10 to .15% apparent digestible methionine) linearly improved ADG, ADFI, and F/G (linear, $P<.001$, .01, .003, respectively; Table 6). A tendency for a quadratic effect was observed for ADG ($P<.12$). No effect was observed for 10th rib fat depth ($P<.68$). Feed efficiency also was improved quadratically ($P<.02$) with increasing total methionine up to .14% (.125% apparent digestible methionine).

The results of these experiments are consistent with results presented in the previous article (p. 133) indicating that the total dietary requirement of total sulfur amino acids for finishing gilts is .285% (.25% apparent digestible; approximately 50% of lysine). Approximately half of the total sulfur amino acid requirement is met by methionine, which suggests that the requirement should be approximately .13% total methionine (.125% apparent digestible). Additionally, in the 1994 KSU Swine Day Report of Progress, researchers indicated that the methionine requirement was less than .25% apparent digestible methionine (25% of lysine). However, those diets were formulated with a high level of lysine and an attempt was made to maintain a constant lysine:methionine ratio between treatments, resulting in over-supplementation of dietary methionine. In our current trial, more focus was placed on dietary methionine levels with secondary emphasis on a constant lysine: methionine ratio. This experiment also indicates that recommendations based upon the ideal amino acid pattern suggested by the University of Illinois tend to overestimate the methionine requirement of finishing pigs. Our results indicate that the methionine requirement in diets containing adequate cystine for finishing pigs is .14 % or 3.3 g/d total methionine (.125 % or 2.9 g/d apparent digestible methionine).

Table 5. Effects of Dietary Methionine on Early Finishing Pig Performance[a] (Exp. 1)

	Apparent Digestible Methionine, %						Probability (*P*<)	
Item,	.10	.125	.15	.175	.20	CV	Linear	Quadratic
Overall								
ADG, lb	2.29	2.36	2.37	2.27	2.51	8.90	.16	.45
ADFI, lb	7.50	7.38	7.50	7.00	7.40	11.59	.56	.72
F/G	3.29	3.14	3.17	3.09	2.98	10.03	.07	.91
PUN, mg/dl	5.56	6.21	4.79	5.63	5.76	23.5	.90	.49
10th rib BF	.75	.77	.73	.72	.76	13.05	.86	.58
LMA, in^2	4.93	5.17	4.67	4.97	4.54	10.68	.11	.42

[a]Eighty gilts (PIC 326 × C-22; initial weight 136 lb) were used in a randomized complete block design with two gilts/pen and eight replications per treatment.

Table 6. Influence of Dietary Methionine on Finishing Pig Growth Performance[a] (Exp. 2)

	Apparent Digestible Methionine, %				Probability (*P*<)	
Item,	.10	.125	.15	CV	Linear	Quadratic
d 0 to 34						
ADG, lb	1.69	1.93	1.98	5.02	.001	.12
ADFI, lb	4.93	5.31	5.47	5.07	.01	.48
F/G	2.93	2.76	2.77	2.04	.003	.02
10th rib fat depth, in	.84	.88	.80	10.68	.68	.30
Lysine, g/d	12.53	13.50	13.92	5.07	.01	.48
Methionine, g/d	2.53	3.33	4.05	4.71	.0001	.68

[a]A total of 105 gilts (PIC 326 × C-22; initial weight 159 lb) was arranged in a randomized complete block with seven pigs/pen and five replications per treatment.

USE OF SORGHUM-BASED DISTILLERS GRAINS IN DIETS FOR NURSERY AND FINISHING PIGS

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Summary

Two experiments were conducted to determine the effects of sorghum-based distillers dried grains with solubles in isocaloric diets for nursery and finishing pigs. Rate and efficiency of gain in nursery pigs were decreased with 45% or more distillers grains. For finishing pigs, efficiency of gain was improved as distillers grains was increased to 60% of the diet, and carcass fatness was increased by about .1 inch at the highest concentration.

(Key Words: Distillers Grains, Nursery Pigs, Finishing, Sorghum.)

Introduction

Distillers dried grains with solubles (DDGS) are a co-product of the ethanol industry. When grain is fermented to produce ethanol, primarily the starch is utilized, leaving a protein rich residue that can be used in animal diets. As the ethanol industry grows, greater quantities of DDGS will become available for use in pig diets at potentially reasonable prices.

In a previous study (see the 1995 KSU Swine Day Report), we demonstrated that as much as 30% sorghum-based DDGS could be added to isocaloric nursery and finishing pig diets without adverse effects on growth performance. Thus, we designed the experiments reported herein to determine the effects of adding as much as 60% DDGS to pig diets.

Procedures

A total of 180 nursery pigs (average initial wt of 13 lb) was blocked by weight and used in the first experiment. Each treatment had six pigs per pen and six pens (three pens of barrows and three pens of gilts per treatment). For 7 d postweaning, all pigs were fed the same complex starter diet (pelleted form) to allow for adjustment to the nursery environment. On d 7, the pigs were changed to a corn-soybean meal-based control diet or diets with 15, 30, 45, or 60% DDGS. All diets were formulated to 1.4% lysine, .9% Ca, and .8% P (Table 1) and fed in meal form for 21 d. The ME in all diets was adjusted to the same concentration by adding tallow.

The experiment was conducted in an environmentally controlled nursery room equipped with 4-ft x 5-ft pens. Each pen had a self-feeder and nipple waterer to provide ad libitum access to feed and water. Pigs and feeders were weighed at initiation and d 21 of the growth assay to determine ADG, ADFI, and F/G. The data were analyzed as a randomized complete block design with average pig weight at d 7 used as a covariable. Polynomial regression was used to characterize the shape of the response to concentration of DDGS in the diets.

In the second experiment, 80 barrows (average initial wt of 120 lb) were used in a 56-d experiment. The pigs were allotted by weight into 40 totally slatted pens (4-ft x 4-ft) with two pigs per pen and 10 pens per treatment. Treatments were a corn-soybean meal-based control and 20, 40, and 60% DDGS

(Table 2). The diets were fed in three phases with 1.25, 1.10, and .80 % lysine for 120 to 160 lb, 160 to 220 lb, and 220 lb to market weight, respectively. Pigs were allowed ad libitum access to feed and water, and diets were fed in meal form with tallow used to equalize ME.

Weights were taken at d 0 and 56 of the experiment to determine ADG, ADFI, and F/G. When weight in the first pen of a block averaged 250 lb, the pigs were slaughtered to determine last rib backfat thickness and hot carcass weight. Dressing percentage was calculated with hot carcass weight as a percentage of preshipping live weight, and fat-free lean index was calculated using NPPC equations. The data were analyzed as a randomized complete block design with initial weight as the blocking criterion. Slaughter weight was used as a covariate for analysis of the carcass data. Polynomial regression was used to characterize the shape of the response to concentration of DDGS in the diets.

Results and Discussion

Chemical analysis of ingredients (Table 3) indicated that the compositions of corn and sorghum were similar to one another and to values published for swine by the NRC (1988). However, fermentation (to ethanol) greatly concentrates the nonstarch components of the seed (e.g., protein, fat, fiber, ash, and amino acids). Thus, we would anticipate lower metabolizable energy in DDGS (from less starch) despite their high gross energy (i.e., 2.01 Mcal/lb for DDGS versus 1.86 and 1.81 Mcal/lb for the sorghum and corn, respectively).

In the nursery experiment (Table 4), ADG was not affected and F/G was actually improved by as much as 30% DDGS (quadratic effect, $P<.03$). However, with 45 and 60% DDGS, rate and efficiency of gain were decreased . It is important to note that diets with 45 and 60% DDGS had 11 and 15% tallow, respectively, which made feed flowability a problem. Thus, whether the decreased growth performance was caused by feed restriction resulting from continual bridging in the feeders (highly likely), palatability problems (possibly), or reduced nutritional value of the diets (least likely) is not clear.

In the finishing experiment (Table 5), ADG increased slightly (quadratic effect, $P<.01$). ADFI decreased (linear effect, $P<.003$) and F/G was improved (linear effect, $P<.001$) as the concentration of DDGS was increased. However, hot carcass weight (linear effect, $P<.05$), dressing percentage (linear effect, $P<.008$), and backfat thickness (linear effect, $P<.02$) increased as percentage DDGS was increased. These data (decreased feed intake, greater efficiency of gain, and fatter carcasses) suggest that energy content of the diets increased as percentage DDGS was increased. This most likely resulted from underestimation of the energy value of the tallow, DDGS, or both in this experiment.

In conclusion, DDGS can be used in greater concentrations than previously suggested for pigs, if energy content of diets is adjusted with added fat. Nutritionists should let ingredient prices and availability determine use of as much as 30% DDGS in diets for nursery pigs and 60% DDGS in diets for finishing pigs.

Table 1. Diet Composition for the Nursery Experiment[a]

		Dried Distillers Grains with Solubles, %			
Ingredient, %	Control	15	30	45	60
Corn	49.06	36.43	24.00	11.57	---
Soybean meal (46.5 % CP)	29.61	23.46	16.99	10.50	2.99
Dried whey	15.00	15.00	15.00	15.00	15.00
Dried distillers grains	---	15.00	30.00	45.00	60.00
Lysine·HCl	.15	.30	.46	.63	.83
Methionine	.06	.05	.05	.04	.04
Threonine	---	.01	.04	.07	.12
Tryptophan	---	---	.02	.05	.09
Fish meal	2.00	2.00	2.00	2.00	2.00
Tallow	---	3.69	7.44	11.20	15.03
Monocalcium phosphate	1.44	1.32	1.21	1.10	1.02
Limestone	.83	.89	.94	.99	1.03
Vitamin premix	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15
Salt	.20	.20	.20	.20	.20
Zinc oxide	.25	.25	.25	.25	.25
Antibiotic[b]	1.00	1.00	1.00	1.00	1.00

[a]Diets were formulated to 1.4 % lysine, .9 % Ca, .8 % P, and 1.46 Mcal ME/lb of diet.
[b]Supplied 50 g/ton of mecadox.

Table 2. Diet Composition for the Finishing Experiment[a]

		Dried Distillers Grains with Solubles %		
Ingredient, %	Control	20	40	60
Corn	78.55	63.05	48.05	26.30
Soybean meal 46.5 % CP	18.75	10.48	1.62	.13
Dried distillers grains	---	20.00	40.00	60.00
Lysine·HCl	.02	.22	.39	.45
Tryptophan	---	---	.03	.04
Tallow	---	3.68	7.42	10.81
Monocalcium phosphate	1.00	.83	.67	.38
Limestone	1.00	1.06	1.14	1.21
Salt	.30	.30	.30	.30
Vitamin premix	.20	.20	.20	.20
Trace mineral premix	.10	.10	.10	.10
Antibiotic [b]	.08	.08	.08	.08

[a]Diets were formulated to 1.25 % lysine, .75 % Ca, .65 % P, and 1.48 Mcal ME/lb for 120 to 160 lb, 1.10 % lysine, .75 % Ca, .65 % P, and 1.49 Mcal ME/lb for 160 to 220 lb, and .80 % lysine, .65 % Ca, .55 % P, and 1.51 Mcal ME/lb for 220 to 250 lb.
[b]Supplied 65 g/ton of tylosin.

Table 3. Composition of Corn, Sorghum, and Sorghum-Based Distillers Dried Grains with Solubles[a]

Ingredient	Corn	Sorghum	DDGS
DM, %	91.9	91.9	89.8
CP, %	7.3	8.7	22.7
Ether extract, %	3.6	2.7	7.2
Crude fiber, %	2.9	2.3	8.6
Ash, %	1.2	1.2	4.0
GE, Mcal/lb	1.6	1.6	1.8
ME, Mcal/lb	1.55[b]	1.49[b]	1.18[c]
Amino acids, %			
Arginine	.38	.29	.84
Histidine	.24	.19	.50
Isoleucine	.27	.31	.84
Leucine	.89	.95	2.16
Lysine	.26	.21	.52
Methionine + cystine	.38	.31	.87
Phenylalanine + tyrosine	.60	.62	1.67
Threonine	.25	.24	.73
Tryptophan	.05	.07	.18
Valine	.37	.40	1.08

[a]As fed basis.
[b]From NRC (1988).
[c]Determined in our laboratory via chick bioassays.

Table 4. Effects of Sorghum-Based Dried Distillers Grains with Solubles on Growth Performance of Nursery Pigs[ab]

		Dried Distillers Grains with Solubles, %					Contrasts		
Item	Control	15	30	45	60	CV	Linear	Quadratic	Cubic
ADG, lb	1.07	1.10	1.02	.88	.71	5.7	.001	.001	--[c]
ADFI, lb	1.72	1.62	1.43	1.42	1.28	13.8	.001	--	--
F/G	1.61	1.47	1.39	1.63	1.81	17.9	--	.03	--

[a]A total of 180 weanling pigs (six pigs per pen and six pens per treatment) with an avg initial wt of 13 lb.
[b]The experimental diets were fed from d 7 to 28 of the nursery phase (i.e., a 21 d experiment).
[c]Dashes indicate *P*>.15.

Table 5. Effects of Sorghum-Based Dried Distillers Grains with Solubles on Growth Performance and Carcass Characteristics of Finishing Pigs[ab]

		Dried Distillers Grains with Solubles, %				Contrasts		
Item	Control	20	40	60	CV	Linear	Quadratic	Cubic
ADG, lb	2.09	2.22	2.22	2.19	6.8	--[c]	.10	--
ADFI, lb	6.97	6.75	6.66	6.38	6.2	.003	--	--
F/G	3.34	3.04	3.00	2.91	5.6	.001	.06	--
HCW[d], lb.	169	174	175	175	3.6	.05	--	--
LRBF[e], in	.85	.98	.90	.98	10.2	.02	--	.007
Dressing %	71.1	70.8	71.4	71.9	1.0	.008	--	--
FFLI[f], %	49.0	48.1	48.8	48.0	1.4	.02	--	.003

[a]A total of 80 barrows (two pigs per pen and 10 pens per treatment) with an avg initial wt of 120 lb and avg final wt of 246 lb.
[b]The experimental diets were fed for 56 d.
[c]Dashes indicate *P*>.15.
[d]Hot carcass weight.
[e]Last rib backfat.
[f]Fat-free lean index.

INFLUENCE OF PELLET SIZE ON GROWTH PERFORMANCE IN NURSERY PIGS AND GROWTH PERFORMANCE, NUTRIENT DIGESTIBILITY, AND STOMACH MORPHOLOGY IN FINISHING PIGS

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Summary

Pellet size (i.e., 3/32 in., 5/32 in., 5/16 in., and 1/2 in. diameter) had little effect on growth performance during the early stages (d 0 to 5) of the nursery phase. However, the 5/32 in. diameter pellets supported the best efficiencies of gain during the overall nursery (d 0 to 29) and finishing phases.

(Key Words: Nursery Pigs, Finishing Pigs, Pellet Size, Growth.)

Introduction

Nutritionists and feed manufacturers have suggested that pigs need various pellet sizes as age and weight increase. However, the very few experiments designed to evaluate the effects of pellet size show little consensus about its effects. From a feed manufacturer's perspective, having multiple dies is expensive. Also, constant changing of dies takes time and labor, and the smaller the die openings, the lower the production rate.

Thus, we designed two experiments to determine the effects of pellet size (diameter) on growth performance in nursery pigs and growth performance, nutrient digestibility, carcass measurements, and stomach morphology in finishing pigs.

Procedures

A total of 210 weanling pigs (initial wt of 11.8 lb) was sorted by sex and ancestry and blocked by weight to pens. Each treatment had seven pigs per pen (4 ft × 5 ft) and six pens. The experimental diets (Table 1) were fed in three phases (d 0 to 5, 5 to 15, and 15 to 29). Treatments were a meal control and 3/32 in., 5/32 in., 5/16 in., and 1/2 in. pellets. The pigs were housed in an environmentally controlled nursery room with ad libitum access to feed and water. Pigs and feeders were weighed on d 0, 5, 15, and 29 to allow calculation of ADG, ADFI, and F/G.

All data were analyzed as a randomized complete block design with pen as the experimental unit. Polynomial regression was used to characterize the shape of the response to pellet size.

In the second experiment, 80 barrows (average initial wt of 127 lb) were sorted by ancestry, blocked by weight, and allocated to pens (5 ft × 5 ft). Each treatment had two pigs per pen and eight pens. Treatments were the same used in the nursery experiment. Pigs were fed the experimental diets (Table 1) in two phases (from 127 to 194 lb and from 194 lb to slaughter wt).

The pigs were housed in an environmentally controlled finishing facility and allowed ad libitum access to feed and water. The pigs and feeders were weighed at initiation, midpoint, and conclusion of the growth assay to allow calculation of ADG, ADFI, and F/G. When the pigs in the heaviest pen of a weight block averaged 260 lb, the entire block was slaughtered at a commercial packing plant. Hot carcass weight and last rib backfat thickness were recorded immediately after slaughter. In addition to standard carcass measurements, stomachs were collected and scored for severity of keratiniza-

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tion and ulceration.. The scoring system for keratinization was: 0 = normal; 1 = mild keratosis; 2 = moderate keratosis; and 3 = severe keratosis. The scoring system for ulcers was: 0 = normal; 1 = slight erosions; 2 = ulcers; and 3 = severe ulcers

Carcass measurements were adjusted with final weight as a covariate. All data were analyzed as a randomized complete block design with pen as the experimental unit. Polynomial regression was used to characterize the response to pellet size.

Results and Discussion

For d 0 to 5 of the nursery experiment (Table 2), pigs fed pellets had 27% greater ADG ($P<.04$) and 29% better F/G ($P<.001$) than those fed the meal control. However, pellet size did not affect rate ($P>.41$) or efficiency ($P>.20$) of gain. For d 0 to 15, pelleting improved F/G by 13% ($P<.004$). There was a trend for improved F/G (cubic effect; $P<.09$) as pellet size was increased from 3/32 in. to 5/32 in., but, F/G worsened as pellet size was increased beyond 5/32 in. For the overall period d 0 to 29, pelleting improved ($P<.03$) efficiency of gain by 3%. As pellet size was increased from 3/32 in. to 5/32 in. the pigs consumed less fed and had better F/G (1.43 vs 1.39). However, as pellet size was increased further (beyond 5/32 in.) feed consumption tended to increase ($P<.08$) and F/G worsened (cubic effect; $P<.04$).

For the finishing experiment (Table 3), pigs fed pellets had 4% better F/G ($P<.08$) than those pigs fed the meal diets. As pellet size was increased from 3/32 in. to 1/2 in., pigs gained weight faster ($P<.004$), consumed more feed ($P<.001$), and tended ($P<.07$) to have poorer F/G. Dressing percentage and last rib fat depth were not influenced ($P>.47$) by dietary treatments.

Digestibility of DM and N were increased ($P<.001$) by 5 and 9%, respectively, by feeding pellets vs a meal diet. However, no differences ($P>.22$) occurred in digestibility of DM or N among the pellet size treatments.

Stomach keratinization tended ($P<.08$) to be lower and stomach ulceration was lower ($P<.003$) for pigs fed the meal diets as compared to the pelleted diets. As pellet size was increased from 3/32 in. to 1/2 in., severity of ulceration decreased ($P<.04$). However, it is important to note that all scores for keratosis and ulcers were low (i.e., mild to slight categories).

In conclusion, these data suggest that pellet size had little effect on growth performance during the early nursery stage. However, pigs fed the 5/32 in. pellets had the best efficiencies of gain in both the overall nursery and finishing phases.

Table 1. Composition of Diets

	Nursery Experiment			Finishing Experiment	
Ingredient, %	d 0 to 5[a]	d 5 to 15[b]	d 15 to 29[c]	127 to 194 lb[d]	194 lb to market[e]
Corn	28.37	43.59	59.15	78.52	83.91
Soybean meal	24.95	27.67	33.48	17.79	12.34
Soybean oil	2.00	2.00	3.00	1.00	1.00
Monocalcium phosphate	1.83	1.62	1.51	1.02	.88
Limestone	.65	.73	.90	.92	.92
Salt	.10	.20	.30	.30	.30
Lysine-HCl	.25	.15	.15	.15	.15
Whey powder	20.00	20.00	--	--	--
Lactose	10.00	--	--	--	--
Porcine plasma protein	4.00	--	--	--	--
Wheat gluten	4.00	--	--	--	--
Blood meal	2.00	2.00	--	--	--
Vit/Min/AA/Ab [f]	1.85	1.84	1.51	.30	.30
Chromic oxide [g]	--	--	--	--	.20
Total	100.00	100.00	100.00	100.00	100.00

[a]Formulated to 1.7% lysine, .9 % Ca, .8 % P , and 1.49 Mcal of ME/lb.
[b]Formulated to 1.45% lysine, .9 % Ca, .8 % P , and 1.49 Mcal of ME/lb.
[c]Formulated to 1.3% lysine, .8 % Ca, .7 % P , and 1.56 Mcal of ME/lb.
[d]Formulated to .85 % lysine, .65 % Ca, .55 % P , and 1.52 Mcal of ME/lb.
[e]Formulated to .7 % lysine, .6 % Ca, .5 % P , and 1.52 Mcal of ME/lb.
[f]Provided 150 g/ton of apramycin for d 0 to 15, 50 g/ton of carbadox for d 15 to 29, and 40 g/ton of tylosin for the finishing experiment.
[g]Used as an indigestible marker .

Table 2. Effects of Pellet Size on Gr owth Performance in Nursery Pigs [a]

		Pellet Diameter , in					Probability , *P*<			
Item	Meal	3/32	5/32	5/16	1/2	CV	M vs P	Lin	Quad	Cub
d 0 to 5										
ADG, lb	.27	.33	.33	.36	.35	20.5	.04	-[b]	-	-
ADFI, lb	.34	.29	.29	.36	.31	19.1	-	-	-	-
F/G	1.26	.88	.88	1.00	.89	14.3	.001	-	-	-
d 0 to 15										
ADG, lb	.57	.61	.62	.58	.59	10.1	-	-	-	-
ADFI, lb	.84	.75	.75	.81	.78	6.7	.01	.14	-	.10
F/G	1.48	1.23	1.21	1.40	1.32	9.9	.004	.10	-	.09
d 0 to 29										
ADG, lb	.79	.80	.82	.80	.80	5.0	-	-	-	-
ADFI, lb	1.18	1.12	1.14	1.19	1.17	5.0	-	.08	-	-
F/G	1.49	1.43	1.39	1.49	1.46	4.2	.03	.05	-	.04

[a]A total of 210 weanling pigs (seven pigs per pen and six pe ns per treatment) with an avg initial wt of 1 1.8 lb.

[b]Dashes indicate *P*>.15.

Table 3. Effects of Pellet Size on Growth Performance, Nutrient Digestibility, Carcass Characteristics, and Stomach Morphology in Finishing Pigs[a]

		Pellet Diameter, in					Probability, *P*<			
Item	Meal	3/32	5/32	5/16	1/2	CV	M vs P	Lin	Quad	Cub
ADG, lb	2.27	2.08	2.22	2.24	2.30	6.2	-[b]	.004	-	-
ADFI, lb	6.64	5.76	6.09	6.29	6.72	6.8	.02	.001	-	-
F/G	2.93	2.78	2.74	2.81	2.91	5.6	.08	.07	-	-
Dressing percentage	72.4	72.4	72.5	72.5	72.1	1.3	-	-	-	-
LRFD, in	.97	.91	.91	.93	.92	11.6	-	-	-	-
Apparent digestibility (d 38), %										
DM	85.0	89.5	89.7	90.1	89.3	1.7	.001	-	-	-
N	78.8	85.0	85.7	87.1	85.0	3.8	.001	-	-	-
Stomach keratinization										
Total observations	16	16	15	16	16					
Normal	5	1	2	3	3					
Mild	6	6	7	4	8					
Moderate	4	9	4	7	3					
Severe	1	0	2	2	2					
Mean score[e]	1.22	1.75	1.60	1.69	1.50	49.5	.08	-	-	-
Stomach ulceration										
Total observations	16	16	15	16	16					
Normal	14	6	5	8	11					
Erosions	2	4	6	2	4					
Ulcerations	0	6	2	4	1					
Severe ulcers	0	0	2	2	0					
Mean score[f]	.19	1.19	1.10	1.09	.50	112.4	.003	.05	-	-

[a]A total of 80 barrows (two pigs per pen and eight pens per treatment) with an avg initial wt of 127 lb and an avg final wt of 248 lb.
[b]Dashes indicate *P*>.15.
[c]Scoring system was: 0 = normal; 1 = mild keratosis; 2 = moderate keratosis; and 3 = severe keratosis.
[d]Scoring system was: 0 = normal; 1 = slight erosions; 2 = ulcers; and 3 = severe ulcers.
[e]Cochran-Mantel-Haenszel statistic, row mean scores differ test was *P*>.36.
[f]Cochran-Mantel-Haenszel statistic, row mean scores differ test was *P*<.003.

Swine Day 1996

EFFECTS OF EXPANDERS (HIGH SHEAR CONDITIONING) ON GROWTH PERFORMANCE IN FINISHING PIGS

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Summary

Diets that had been processed using standard, long-term, and expander (high shear) conditioning tended to support greater ADG than an unconditioned meal control diet. Pelleting was necessary to maximize efficiency of growth, but only with standard and long-term conditioning. Indeed, the best efficiencies of gain were for pigs fed the expander processed diets, with no additional benefits from pelleting the expanded mash.

(Key Words: Expander, Pellet, Ulcers, Finishing Pigs.)

Introduction

Expansion (high shear conditioning) is a technology that is entering the U.S. from Europe and has been embraced by many U.S. poultry producers. However, little research has been conducted to determine the effects of expanding swine diets. Thus, the objective of the experiment reported herein was to compare growth performance among pigs fed diets hydrothermally processed with a standard steam conditioner, a long-term steam conditioner, and an expander.

Procedures

A total of 70 (avg initial wt of 119 lb) terminal-cross barrows (PIC line 326 boars × C15 sows) was allotted by weight and ancestry to 35 pens in an environmentally controlled building. Each treatment had two pigs per pen (5-ft by 5-ft) and five pens. The experiment was arranged in a 2 × 3 factorial plus a meal control. Main effects were feed form (mash vs pellets) and conditioner type (standard steam conditioner, long-term steam conditioner, and expander conditioner).

All diets were corn-soybean meal-based and formulated to .9 % lysine, .65 % Ca, and .55 % P. However, because of anticipated loss of vitamin stability, the expanded diets were formulated to 125% of the normal KSU vitamin additions. The diets for the standard conditioner (California Pellet Mill) were processed at a temperature of 175°F with a retention time of 10 seconds. The long-term (California Pellet Mill, two-pass) conditioner had a retention time of 2 min 40 sec and a conditioning temperature of 175°F. The expander (Amandus-Kahl, high-shear) conditioner had a cone pressure of 200 psi and a conditioning temperature of 170°F. The conditioned diets were fed as a mash or after pelleting through a 3/16 in. × 1 ½ in. die.

Each pen had a self-feeder and a nipple waterer to allow ad libitum consumption of food and water. The pigs and feeders were weighed at initiation and conclusion of the growth assay to allow calculation of ADG, ADFI, and F/G. Pigs were slaughtered, and stomachs were collected and scored for keratosis and ulceration. Response criteria were ADG, ADFI, F/G, and scores for keratosis and ulceration. All data were analyzed using the GLM procedure of SAS with pen as the experimental unit.

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Results and Discussion

A trend ($P<.07$) was observed for greater ADG in pigs fed diets that had been thermally conditioned vs the unconditioned meal control. Also, a general advantage in F/G occurred with pelleting ($P<.04$), but this advantage was pronounced only with standard conditioning (conditioned mash vs pellet × standard vs advanced conditioning interaction, $P<.02$). Indeed, the lowest F/G was observed for pigs fed the expander treatments ($P<.03$), and the expander mash was used as efficiently as the expander pellets. Finally, as is often the case with advanced feed processing technologies, the more extreme the processing technique (i.e., expander > long-term conditioner > standard conditioner > unconditioned meal), the greater the incidence and severity of stomach lesions ($P<.04$).

In conclusion, our results suggest marked improvements in efficiency of growth with pelleting after standard steam conditioning or simply feeding an expanded mash, compared to an unconditioned meal. Thus, the decision of which technology to adopt will depend on cost of processing, capital available to purchase the different equipment, and the time and degree of expertise available to operate the equipment.

Table 1. Effects of Feed Conditioning on Growth Performance in Finishing Pigs[a]

		Standard Conditioning		Long-Term Conditioning		Expander Conditioning			Contrasts[b]					
Item	Meal	Mash	Pellet	Mash	Pellet	Mash	Pellet	CV	1	2	3	4	5	6
ADG, lb	1.99	2.01	2.20	2.05	2.19	2.17	2.12	6.6	.06	.08	---[c]	---	---	.12
ADFI, lb	6.03	6.53	6.23	6.27	6.57	6.13	5.98	8.7	---	---	---	.13	---	---
F/G	3.03	3.25	2.83	3.06	3.00	2.82	2.82	6.6	---	.03	.14	.03	.01	---

[a]A total of 70 pigs (avg initial wt of 119 lb) two pigs/pen with five replications/treatment was used.
[b]Contrasts were: 1) meal vs thermal conditioning; 2) conditioned mash vs pellets; 3) standard vs advanced conditioning; 4) long-term vs expander conditioning; 5) conditioned mash vs pellet × standard vs advanced conditioning; 6) mash vs pellet × long-term vs expander conditioning.
[c]Dashes indicate $P>.15$.

Table 2. Effects of Feed Conditioning on Stomach Lesions in Finishing Pigs

		Standard Conditioning		Long-Term Conditioning		Expander Conditioning			Contrasts[a]					
Item	Meal	Mash	Pellet	Mash	Pellet	Mash	Pellet	CV	1	2	3	4	5	6
Stomach keratinization[b]														
Total observations	10	9	10	10	9	10	10							
Normal	6	3	2	4	0	0	0							
Mild	1	3	3	4	3	4	4							
Moderate	3	2	4	2	6	1	5							
Severe	0	1	1	0	0	5	1							
Mean score	.70	1.11	1.40	.80	1.73	2.10	1.70	56	.005	---[d]	---	.002	---	.008
Stomach ulcerations[c]														
Total observation	10	9	10	10	9	10	10							
Normal	10	8	7	9	6	2	5							
Mild	0	1	2	0	2	5	1							
Moderate	0	0	0	1	1	2	2							
Severe	0	0	1	0	0	1	2							
Mean score	0	.13	.50	.20	.46	1.20	1.10	160	.04	---	.08	.003	---	---

[a]Contrasts were: 1) meal vs thermal conditioning; 2) conditioned mash vs pellets; 3) standard vs advanced conditioning; 4) long-term vs expander conditioning; 5) conditioned mash vs pellet × standard vs advanced conditioning; 6) mash vs pellet × long-term vs expander conditioning.
[b]The scoring system was: 0 = normal; 1 = mild keratinization; 2 = moderate keratinization; and 3 = severe keratosis.
[c]The scoring system was: 0 = normal; 1 = erosion; 2 = ulcers; and 3 = severe ulcers.
[d]Dashes indicate $P>.15$.

SURVEY OF PORK PRODUCTS AVAILABLE TO CONSUMERS

S. Hollinger and J. A. Unruh

Summary

A survey was conducted to investigate the variety and price per pound of pork products available to consumers. The survey was conducted in the largest store of each of the three leading supermarket chains in Manhattan, KS. The 217.3 pork products per store (642 total) were categorized into fresh pork, smoked/cured pork, sausages, lunch meats, and pastry/pork combinations, which represented 7.4, 13.9, 32.5, 20.4, and 24.4% of the pork products surveyed, respectively. Retail cuts from the loin were the most numerous and highest priced in the fresh pork category. Retail cuts from the ham and belly (bacon) were the most numerous, but cuts from the loin were the highest priced in the smoked/cured pork category. Sausages included more product variety than any other category. Lunch meat, like sausages, varied greatly in percentage of pork as a meat ingredient. They had the greatest variation in price. Ham lunch meat averaged 129% more in price than the bologna and loaf varieties. Pastry/pork combination products had the highest price and constituted the second most numerous category. Pizza was the most numerous subcategory of pastry/pork combinations. Currently, consumers are able to choose from a wide variety of pork products with variations in value (price).

(Key Words: Pork, Retail, Product Variety, Price.)

Introduction

The National Pork Producers Council (NPPC) has proposed a major goal of making pork the meat of choice (edible lean basis) in the U.S. by the year 2000. To accomplish this goal, NPPC is placing emphasis on 1) improving efficiencies and reducing costs of production; 2) improving quality and consistency of the consumer product; and 3) improving consumers' understanding of the quality, safety, and nutritional benefits of today's pork.

The National Live Stock and Meat Board Market Research Group concluded in 1992 that the four factors driving the public in determining what they eat, how they eat it, where they eat it, and when they eat it are variety, convenience, health, and price. Therefore, the object of the following survey was to establish a benchmark as to the variety and price of pork products available to consumers at a local level.

Procedures

In September 1996, we surveyed all major pork products at the largest store of each of the three major supermarket chains in Manhattan, KS. For each pork product, the product name, manufacturing company, product specifications, average weight, and price were recorded. Products were divided into five major categories of fresh pork, smoked/cured pork, sausages, lunch meat, and pastry/pork combinations. Categories were subdivided further into like-product groups. Within each category and subcategory product group, the average number of products available per store, product weight, and price per lb as well as their corresponding low, high, and standard deviations were summarized.

Results and Discussion

Numerous pork products were found in each of the three Manhattan, Kansas supermarkets surveyed. The 217.3 pork products per store (642 total) had an average weight of 16.94 oz and cost $3.27 per pound.

The fresh pork category was the least numerous, had the highest average weight, the lowest price per pound, and the lowest standard deviation for price. Fresh pork has the fewest further manufacturing inputs of the categories listed. Retail cuts from the loin were the most numerous in this category and demanded the highest average price per pound. As a partial result, most loin products are merchandised fresh. Fresh pork cuts from the ham (fresh leg) and belly were sparse, indicating the popularity of adding value and further processing into ham and bacon.

The smoked/cured pork category was the second least numerous, with bacon and ham comprising 89% of this category. Average weight was similar to the fresh pork category, but was more variable as indicated by a larger standard deviation. In general, further processing increased the value of the fresh pork products. Again, retail cuts from the loin demanded the highest price per pound. Of all the products surveyed, smoked and cured loin retail cuts were the highest priced.

Sausages included more products than any other category, with smoked/processed sausages and franks comprising 67%. Smoked/processed sausages included a wide variety of selection, including popular varieties such as Italian, Polish, kielbasa, bratwurst, summer, hard salami, and pepperoni sausages. Franks had varying percentages of pork included in their formulation. In general, less expensive franks had higher percentages of chicken and turkey, whereas higher priced franks had higher percentages of pork and beef. Sausage production appears to be an effective method of increasing the value of lower-valued pork cuts and trimmings.

The lunch meat category had the lowest standard deviation for weight and highest standard deviation for price. This narrow weight range resulted from products packaged at primarily 6, 8, 12, or 16 ounces. The high variation in price resulted from varied meats and other ingredients used in their formulation. The higher quality ham lunch meats were consistently higher priced than the bologna and loaf subcategories. Similar to the sausages, the varying percentages of pork and other meat ingredients influenced price. In general, lunch meats with a higher percentage of pork meat had higher prices.

Pastry/pork combination products had the highest price per pound and constituted the second most numerous category. In recent years, food companies have focused on the development of these consumer-friendly, convenience-oriented products. Within this category, pizza products were the most numerous, but had the lowest price per pound. The pastry/pork category seems to be the most innovative and will be an area of future growth.

Pork products appear popular and are targeted toward many different consumer niches. They appeal to a diverse consumer population by having selections that focus on variety, convenience, health, and price.

Table 1. Characteristics of Pork Products Surveyed from Supermarkets in Manhattan, Ksa

	Number of Items per Store			Item Weight, oz				Item Price per lb			
Item	Mean	Low	High	Mean	SD	Low	High	Mean	SD	Low	High
Fresh pork	16.0	14	20	30.87	19.14	9.12	79.52	2.75	1.09	1.39	5.29
Ham	.7	0	1	39.84	42.54	9.76	69.92	2.69	.42	2.39	2.99
Loin	.9	6	12	25.90	16.03	9.12	58.88	3.38	1.02	1.99	5.29
Boston butt	3.0	2	4	42.65	25.63	12.96	79.52	1.82	.44	1.39	2.79
Spareribs	2.7	1	4	43.38	16.97	15.36	70.4	2.82	.53	2.19	3.50
Belly	.7	0	1	13.44	4.53	10.24	16.64	2.11	.40	1.83	2.39
Smoked/cured	30.3	16	39	30.53	30.85	3.5	152	3.38	1.63	1.14	9.57
Ham	12.3	5	16	44.80	35.26	12	152	2.98	.99	1.29	4.99
Loin	2.3	1	3	8.21	45.67	3.5	20.64	7.61	1.87	3.99	9.57
Picnic shoulder	1.0	0	2	108.96	32.42	73.6	137.28	1.32	.27	1.14	1.63
Bacon	14.7	9	20	16.73	4.16	12	32	3.18	.95	1.57	6.44
Sausage	70.7	30	100	14.77	5.25	2.5	18.72	2.84	1.27	.99	7.98
Links/patties	7.0	2	14	9.30	2.79	5.2	14	3.65	1.13	1.96	5.51
Bulk	12.3	6	18	15.49	1.61	10.4	18.72	2.64	.68	1.29	3.83
Smoked/processed	30.3	8	42	15.83	7.12	2.5	48	3.11	1.38	.99	7.68
Franks (hot dogs)	17	10	21	15.14	1.61	10	16	2.06	.84	1.13	3.99
Pate/braunschweiger	4.0	1	6	12.00	4.18	8	16	3.20	1.87	1.50	7.98
Lunch meat	44.3	26	62	10.82	4.31	2.5	16	3.44	1.81	1.07	7.26
Bologna	11.7	8	14	13.71	3.50	6	16	2.13	1.03	1.19	5.47
Ham	20.3	9	32	8.12	3.96	2.5	16	4.97	1.26	2.61	7.26
Loaf (variety)	12.3	9	16	12.54	2.64	8	16	2.17	1.06	1.07	4.38
Pastry/pork combinations	53.0	33	97	12.19	7.89	3	36	3.82	1.30	1.98	8.05
Pockets/pouches/rolls	8.0	4	15	9.64	4.68	7	31	4.18	.66	3.20	4.98
Pizza, small	13.0	3	27	8.97	2.36	3	12.5	3.42	1.32	2.20	5.44
Pizza, large >13 oz	15.3	4	32	22.38	5.87	14.9	36	2.79	.45	1.95	3.53
Breakfast combinations	12.3	5	20	6.51	3.85	3	24	4.74	.98	2.88	8.05
Lunch combinations	4.3	1	9	6.63	2.99	4.5	14.2	5.39	1.45	2.82	7.10
Other	3	2	4	24.53	7.33	14.08	33.28	1.90	1.14	.49	3.50
Total	217.3	119	318	16.94	15.76	2.5	152	3.27	1.50	.49	9.97

[a]Values were obtained from three supermarkets in September, 1996.

Swine Day 1996

EXPLAINING DIFFERENCES IN EFFICIENCY AMONG FARROW-TO-FINISH PRODUCERS

W. W. Rowland [1], M. R. Langemeier [2], B. W. Schurle [2], and A. M. Featherstone [2]

Summary

To remain competitive, hog operations will need to continue to improve production efficiency and manage costs. Kansas Farm Management Association data from 1992 to 1994 were used to measure technical, economic, and overall efficiency for 43 farrow-to-finish operations in Kansas. On average, the farms had .89 technical, .75 economic, and .67 overall efficiencies. Efficiency was related positively to the number of litters produced and pounds of pork produced per litter. Efficiency was related negatively to percentage of labor hired, feed conversion rates, and capital investment per litter. Pounds of pork produced per litter and feed conversion had the largest impacts on efficiency. Results suggest that increasing the pounds of pork produced per litter or decreasing feed conversion would have a sizable impact on technical, economic, and overall efficiency.

(Key Words: Efficiency, Profitability.)

Introduction

The U.S. swine industry has gone through some massive changes during the last 10 to 15 years. Several forces are driving structural change. The first force relates to technologies or innovations. Innovations or increases in the understanding of the biological process have made specialization more feasible. In addition to increasing production efficiency, specialization often has led to a reduction in production costs. The second force relates to economies of size. Advances in technology and management practices have increased the maximum size of operation that can be managed effectively. Other forces driving structural change include corporate organization, changing consumer preferences, and the benefits associated with vertical integration. Vertical integration may include production or marketing contracts between packers or feed companies and producers or direct ownership of production facilities by packers and feed companies. Vertical integration can be used as a means to lower transaction costs among sectors in the industry.

The objective of this study was to examine the efficiency of a sample of farrow-to-finish producers in Kansas. To remain competitive, hog operations will need to continue to improve production efficiency and manage costs. Survival in this extremely competitive industry hinges on economic efficiency. Identifying the key ingredients of economic efficiency helps producers focus on the management areas that are important to their competitive and strategic position.

Procedures

Kansas Farm Management Association data for 43 farrow-to-finish producers from 1992 to 1994 were used in this study. The efficiency analysis required data on output, inputs, and costs of production. Output was measured as total pounds of pork produced. Input cost categories included labor, utilities and fuel, veterinarian expenses, feed, capital, and miscellaneous. Labor costs included hired labor and a charge for unpaid operator labor. Capital costs included interest, repairs, depreciation,

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and machinery hired. The opportunity charges associated with owning swine facilities were included in capital costs. Input costs were converted to real 1994 dollars.

Table 1 presents the mean and standard deviations of gross income, cost, profit, and selected farm characteristics. Capital investment per litter was computed using depreciation data. The feed conversion index was computed using feed cost data for each farm and the average grain sorghum price in the district in which the farm was located. On average, the farms lost about $1.75 per cwt. during the 3-year period. Feed costs comprised about 64% of the total cost per cwt. Labor and capital costs accounted for 13 and 14% of total cost per cwt., respectively.

Technical efficiency measures the extent to which a farm uses the best available technologies. Farms not producing as much as other farms would if they had the same inputs are technically inefficient. Economic efficiency measures the extent to which a farm minimizes cost for a given level of output. A farm can be economically inefficient because of technical inefficiency or allocative inefficiency (resulting from a failure to use inputs in a cost-efficient manner). Overall efficiency represents the minimum cost of producing a given level of output using constant returns-to-scale technology. Overall inefficiency can be due to economic inefficiency or not producing at the most efficient size. A series of mathematical programs was used to measure technical, economic, and overall efficiency. Regression coefficients were used along with the means of the variables to compute elasticities. The elasticity measures provided information on the sensitivity of efficiency to specific farm characteristics. Efficiency estimates were used as the dependent variables in the regressions. Independent variables included age of operator, number of litters, percent of income from swine, pounds of pork produced, percent hired labor, feed conversion index, percent of acres devoted to feed grains, capital investment, and the debt to asset ratio.

Results and Discussion

Table 2 reports distributional information for technical, economic, and overall efficiencies. Technical efficiency ranged from .54 to 1.00. About 40% of the farms were technically efficient. Average technical efficiency for the sample of farrow-to-finish producers was .89, indicating that the output of these farms potentially could be increased by 11%, if each farm was operating in a technically efficient manner.

Economic efficiency ranged from .47 to 1.00 and averaged .75. If all of the farms had been operating on the average cost frontier, the same level of output could have been produced with 25% less cost. Only 12.4% of the farms had an economic efficiency index that was greater than .90. In contrast, over 57% of the farms had a technical efficiency index that was greater than .90. Thus, producing in a cost efficient manner was more difficult for these farms than producing in a technically efficient manner.

Overall efficiency ranged from .34 to 1.00 and averaged .67. If all of the farms had been operating at the minimum cost, the same level of output could have been produced with 33% less cost. Only one farm had overall efficiency. The minimum average cost occurred at an output of 149,355 lb or about 78 litters using the average pounds of pork produced per litter. The minimum average cost was $28.05 per cwt.

Elasticities are reported in Table 3. An asterisk indicates that the variable was significant at the 5% level in the corresponding regression. The coefficients on age of operator were not significant in any of the regressions. The percent of crop acres devoted to feed grain production variable was significant in the economic efficiency regression but not in the other two regressions. The debt to asset ratio was significant in the overall efficiency regression but not in the other two regressions. The regression coefficient on

the percent of income from swine variable was significant and negative in the technical and economic efficiency regressions. For this sample of farms, advantages were associated with engaging in multiple enterprises.

The number of litters produced, pounds of pork produced per litter, percent of labor hired, feed conversion, and capital investment were significant in all three efficiency regressions. Efficiency was related positively to the number of litters and pounds of pork produced. An increase in either of these two variables would increase efficiency. Efficiency was related negatively to the percent of labor hired, feed conversion, and capital investment. A decrease in any of these variables would increase efficiency.

Pounds of pork produced per litter and feed conversion had the largest impacts on efficiency. Each 1 percent increase in pounds of pork produced per litter would result in a .8004% increase in overall efficiency. Each 1% decrease in the feed conversion would result in an increase in overall efficiency of .6357%. Given the wide range of feed conversion and pounds of pork produced per litter exhibited by the farms in the sample, opportunities are available for many of the farms to increase technical, economic, and overall efficiencies.

Table 1. Summary Statistics for a Sample of Kansas Farrow-to-Finish Producers

Variable	Mean	Standard Deviation
Income, cost, and profit ($/cwt.)		
Gross income	41.16	5.83
Labor costs	5.61	2.42
Utilities and fuel	1.69	.88
Veterinarian expenses	.87	.65
Feed costs	27.47	5.71
Capital costs	5.88	2.71
Miscellaneous costs	1.41	1.10
Profit	-1.77	8.71
Other variables		
Percentage of income from swine production	55.60	21.38
Percentage of acres devoted to feed grain production	27.77	16.77
Ratio of hired labor costs to total labor costs (%)	18.20	25.99
Debt to asset ratio (%)	32.96	26.77
Age of operator	48.63	11.98
Number of litters	257.53	298.04
Pounds of pork produced per litter	1910.32	358.71
Capital investment per litter ($)	347.67	342.31
Feed conversion index	1.00	.23

Source: Kansas Farm Management Associations.

Table 2. Efficiency Measures for a Sample of Kansas Farrow-to-Finish Producers

Variable	Technical Efficiency	Economic Efficiency	Overall Efficiency
Summary statistics			
Mean	.89	.75	.67
Standard deviation	.12	.13	.11
Minimum	.54	.47	.34
Maximum	1.00	1.00	1.00
Distribution of measures (% of farms)			
Less than .40	0	0	.78
.40 to .50	.60	1.55	5.43
.50 to .60	2.33	9.30	17.05
.60 to .70	3.88	26.35	33.33
.70 to .80	19.38	25.58	30.23
.80 to .90	17.05	24.81	9.30
.90 to 1.00	17.05	6.98	3.10
1.00	40.31	5.43	.78

Table 3. Farm Characteristic Elasticities

Variable	Technical Efficiency	Economic Efficiency	Overall Efficiency
Age of operator	-.0235	.0022	-.0415
Number of litters	.0892*	.0938*	.0349*
Percent of income from swine	-.0854*	-.1011*	-.0301
Pounds of pork produced	.5323*	.7989*	.8004*
Percent hired labor	-.0599*	-.0459*	-.0306*
Feed conversion index	-.2710*	-.5632*	-.6357*
Percent feed grains	-.0301	-.0353*	.0137
Capital investment	-.0645*	-.0935*	-.0942*
Debt to asset ratio	-.0184	-.0195	-.0396*

Note: An asterisk indicates that the regression coefficient used to compute the elasticity was significant ($P<.05$).

EXAMINATION OF PORK MARKETING MARGINS [1]

T. C. Schroeder and J. Mintert [2]

Summary

This study analyzes recent changes observed in pork, farm-to-wholesale and wholesale-to-retail, marketing margins. Although the inflation-adjusted, farm-to-wholesale margin has declined over the last 25 years, the wholesale-to-retail margin has increased. Pork producers need to know why these trends have occurred so they better understand pork marketing margin determinants as they develop policy positions and consider vertical marketing alliances.

(Key Words: Pork Marketing Margins, Pork Price Spreads.)

Introduction

Marketing margins are among the most scrutinized measures of market performance by both meat producers and consumers. Hog producers in particular become concerned when live animal prices decline without a corresponding decline in retail pork prices. Especially distressing to producers is the fact that, when live hog supplies are at high levels, marketing margins are typically also at high levels. Thus, producers face the double burden of low live hog prices induced by large meat supplies coupled with increased marketing margins. Together, these two events reduce hog farmers' share of the retail dollar.

The purpose of this report is to examine recent changes in the pork farm-to-retail marketing margin. In particular, reasons behind changes in the pork marketing margin over time are explored and economic factors affecting the margin are examined. Results provide pork producers an improved understanding of determinants of pork marketing margins so they can make more informed policy decisions. In addition, hog producers need to understand marketing margin determinants so they will be better equipped to negotiate pricing arrangements with processors and retailers as they develop marketing alliances.

Procedures

Monthly farm, wholesale, and retail pork price and price spread data were collected over the 1970 to 1995 period. Economic factors affecting the farm-to-wholesale and wholesale-to-retail marketing margins also were collected. Factors examined were average daily hog slaughter, pork production, packing plant hourly wage rates, energy costs, measures of processor and retailer pork marketing risk, the amount of pork in cold storage, and meat packing and food store labor productivity. Regression models were estimated to quantify the impact of these economic factors on the farm-to-wholesale and wholesale-to-retail pork marketing margins.

Results and Discussion

Marketing margins are differences in prices (adjusted to equivalent processing weights) across different stages of the market channel. For example, the farm-to-retail margin for pork is a composite retail pork price (each cut's price

[1]Appreciation is extended to the National Pork Producers Council for providing financial support to conduct this study.

[2]Department of Agricultural Economics.

weighted by the proportion of the carcass it represents) minus the live hog price adjusted for the value of by-products that are not processed into retail product. Both prices are converted to retail weight equivalents so that the margin precisely measures changes in retail price relative to the price of pork at the live animal level, after adjusting for waste and by-products that do not go to the retail market.

Although margins are related to wholesale and retail profits, they are not indicators of profitability. Margins are only barometers of costs to process and market pork products. As processing costs increase or as more processing is performed on meat products, the farm-to-retail pork margin will necessarily increase. Alternatively, technology that makes processing and marketing less costly will reduce margins.

The inflation-adjusted, pork, farm-to-retail margin (1995 dollars) has declined at a gradual rate since 1976 (Figure 1). This decline was caused primarily by declining farm-to-wholesale price spreads. During the 1980 to 1995 period, inflation-adjusted pork prices at all three market levels declined, but wholesale and live prices declined more than retail prices.

Relative to retail prices, farm pork and beef prices have fallen steadily since the early 1970s. Since 1975, the farmer's share of the retail dollar declined from 65% to 49% for beef and from 59% to 34% for pork (Figure 2). This decline in share is reflective of more intensive processing of beef and pork over the time period. Given the larger percentage of highly processed pork products relative to beef at the retail counter, it is not surprising that pork producers receive a smaller percentage of the retail dollar than do beef producers.

The long-term trends of declining farm-to-wholesale margins and increasing wholesale-to-retail margins are important considerations. These trends suggest that real costs associated with slaughtering and processing pork and beef by packers declined, while food store processing and marketing costs gradually increased. This also is reinforced by examining labor productivity in both sectors. Figure 3 illustrates labor productivity (level of output per employee hour) in meat packing and in retail food stores. Over the last 25 years, meat-packing labor productivity increased at an average annual rate of 2.4%, while food-store labor productivity declined at an average annual rate of 0.8%. Meat-packing labor productivity increased primarily as a result of improved slaughtering technology. Food-store labor productivity declined primarily because of the increased services being offered by retail food stores. Although optical scanners and warehouse shelving methods increased food-store labor productivity, this was more than offset by the introduction of labor-intensive store services, such as fresh meat delis and cooked meat products. This increase in store services gives the appearance that labor productivity has declined.

Other important pork margin determinants also were identified. In particular, as the number of hogs slaughtered per day increased, pork farm-to-wholesale margins increased. This is because, as packing plants attempt to increase slaughter beyond efficient capacity levels, they do so at higher costs. These higher costs are passed directly back to producers in the form of lower live hog prices. Similarly, as total pork production (number of hogs times average processed weight) rose, the wholesale-to-retail margin also increased. Labor costs were also important margin determinants. A 1% increase in packing plant wage rates was associated with a 0.3% increase in farm-to-wholesale margins. Also, a 1% increase in pork cold storage stocks increased farm-to-wholesale margins by 0.2%. As cold storage stocks increase, processors need fewer hogs to meet retail pork demand and reduce live hog prices accordingly.

In summary, inflation-adjusted, pork, farm-to-wholesale margins declined at a gradual rate over the last 20 years. This occurred because improved processing technology allowed for substitution of capital for labor. During this same time frame, wholesale-to-retail margins increased as food stores offered more in-store services including finer meat processing and food preparation. Because of the costs associated with moving

large amounts of pork through the marketing chain, when hog numbers are high, marketing margins increase. In addition, because cold storage stocks buffer pork production declines, declines in pork marketing margins may lag behind declines in hog production.

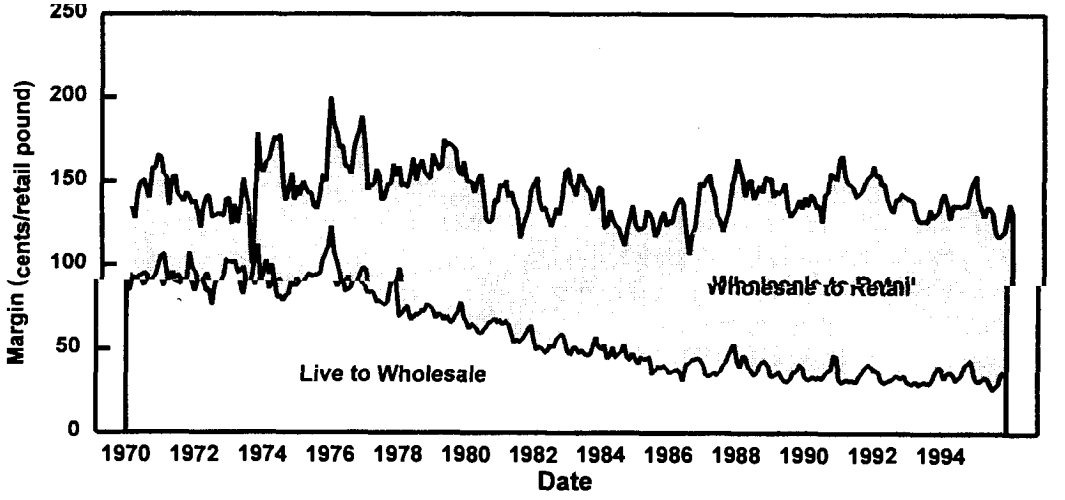

Figure 1. Pork Farm-to-Wholesale and Wholesale-to-Retail Margins in Real 1995 Dollars, Monthly 1970-1995

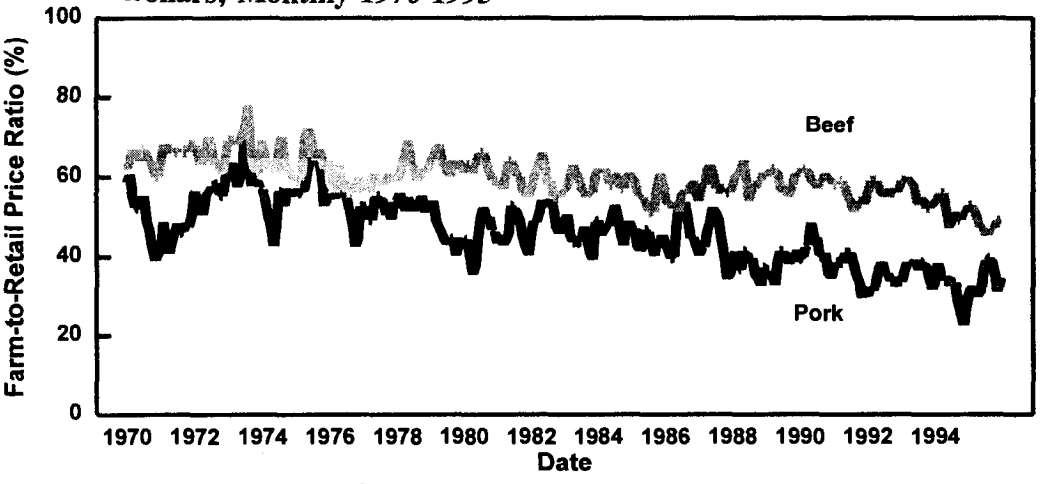

Figure 2. Farmer's Share of Retail Pork and Beef Prices, Monthly 1970-1995

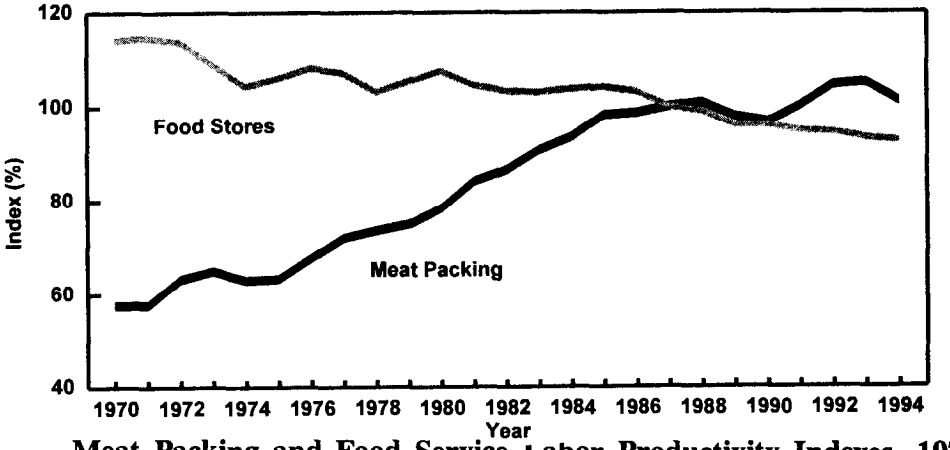

Figure 3. Meat Packing and Food Service Labor Productivity Indexes, 1970-1994 (1987=100)

MONTHLY VARIATION IN HOG CARCASS TRAITS

J. Mintert [1], S. Dritz [2], T. Schroeder [1], and S. Hedges [1]

Summary

Little research has been conducted regarding the impact that time of year when hogs are marketed has on various carcass traits. This study examined monthly variation in a variety of hog carcass traits based upon 1995 slaughter summaries provided by a midwestern hog marketing network. Results indicate that carcass traits did indeed vary throughout the 1995 calendar year. However, given that these monthly variations were observed only during one year, it remains to be seen whether they indicate a seasonal relationship that hog producers can expect to see year after year or specific factors operative only in 1995. Additional years of data will be collected to extend this study and validate the results.

(Key Words: Carcass Traits, Monthly Variation in Carcass Traits.)

Introduction

Marketing hogs on a carcass-merit basis has become the dominant method of pricing hogs in the U.S. The percentage of hogs sold via carcass-merit programs increased from 14% in 1984 to 67% by 1994. As a result, changes in carcass characteristics can have a significant impact on hog producers' net returns. Improved knowledge of variation in carcass characteristics will provide producers with an opportunity to better manage the carcass characteristics of the hogs they market. This study examined the monthly variation of hog carcass characteristics based upon hogs marketed by a midwestern hog marketing network during 1995.

Procedures

Slaughter summaries covering the period from Dec. 28, 1994 through Dec. 27, 1995 were obtained from a midwestern hog marketing network. All of the hogs were procured by a single packer under a contractual carcass merit-based marketing agreement and were slaughtered at the same packing plant. Five observations from Dec. 1994 were omitted from the data set so that all data in this study were taken from hogs marketed in 1995. Consequently, the data set consisted of 121,087 market hogs marketed in 1,232 groups.

Carcass weight was reported as total weight for each group, and carcass characteristics were reported as averages for the group. To obtain an average hot carcass weight for the hogs within each group, the total carcass weight in pounds was divided by the number of hogs in the group. Other data included in the analysis were the average backfat depth in inches measured at the 3/4 position on the last rib, the average loin depth in inches measured at the 3/4 position on the last rib, the average percentage of lean within a carcass, carcass yield, and the number of animals marketed in a group. Measurements for backfat depth and loin depth were taken simultaneously using an optical probe. Lean percentage was determined by a proprietary plant formula based on carcass weight, backfat depth, and loin depth.

[1]Department of Agricultural Economics.
[2]Food Animal Health and Management Center, College of Veterinary Medicine.

Monthly averages for backfat, loin depth, lean percentage, carcass yield, and carcass weight were computed. Averages were weighted by the number of head marketed in each group to account for variation in group size.

Results and Discussion

Monthly weighted average carcass attributes for 1995 are reported in Table 1 and in Figures 1 through 4. The weighted average annual backfat depth was .747 in., but backfat depth was above the annual average from January through July and below the annual average from August through December.

Monthly weighted average carcass weight varied substantially from the annual average of 191 lb during the course of the year. The average weights during January and February were below the annual average, but weights during March through July were well above the annual average. During the August through November period, weights again fell below the annual average before rising modestly above the annual average in December.

Table 1. Monthly Weighted Average Carcass Traits, 1995

Month	Backfat (in.)	Loin Depth (in.)	Lean (in.)	Yield (%)	Carcass Weight (lbs.)
January	.760	2.11	53.50	74.794	188.54
February	.78	2.10	53.17	75.378	187.59
March	.783	2.17	53.31	74.984	193.63
April	.794	2.14	53.09	75.62	196.50
May	.756	2.17	53.73	75.372	195.56
June	.750	2.16	53.79	75.469	193.28
July	.777	2.14	53.27	75.065	195.10
August	.732	2.12	53.97	75.002	187.86
September	.711	2.06	54.13	74.329	187.11
October	.685	2.11	54.65	74.346	187.41
November	.695	2.09	54.45	74.568	188.22
December	.735	2.16	54.03	74.955	192.10
Annual Average	.747	2.127	53.76	74.990	191.08

Other carcass characteristics also exhibited some variation within the year. The annual weighted average lean percentage was 53.8%. Monthly average lean percentages rose above the annual average in the fall, particularly in October and November. Finally, carcass yield averaged 74.99 during 1995, but carcass yields were above that level during most of the January through August period but fell below that level from September through November.

In general, the variations in observed carcass traits across the year are consistent with the expected fundamental dynamics of growth. Results from this study suggest that pigs marketed in the winter and early spring have higher amounts of backfat and larger loin depths compared to pigs marketed in late summer and early fall. The winter-marketed pigs were raised during a time of the year when environmental temperature could be regulated for maximizing feed intake. That would be expected to increase muscle (loin depth) and backfat deposition. However, the increased intake should result in a larger proportional increase in backfat compared to muscle. Pigs marketed in the fall were on feed over the summer, when environmental temperatures generally cause a decrease in feed intake. This reduction is expected to lead to slower growth and the deposition of less backfat. Additional data are needed from subsequent years to validate the trends observed.

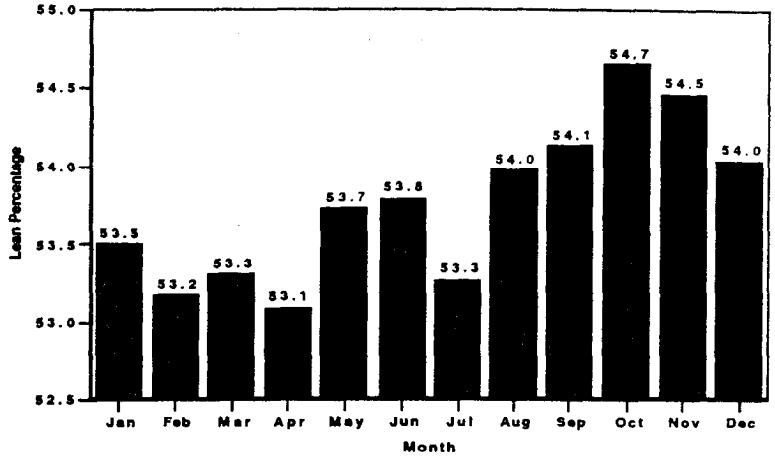

Figure 1. Monthly Weighted-Average Lean Percentage, 1995

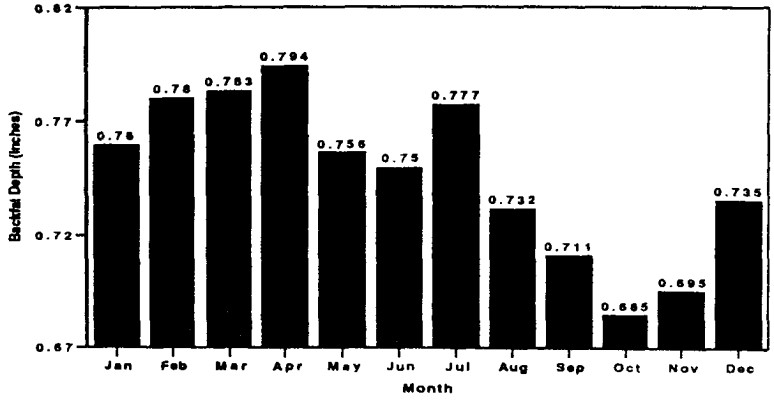

Figure 2. Monthly Weighted-Average Backfat Depth, 1995

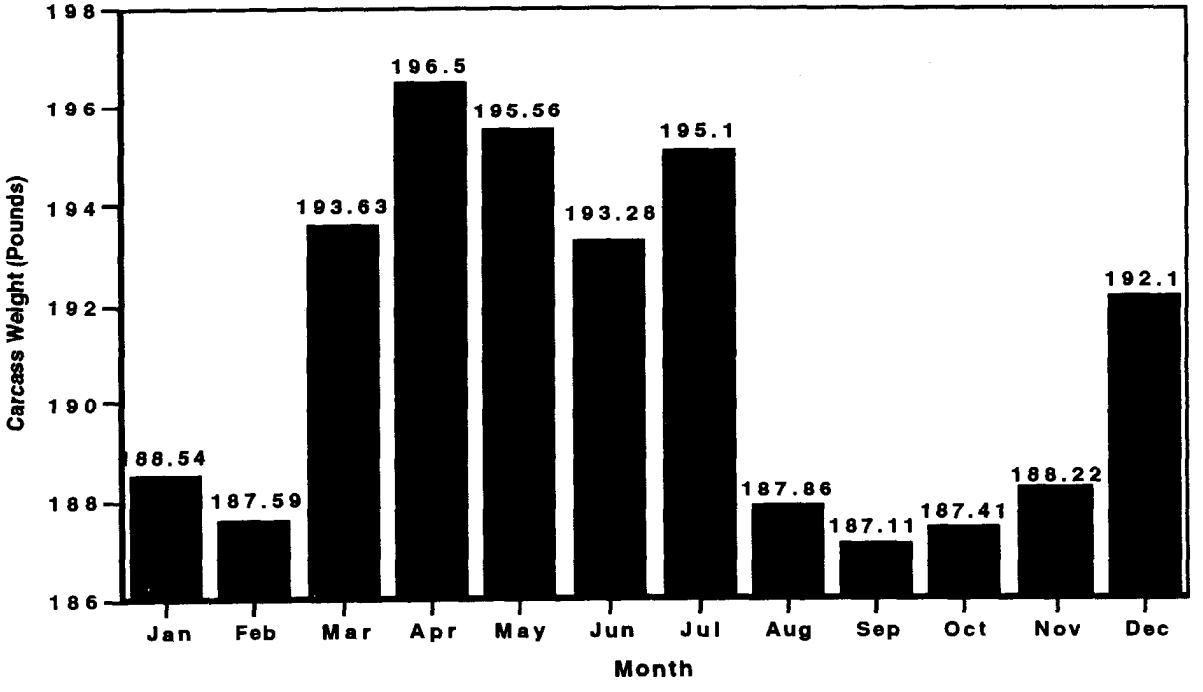

Figure 3. Monthly Weighted-Average Carcass Weight, 1995

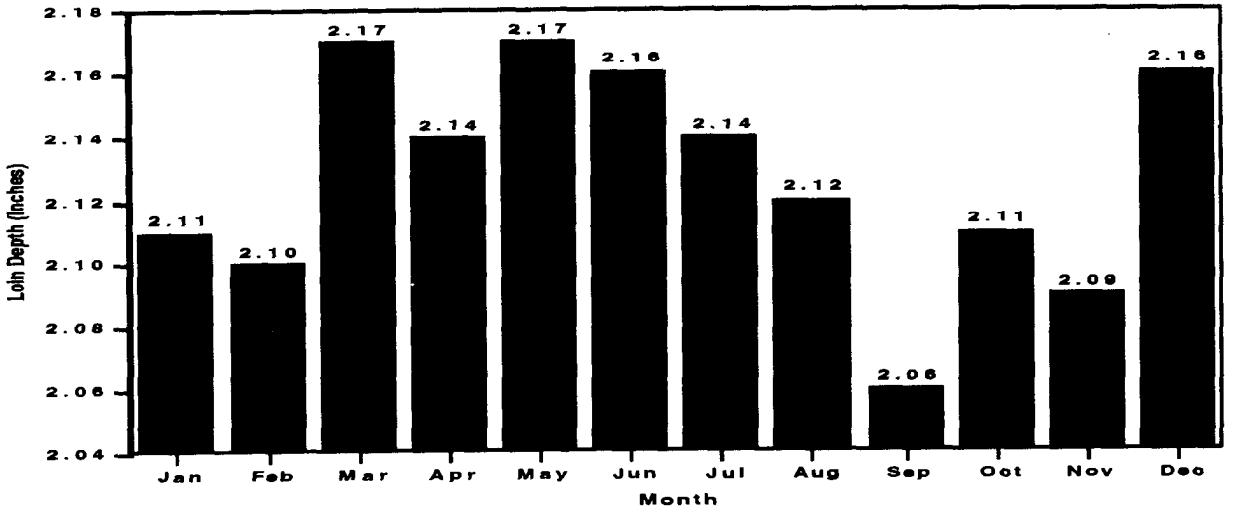

Figure 4. Monthly Weighted-Average Loin Depth, 1995

Swine Day 1996

THE IMPACT OF SELECTED HOG CARCASS TRAITS ON PRICES RECEIVED

J. Mintert [1], S. Dritz [2], T. Schroeder[1], and S. Hedges [1]

Summary

Hog producers can control the quality of the hogs they market. Through genetic selection and management, producers can have a large impact on hog carcass characteristics such as weight, backfat depth, and loin depth. Determining how much emphasis to place on changing or managing various carcass traits requires knowledge of the trait's value to the individual producer. Results from this study provide information on expected changes in price at one major midwestern packer associated with changes in carcass weight, backfat depth, and loin depth. Number of hogs marketed in each group did not affect net carcass value. However, these results might not apply to other packing companies that employ different pricing matrices.

(Key Words: Carcass Traits, Merit, Pricing.)

Introduction

A dramatic shift away from selling hogs on a liveweight basis towards marketing hogs on a carcass merit basis has taken place in the U.S. hog industry. For example, in 1984, marketing of approximately 14% of hogs in the U.S. used some type of merit pricing system. But by 1994, two-thirds of the nation's hogs were priced under some form of a grid or carcass-merit pricing system. Despite the dramatic shift in pricing techniques, little research has been conducted to identify the value of individual hog carcass traits from a producer's perspective. The purpose of this study was to identify and quantify the impact of various factors on prices received by farmers under a hog carcass-merit pricing system.

Procedures

Slaughter summaries covering the period from Dec. 28, 1994 through Dec. 27, 1995 were obtained from a midwestern hog marketing network. All of the hogs were procured by a single packer under a contractual carcass merit-based marketing agreement and were slaughtered at the same packing plant. The data set consisted of 121,961 market hogs marketed in 1,237 groups.

Carcass weight was reported as total weight for each group, and carcass characteristics were reported as averages for the group. To obtain an average hot carcass weight for the hogs within each group, the total carcass weight in pounds was divided by the number of hogs in the group. Other data included in the analysis were the average backfat depth in inches measured at the 3/4 positions on the last rib, the average loin depth in inches measured at the 3/4 position on the last rib, the number of animals marketed in a group, and the average percentage of lean within a carcass. Measurements for backfat depth and loin depth were taken simultaneously using an optical probe. Lean percentage was determined by a proprietary plant formula based on carcass weight, backfat depth, and loin depth.

Other data included in the analysis were the weekly Iowa-Minnesota live hog prices reported by the USDA, converted to a carcass weight basis. This was included because hogs

[1]Department of Agricultural Economics.
[2]Food Animal Health and Management Center, College of Veterinary Medicine.

from this marketing network were marketed to a single packer under a long-term marketing agreement, which was based on the previous week's live hog price. The contract also prescribed how price would be determined if the live hog price fell below or moved above a predetermined price level. Three additional variables were included to account for price variability attributable to this marketing arrangement. The origin of each load of hogs was included to account for hog carcass variability not measured directly by the carcass quality characteristics identified at the packing plant.

A regression model that estimated net carcass price per cwt. as a function of the weekly average Iowa-Minnesota hog price lagged 1 week, carcass weight, carcass weight squared, backfat, loin depth, number of head and number of head squared in each group, the hogs' origin, and three variables designed to capture price variability attributable solely to the hog price contract was employed to identify the value of various hog carcass characteristics.

Results and Discussion

Hogs marketed by the network had an average carcass weight of 190.5 lb and ranged from a minimum of 157.8 to a maximum of 219.3 lb. The average backfat depth was 0.74 in. and varied between 0.47 and 1.07 in. Loin depth averaged 2.12 in. and ranged from a minimum of 1.7 to a maximum of 2.8 in. The lean percentage of the hogs averaged 53.9% and varied between 48.3% and 59.7%. The number of head marketed in each group averaged 66, with a low of 4 head and a maximum of 229 head marketed per group. Finally, carcass prices received for the hogs ranged from $54.55 to $74.30 per cwt. and averaged $63.95 per cwt.

Regression model results indicated that increases in backfat led to lower carcass prices. A backfat increase of 0.1 in. was associated with an average carcass price decline of $0.88 per cwt. At the average carcass weight of 190.5 lb, this means a 0.1 in. backfat increase would be expected to reduce the net carcass price received by $1.67 per head. If we examine, the impact of changes in backfat alone on net carcass value, at the mean carcass weight of 190.5 lb, the group of hogs with the lowest average backfat depth of 0.47 in. likely earned a premium of $2.90 per head compared to a group of hogs that had a backfat measurement equal to the overall mean of 0.74 in.

Increases in loin depth were associated with higher carcass prices. Regression model results indicated that a 0.1 in. increase in loin depth was associated with a $0.19 per cwt. price increase. At the average carcass weight of 190.5 lb, and holding all other factors constant, this means the group of hogs in the study with the highest loin depth of 2.8 in. likely received a premium of $2.46 per head compared to a group of hogs with a loin depth measurement equal to the overall mean of 2.12 in.

Carcass weight had a significant, nonlinear impact on price received. Adding weight to hog carcasses had a positive impact on net price received until dressed weight reached approximately 188 lb. Carcasses that weighed 188 lb, on average, received a net price that was $1.40 per cwt. greater than the price paid for carcasses that weighed only 158 lb. Conversely, carcasses that weighed more than 188 lb were discounted by the firm that purchased the hogs. Figure 1 depicts the impact of changes in carcass weight on prices received for hogs sold. Note that all price changes reflect those expected compared to a 158 lb carcass.

In summary, the three carcass traits that had a significant impact on net carcass value were backfat, loin depth, and carcass weight. The number of hogs marketed in each group did not have a significant impact on net carcass value. This could reflect the nature of the contractual marketing agreement between the packing company and the hog marketing network.

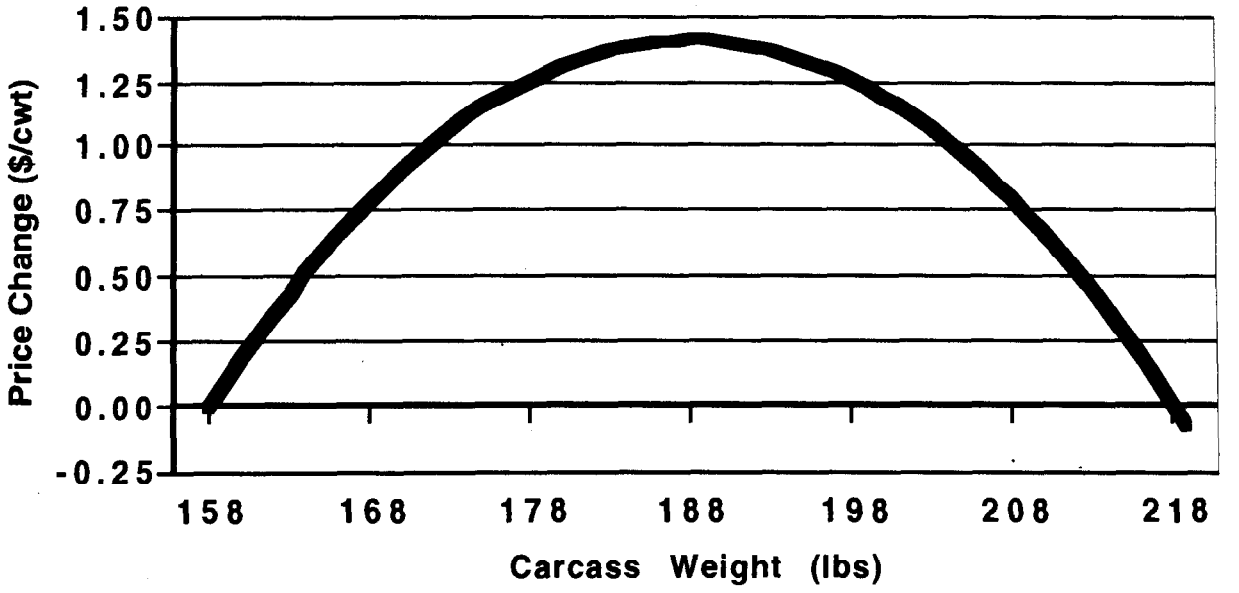

Figure 1. Impact of Weight on Net Carcass Price

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DETERMINATION OF CONTRACT BASE PAYMENTS TO FEEDER-PIG PRODUCERS

J. L. Parcell [1] and M. R. Langemeier [1]

Summary

Risks associated with independent feeder-pig production have prompted producers to seek alternative production and marketing methods. A means of reducing risk has developed through contract feeder-pig producing. Research results indicate that slightly risk-averse producers required contract base payments ranging from $7.50 to $28.50 per head. Strongly risk-averse producers required contract base payments ranging from $2.50 to $17.75 per head. The lower end of the ranges is for a low-profit producer. The upper end of the ranges is for a high-profit producer.

(Key Words: Risk Management, Contract Feeder-Pig Production.)

Introduction

Contractors and feeder-pig producers are interested in contract relationships for several reasons. Contract production is an effective way for contractors to rapidly expand production. By using contracts, contractors shift costs associated with facilities to feeder-pig producers and mitigate risk associated with owning facilities. In addition, contracting enables contractors to produce the volume and quality of pigs that attract packer premiums. Feeder-pig producers enter contracts to reduce production risk, to reduce price risk, and to obtain financing for facilities. Risks associated with changes in feed costs, breeding stock prices, and feeder-pig prices typically remain with the contractor. Depending on the type of contract used, fixed payment or base payment plus performance, risk also can be reduced substantially through contracts. By reducing production risk and price risk, contract production provides a more stable cash flow per pig.

Given the variety of production contracts used to produce feeder pigs, how do contractors and producers arrive at optimal contracts? The optimal contract depends on the extent to which moral hazard is a problem and the risk attitudes of the contractor and feeder-pig producer. Moral hazard occurs when one party in the contract has imperfect information pertaining to actions of the other party. In contract feeder-pig arrangements, moral hazard is related to the potential lack of effort put forth by the feeder-pig producer. Providing contract feeder-pig producers with a fixed payment per head, per pound, or per litter does not effectively address the moral hazard problem. However, producers who have not produced feeder pigs before or do not know what level of production performance to expect may prefer fixed payment contracts. To address the moral hazard problem, many contractors offer incentives and discounts to induce effort by the producer.

Contract payment provisions vary widely among producers. Contract producer fees range from receiving a set fee with no performance incentives to receiving most of the fee in the form of performance incentives. Pigs weaned per litter and average feeder-pig weights commonly are used as a basis for contract feeder-pig performance incentives.

Realization of low hog prices in 1994 may have temporarily slowed contract hog expansion. However, hog prices during 1995

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and 1996 have again offered profits to growers. Increased expansion in contract hog production is already under way, as investors realize the potential for high returns on investment historically realized for hog production. With the increasing supply of contracts available, feeder-pig producers need to be aware of the cost/profit relationship between independent and contract production. The objective of this study was to determine the level of contract payments at which producers would switch from independent to contract feeder-pig production.

Procedures

Three feeder-pig production contracts and independent feeder-pig production were evaluated. Contract **A** stipulated that the feeder-pig producer receive a base payment at time of marketing based on the number of feeder-pigs produced. No bonus payments were offered. Contract **B** stipulated that the feeder-pig producer receive a base payment at time of marketing plus bonus payments of $0.20/pig for every 0.5 increase above 18.00 pigs/female/year. Deductions in contract **B** occurred at a rate of $0.10/pound for average pig weights below 42.5 pounds/pig. Contract **C** stipulated that the feeder-pig producer receive a base payment at time of marketing plus bonus payments of $0.60/pig for every 0.5 increase above 12 pigs/female/year and $0.08/pounds/pig for average pig weights above 50 pounds. Deductions for contract **C** occurred for pigs under 50 pounds at a rate of $0.08/pound/pig.

Using data obtained through the Iowa State Swine Enterprise Analysis Reports and Kansas State University Farm Management Data Base, yearly profits to independent feeder-pig producers were computed for the period 1986 to 1995. Data were used to compute costs for independent and contract production for alternative profit groups. Total costs incurred by the low-, average-, and high-profit independent feeder-pig producers in Iowa (Kansas) were $44.92, $38.27 ($54.49), and $33.66, respectively (Table 1). Average total costs for an average-profit contract feeder-pig producer were calculated to be $20.49/pig in Iowa and $19.25/pig in Kansas. Total costs for low- and high-profit feeder-pig finishers averaged 1.17 and 0.88, respectively, times the costs incurred by average profit producers in Iowa. Contract costs included labor, repairs, gas-fuel-oil, property taxes, insurance, utilities, and interest and depreciation on buildings and equipment.

This study used calculated profits to feeder-pig producers and stochastic dominance to compare contract and independent feeder-pig production for a slightly risk-averse (profit maximizer), moderately risk-averse, and strongly risk-averse producer. Stochastic dominance is a technical procedure used to evaluate potential alternative strategies, whether it be feeder-pig production or any other production activity, for alternative risk levels.

Although the risk level of the producer may be ambiguous, most producers would be slightly to moderately risk averse. A risk-averse producer would prefer a low level of variability in annual profits or a low probability of negative returns. Average profits for independent feeder-pig production are substantially higher than those for contract feeder-pig production. However, independent feeder-pig profits are considerably more variable and negative profits occur periodically (Table 1). Thus, risk-averse producers or those wanting to better manage cash flows may prefer contract production.

Results and Discussion

Table 2 provides a summary of base payments at which feeder-pig producers would switch from independent to contract producing for alternative risk levels. Note that performance premiums were not included in base payments for contract **B** and contract **C**. An average-profit producer who is not particularly concerned about risk would require base payments of $19.50/pig for contract **A** and $16.75/pig for contract **C**. A producer who is extremely concerned about the variability of returns (i.e., a strongly risk-averse producer) would require base payments of $11.50/pig for contract **A** and $9.00/pig for contract **C**.

As producers become more risk averse, contract values decline. The strongly risk-averse average-profit producer would require

base payments of $11.50/pig for contract **A** and $9.00/pig for contract **C**. This decline in value is indicative of the producer's concern for obtaining relatively stable annual profits from contract feeder-pig producing.

Contract rates for low- and high-profit producers are included in Table 2. Deviations from the value obtained by the average-profit producers are functions of the management practices of the producer. High-profit producers would require substantially higher payments than low-profit producers.

Table 3 provides a sensitivity analysis of contract **A** (flat per-pig contract) to variation in expected profit levels for both the Kansas and Iowa average-profit feeder-pig producers. As the level of expected profits declines, the required contract payment declines. For instance, a producer entering into a multi-year contract may require payments less than historical computed payments, if profitability is expected to decline. The moderately and strongly risk-averse Kansas feeder-pig producer would prefer contracting to independent production regardless of the payment.

Table 1. Summary Statistics of Selected Cost and Profit Characteristics (1986-1995)

		Profits		
Profit Level	Total Costs	Average	Min	Max
Independent Feeder-Pig Producing (1995 real dollars/per pig)				
Iowa				
Low	44.92	-7.54	-17.87	1.76
Average	38.27	6.01	-7.32	18.95
High	33.66	17.60	2.08	35.78
Kansas				
Average	54.49	2.54	-24.70	18.23

Table 2. Minimum Base Payment Levels ($/pig) for Which Feeder-Pig Producers Will Be Indifferent between Independent and Contract Production (Iowa)

Contract	Slightly Risk Averse[a]	Moderately Risk Averse[a]	Strongly Risk Averse[a]
Low-profit producer			
Contract **A**	9.75	6.00	4.50
Contract **B**	9.00	5.25	3.75
Contract **C**	7.50	3.75	2.50
Average-profit producer			
Contract **A**	19.50	13.75	11.50
Contract **B**	19.25	13.00	11.00
Contract **C**	16.75	10.75	9.00
High-profit producer			
Contract **A**	28.50	19.75	17.75
Contract **B**	27.50	18.75	16.75
Contract **C**	24.50	16.00	14.50

[a]If the base payment is higher than the level indicated, a producer would prefer contract production over independent production. If the base payment is lower than the level indicated, a producer would prefer independent production over contract production.

Table 3. Sensitivity Analysis of the Flat Contract to Variations in Expected Profit Levels for Average-Profit Producers in Iowa and Kansas

	Expected Level of Economic Profits	Slightly Risk Averse	Moderately Risk Averse	Strongly Risk Averse
		Feeder-Pig Producing per Pig Contract ($/pig)		
Iowa				
	historical	19.50	13.75	11.50
	half	16.75	10.75	8.00
	zero	13.75	8.00	5.75
Kansas				
	historical	22.00	Pc[a]	Pc
	half	20.50	Pc	Pc
	zero	17.00	Pc	Pc

[a]Moderately to strongly risk-averse producers in Kansas would prefer contracting to independent production regardless of the payment.

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DETERMINATION OF CONTRACT BASE PAYMENTS TO FEEDER-PIG FINISHERS

J. L. Parcell[1] *and M. R. Langemeier*[1]

Summary

Risks associated with independent feeder-pig finishing have prompted finishers to seek alternative finishing and marketing methods. A means of reducing risk has developed through contract feeder-pig finishing. Research results indicated that slightly risk-averse finishers required contract base payments ranging from $11.00 to $30.00 per head. Strongly risk-averse finishers required contract base payments ranging from $8.50 to $19.00 per head. The lower end of the ranges is for a low-profit finisher. The upper end of the ranges is for a high-profit finisher.

(Key Words: Risk Management, Contract Feeder-Pig Finishing.)

Introduction

Contractors and feeder-pig finishers are interested in contract relationships for several reasons. Contract finishing is an effective way for contractors to rapidly expand finishing. By using contracts, contractors shift costs associated with facilities to feeder-pig finishers and mitigate risk associated with owning facilities. In addition, contracting enables contractors to produce the volume and quality of pigs that attract packer premiums. Feeder-pig finishers enter contracts to reduce finishing risk, to reduce price risk, and to obtain financing for facilities. Risks associated with changes in feed costs, feeder-pig prices, and market hog prices typically remain with the contractor. Depending on the type of contract used, fixed payment or base payment plus performance, risk also can be reduced substantially through contracts. By reducing production risk and price risk, contract finishing provides a more stable cash flow per pig.

Given the variety of finishing contracts used to finish feeder pigs, how do contractors and finishers arrive at optimal contracts? The optimal contract depends on the extent to which moral hazard is a problem and the risk attitudes of the contractor and feeder-pig finisher. Moral hazard occurs when one party in the contract has imperfect information pertaining to actions of the other party. In contract feeder-pig arrangements, moral hazard is related to the potential lack of effort put forth by the feeder-pig finisher. Providing contract feeder-pig finishers with a fixed payment per head and/or per pound does not effectively address the moral hazard problem. However, finishers who have not finished feeder pigs before, or do not know what level of finishing performance to expect, may prefer fixed payment contracts. To address the moral hazard problem, many contractors offer incentives and discounts to induce effort by the finisher.

Contract payment provisions vary widely among finishers. Contract finisher fees range from receiving a set fee with no performance incentives to receiving most of the fee in the form of performance incentives. Performance incentives typically involve feed conversion and/or death loss.

Realization of low hog prices in 1994 may have temporarily slowed contract hog expansion. However, hog prices during 1995 and 1996 have again offered profits to growers. Increased expansion in contract hog finishing

[1]Department of Agricultural Economics.

is already under way, as investors realize the potential for high returns on investment. With the increasing supply of contracts available, feeder-pig finishers need to be aware of the cost/profit relationship between independent and contract finishers. The objective of this study was to determine the level of contract payments at which finishers would switch from independent to contract feeder-pig finishing.

Procedures

Three feeder-pig finishing contracts and independent feeder-pig finishing were evaluated. Contract **A** stipulated that the feeder-pig finisher receive a base payment at the time of marketing, based on the number of finished pigs marketed (per pig payment). No bonus payments were offered. Contract **B** offered the feeder-pig finisher a relatively high base payment at the time of marketing and relatively low bonus payments. Table 1 summarizes the bonus schedule for this contract. Contract **C** offered the feeder-pig finisher a relatively low base payment at the time of marketing and relatively high bonus payments. Table 2 summarizes the bonus schedule for this contract.

Using data obtained through the Iowa State Swine Enterprise Analysis Reports and Kansas State University Farm Management Data Base, yearly profits to independent feeder-pig finishers were computed for the period 1986 to 1995. Data were used to estimate costs for independent and contract finishing. Total costs incurred by the low-, average-, and high-profit independent feeder-pig finishers in Iowa (Kansas) were $79.76, $71.22 ($76.62), and $63.13, respectively (Table 3). Average total costs for an average profit contract feeder-pig finisher were calculated to be $19.53/pig in Iowa and $16.23/pig in Kansas. Total costs for low- and high-profit feeder-pig finishers averaged 1.12 and 0.89, respectively, times the costs incurred by average profit finishers in Iowa. Contract costs included labor, repairs, gas-fuel-oil, property taxes, insurance, utilities, and interest and depreciation on buildings and equipment.

This study used calculated profits to feeder-pig finishers and stochastic dominance to compare contract and independent feeder-pig finishing for a slightly risk-averse (profit maximizer), moderately risk-averse, and strongly risk-averse finisher. Stochastic dominance is a technical procedure used to evaluate potential alternative strategies, whether it be feeder-pig finishing or any other production activity, for alternative risk levels.

Although the risk level of the finisher may be ambiguous, most finishers would be slightly to moderately risk averse. A risk-averse finisher would prefer a low level of variability in annual profits or a low probability of negative returns. Average profits for independent feeder-pig finishing are substantially higher than those for contract feeder-pig finishing. However, independent feeder-pig finishing profits are considerably more variable, and negative profits occur periodically (Table 3). Thus, risk-averse finishers or those wanting to better manage cash flows may prefer contract finishing.

Results and Discussion

Table 4 provides a summary of base payments at which feeder-pig finishers would switch from independent to contract finishing for alternative risk levels. Note that performance premiums were not included in base payments for contract **B** and contract **C**. An average-profit finisher who is strongly risk averse would require base payments of $12.50/pig for contract **A** and $10.00/pig for contract **C**. A slightly risk-averse finisher would require base payments of $21.50/pig for contract **A** and $18.50/pig for contract **C**.

Contract rates for low- and high-profit finishers are included in Table 4. Deviations from the value obtained for the average-profit finisher are functions of the management practices of the finisher. High-profit finishers would require contract payments in excess of current rates. Thus, these finishers will not finish hogs under contract.

Table 5 provides a sensitivity analysis of contract **A** (flat per-pig contract) to variation in expected profit levels for both the Kansas and Iowa average-profit feeder-pig finishers. As the level of expected profits declines, the required contract payment declines. For instance, a finisher entering into a multi-year contract may require payments less than

historical computed payments, if profitability is expected to be lower in the future. Contract payments differ little between the moderately and strongly risk-averse Kansas feeder-pig finisher. This is indicative of the low variability in returns realized by these groups.

Table 1. Bonus Payment Schedule for Contract B

Feed Efficiency (lbs feed/lbs gain)	Dollars per Head Sold	Death Loss (percent)	Dollars per Head Sold
2.80-2.89	5.10	0.00-0.00	2.10
2.90-2.99	4.80	0.01-0.50	1.80
3.00-3.09	4.50	0.51-0.99	1.50
3.10-3.19	4.20	1.00-1.50	1.20
3.20-3.29	3.90	1.51-1.99	0.90
3.30-3.39	3.60	2.00-2.50	0.60
3.40-3.49	3.30	2.51-3.00	0.30
3.50-3.59	3.00	3.01-3.99	0.00
3.60-3.69	2.70	4.00 or above	split death loss
3.70-3.79	2.40		
3.80-3.89	2.10		
3.90-3.99	1.80		
4.00-4.09	1.50		
4.10-4.19	1.20		
4.20-4.29	0.90		
4.30-4.39	0.60		
4.40-4.49	0.30		
4.50 or above	0.00		

Table 2. Bonus Payment Schedule for Contract C

Feed Efficiency (lbs feed/lbs gain)	Dollars per Head Sold	Death Loss (percent)	Dollars per Head Sold
0.00-2.29	7.00	0.00-0.99	1.50
2.30-2.39	6.50	1.00-1.99	1.00
2.40-2.49	6.00	2.00-2.99	0.50
2.50-2.59	5.50	3.00 or above	0.00
2.60-2.69	5.00		
2.70-2.79	4.50		
2.80-2.89	4.00		
2.90-2.99	3.50		
3.00-3.09	3.00		
3.10-3.19	2.50		
3.20-3.29	2.00		
3.30-3.39	1.50		
3.40-3.49	1.00		
3.50-3.59	0.50		
3.60 or above	0.00		

Table 3. Summary Statistics of Selected Cost and Profit Characteristics (1986-1995)

		Profits		
Profit Level	Total Costs	Average	Min	Max
Independent Feeder-Pig Finishing (1995 real dollars/per pig)				
Iowa				
Low	79.76	-2.78	-11.86	6.84
Average	71.22	8.50	-4.97	25.79
High	63.13	19.68	4.40	50.45
Kansas				
Average	76.62	1.57	-7.27	13.25

Table 4. Minimum Base Payment Levels ($/pig) for Which Feeder-Pig Finishers Will Be Indifferent between Independent and Contract Finishing (Iowa)

Contract	Slightly Risk Averse[a]	Moderately Risk Averse[a]	Strongly Risk Averse[a]
Low-profit finisher			
Contract **A**	13.75	10.75	10.75
Contract **B**	13.50	10.50	10.50
Contract **C**	11.00	8.50	8.50
Average-profit finisher			
Contract **A**	21.50	14.50	12.50
Contract **B**	21.00	14.25	12.25
Contract **C**	18.50	11.75	10.00
High-profit finisher			
Contract **A**	30.00	21.25	19.00
Contract **B**	28.75	20.00	17.75
Contract **C**	26.50	17.75	15.50

[a]If the base payment is higher than the level indicated, a finisher would prefer contract finishing over independent finishing. If the base payment is lower than the level indicated, a finisher would prefer independent finishing over contract finishing.

Table 5. Sensitivity Analysis of the Flat Contract to Variations in Expected Profit Levels for Average Profit Finishers in Iowa and Kansas

	Expected Level of Economic Profits	Slightly Risk Averse	Moderately Risk Averse	Strongly Risk Averse
		Feeder-Pig Finishing per Pig Contract ($/pig)		
Iowa				
	historical	21.25	14.50	12.50
	half	17.00	10.25	8.00
	zero	12.75	6.00	3.75
Kansas				
	historical	18.00	16.25	16.25
	half	17.00	15.50	15.50
	zero	16.25	14.25	14.25

Swine Day 1996

SWINE MANURE MANAGEMENT

J. P. Murphy [1]

Land Application

Manure nutrients help build and maintain soil fertility. Manure also improves tilth, increases waterholding capacity, lessens wind and water erosion, improves aeration, and promotes beneficial organisms. When wastes include runoff or dilution water, they can supply water as well as nutrients to crops. The economic value of manure fertilizer is calculated from its available nitrogen (N), phosphorus (P), and potassium (K) at commercial fertilizer prices. These values change with the costs of fertilizer and handling practices.

Applying excess wastes can harm crop growth, contaminate soil, cause surface and groundwater pollution, and waste nutrients. Although most soils have a tremendous capacity to absorb P, very high soil P levels can interfere with plant nutrition by inhibiting uptake of metallic trace elements such as iron, zinc, and copper. When plant residue or manure is added to soil, an immediate and marked drop in O_2 and an increase in CO_2 occur in the soil air, which can inhibit plant growth.

The carbon-nitrogen ratio (C/N) of applied wastes affects both microbial and plant growth. If a waste having a high C/N ratio, such as manure with a lot of bedding, is added to a soil, organisms decomposing the organic matter grow until available mineral and N become limiting. All the immediately available N is bound by the microorganisms. In the short run, N is unavailable for plant use and more chemical fertilizer may have to be added than before the waste application.

Heavy manure applications can increase soil salinity, especially in arid regions where little or no leaching occurs. Salts can inhibit plant growth and depress yields. If salinity becomes a problem, consult a crop specialist. Sodium and K can alter soil structure and reduce water movement rates. Field equipment, such as heavy manure wagons, compacts wet soils, alters soil structure, and reduces water movement.

Nutrient Losses during Collection and Storage

Table 1 gives the nutrient content of swine manure as produced. Housing and waste handling systems affect the nutrient composition of wastes. Bedding and water dilute manure, resulting in less nutrient value per pound. Much N can be lost to the air as ammonia. Runoff and leaching in open lots can remove N. Much less N is lost from compost pits, liquid storage systems, or roofed feeding areas as shown in Table 2.

Phosphorus and K losses are negligible except for open lots or lagoons. About 20% to 40% of the P and 30% to 50% of the K can be lost by runoff and leaching in open lots. However, much of the P and K can be recovered by runoff control systems such as settling basins and holding ponds. Up to 80% of the P in lagoons can accumulate in bottom sludges and is not applied to land unless the sludge is removed.

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Application

Manure is usually:

- Broadcast (top dressed) with plowing or disking.
- Broadcast without plowing or disking.
- Knifed (injected under the soil surface).
- Irrigated.

Table 3 shows average N losses by method of application. The greatest nutrient response follows land application and immediate incorporation into the soil. Incorporate solid manure as soon as possible to minimize N loss and to begin release of nutrients for plant use. Most losses occur in the first 24 hours after application. Injecting, chiseling, or knifing liquids into the soil minimizes odors and nutrient losses to the air and/or to runoff.

Nitrogen loss as ammonia from land is greater during dry, warm, windy days than during humid or cold days. Ammonia loss is generally greater during the spring and summer months. Uniform application prevents local concentrations of ammonium or inorganic salts that can reduce seed germination and yields.

Crop Nutrient Removal

Apply manure so additional nutrients do not greatly exceed crop needs (see Table 4). Before heavy manure applications, have your soil tested for fertilizer needs and nutrient imbalance. Adjust waste application rates for your soil conditions against soil tests for N, P, and K.

Available N is N the plant can use. Total N is mostly organic and ammonium N. Ammonium N is equivalent to commercial fertilizer and, except for that lost to the air, can be used by plants in the application year. Organic N must be released before plants can use it but is slow releasing.

Variable amounts of organic N are released in a plant-available form during the first cropping year after application. Organic N released during the second, third, and fourth cropping years after initial application is usually about 50%, 25%, and 12.5%, respectively, of that mineralized during the first cropping season.

Nearly all of the P and K in animal wastes are available for plant use in the year of application. After a few years of regular waste applications, the amounts available are about the same as those for one year's application.

Manure Management Plan

All swine producers are encouraged to develop a manure management plan for their operations. The N loss tables point out the variability of N content of swine manure. That variability coupled with the inherent variabilities of soil type, tillage practices, weather patterns, and crop response means that the swine producer can estimate N application from manure only within broad ranges. For three different swine production systems, Table 5 gives an estimate of acres needed for 100 lb of available N per year using various methods of manure collection, storage, and field application.

Each producer must fine-tune manure management. Swine producers should develop a fertilizer application plan that first maximizes the use of manure nutrients and then supplement these nutrients with commercial fertilizer only if additional nutrients are needed for the crop. The major elements of such a plan include: 1) periodic analysis of the manure produced, 2) a routine soil testing program, 3) keeping records of manure applications and soil tests over time to minimize nutrient and salt buildup.

Diligent and conscientious management of swine manure is necessary to minimize water contamination and odor production, while maximizing the nutrient value of the manure.

Table 1. Nutrients in Swine Manure as Produced

		Nutrients Produced per Animal per Year		
Animal	Size, lb	N, lb	P_2O_5, lb	K_2O, lb
Nursery pig	35	7.3	4.4	4.4
Growing pig	65	11	8.0	8.4
Finishing pig	150	26	18	20
	200	33	24	26
Gestating sow	275	26	18	18
Sow and litter	375	37	20	20
Boar	350	33	23	23

Table 2. Nitrogen Losses during Handling and Storage[a]

System	Nitrogen Lost, %
Solid	
Daily scrape and haul	20-35
Manure pack	20-40
Open lot	40-55
Liquid	
Anaerobic pit	15-30
Aboveground storage	10-30
Earth storage	20-40
Lagoon	70-85

[a]Typical losses between excretion and land application adjusted for dilution in the various systems. These values are in addition to land application losses, based on Purdue University data.

Table 3. Nitrogen Losses during Land Application[a]

Application Method	Type of Waste	Nitrogen Lost, %
Broadcast	Solid	15-30
	Liquid	10-25
Broadcast with immediate cultivation	Solid	1-5
	Liquid	1-5
Injection into soil	Liquid	0-2
Sprinkler irrigation	Liquid	15-40

[a]Percent of N applied that is lost within 4 days of application.

Table 4. Crop Nutrient Utilization[a]

Crop	Yield	N	P_2O_5	K_2O
		))))))) lb/acre)))))))		
Corn	80 bu	121	42	77
	100 bu	160	60	120
	150 bu	185	80	215
	180 bu	240	100	240
Corn silage	16 tons	130	45	102
	32 tons	200	80	245
Soybeans	30 bu	123	32	52
	40 bu	180	45	80
	50 bu	257	48	120
	60 bu	336	65	145
Grain sorghum	4 tons	150	90	200
Wheat	40 bu	70	30	50
	60 bu	125	50	110
	80 bu	186	54	162
Oats	80 bu	75	35	95
	100 bu	150	55	150
Barley	65 bu	74	32	63
	100 bu	150	55	150
Alfalfa 4 tons	180	40	180	
	8 tons	450	80	480
Bromegrass	5 tons	166	66	254
Tall fescue	3.5 tons	135	65	185
Bluegrass	3 tons	200	55	180
Sorghum-sudan grass	8 tons	319	122	467

[a]Values are for the aboveground portion of the plants. Source: Potash Phosphate Institute of America.

Table 5. Acres Needed for Land Application of Manure

Manure Handling Method	Acres/100 Sows to Yield 100 lb N/Acre		
	Feeder Pig Production	Farrow to Finish	Pigs Fed 50-220 lb
Anaerobic pit			
Broadcast	13	129	9
Broadcast/cultivate	16	152	10
Injection	16	155	10
Irrigation	12	113	8
Open lot			
Broadcast	11	102	7
Broadcast/cultivate	14	128	9
Lagoon			
Irrigation	5	48	3

[a]Values based on 100 lb. of available N per year for one time capacity of swine facilities.
[b]Based on 16 pigs sold/productive sow-yr. Manure production per productive sow accounts for all animals in the operation.

ACKNOWLEDGEMENTS

Appreciation is expressed to these organizations for assisting with swine research at Kansas State University:

A & L Labs, Chicago, IL
Albion Labs, Atlantic, IA
American Livestock Equipment, Clay Center, KS
American Proteins Corporation, Ames, IA
American Soybean Association, St. Louis, MO
Archer Daniels Midland Company, Decatur, IL
Avebe America, Inc., Princeton, NJ
BASF, Parsippany, NJ
BioKyowa, Inc., St. Louis, MO
California Spray-Dry, Modesto, CA
Church and Dwight Co, Inc., Princeton, NJ
Cryovac Division, W.R. Grace & Co., Duncan, SC
Custom Ag Products, Beloit, KS
Degussa Inc., Alandale, NJ
Eichman Farms, St. George, KS
Elanco Products Company, Indianapolis, IN
Excel Corp., Wichita, KS
Farmland Foods, Crete, NE
Feed Products and Service Company, St. Louis, MO
Feed Specialties Inc., Des Moines, IA
Finnfeeds International LTD, Surrey, U.K.
Global Ventures, Pipestone, MN
Havercamp Brothers, Burns, KS
Heartland Lysine, Inc., Chicago, IL
Henry's LTD, Longford, KS
H.J. Baker & Bros., Little Rock, AR
Hoffman-LaRoche, Inc., Nutley, NJ
J-6 Farms, Corning, KS
International Ingredients Co., St. Louis, MO
Iowa Limestone Co., Des Moines, IA
Kansas Pork Producers Council, Manhattan, KS
Kansas Sorghum Commission, Topeka, KS
Kansas Soybean Commission, Topeka, KS
Kansas State Board of Agriculture, Topeka, KS
Keesecker Ag-business, Washington, KS
Key Milling, Clay Center, KS
Land O' Lakes, Fort Dodge, IA
Livestock and Meat Industry Council, Manhattan, KS
Lonza, Inc., Fair Lawn, NJ
M-TEK Inc., Elgin, IL
Manhattan Wholesale Meats Co., Manhattan, KS
McCullough & Co., Kansas City, MO
Midwest Grain Products, Atchison, KS
Monsanto Ag. Co. St. Louis, MO
Morrison Grain Co., Salina, KS
National Pork Producers Council, Des Moines, IA
Newsham Hybrids, Colorado Springs, CO
Novus International Inc., St. Louis, MO
Nutri-Quest, Chesterfield, MO
Pfizer, Inc., Terre Haute, IN
Phoenix Scientific, Inc., St. Joseph, MO
Pig Improvement Co., Franklin, KY
Pioneer Hi-Bred Int., Manhattan, KS
Pipestone Production System, Pipestone, MN
Pork Packers International, Downs, KS
Porter Livestock Products, Nichols, IA
Premium Pork Inc., Kensington, KS
Prince Agric Products, Inc., Quincy, IL
Provesta, Corp., Bartlesville, OK
Seaboard Farms, Inc., Gymon, OK
Seoul National University, Suweon, Korea
SmithKline Animal Health Products, West Chester, PA
Triple "F" Products, Des Moines, IA
Tyson Foods, Springdale, AR
United States Department of Agriculture, Science and Education, Washington, DC
Vita-Plus, Madison, WI
Zapata Proteins, Hammond, LA
Zen-Oh Group, Osaka, Japan

We especially appreciate the assistance and dedication of Roger Anderson, Jon Bergstrom, Mark Nelson, Robert Beckley, Eldo Heller, and Theresa Rathbun.

We gratefully acknowledge Eileen Schofield for editorial assistance, Valerie Stillwell for word processing, and Fred Anderson for cover design for this publication.

Contribution No. 97-142-S from the Kansas Agricultural Experiment Station.

Agricultural Experiment Station, Kansas State University, Manhattan 66506

Report of Progress 772 November 1996