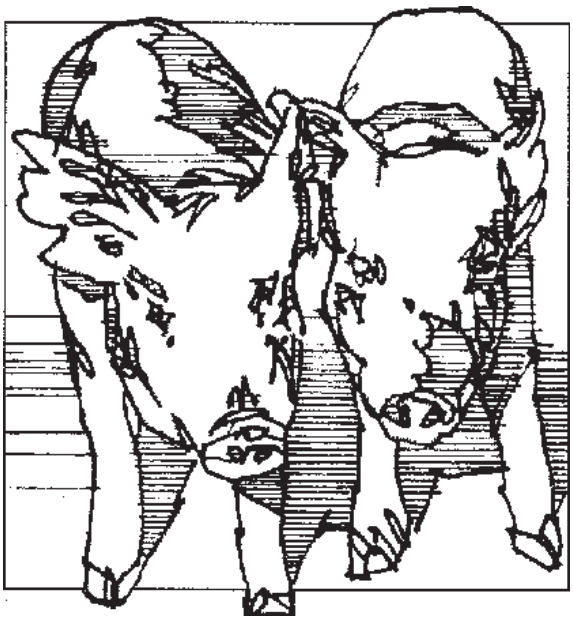


KANSAS
STATE
UNIVERSITY

SWINE DAY 1992

REPORT OF PROGRESS 667, AGRICULTURAL EXPERIMENT STATION, MARC A. JOHNSON, DIRECTOR

FOREWORD

It is with great pleasure that we present to you the 1992 Swine Day Report. This report contains summaries of applied and basic swine research conducted at Kansas State University during the past year. Topics range from economics to physiology and nutrition. We hope that the information will be of benefit, as we attempt to meet the needs of the Kansas swine industry.

Editors, 1992 Swine Day Report,

Bob Goodband Mike Tokach

ABBREVIATIONS USED IN THIS REPORT

avg	=	average	h	=	hour(s)	mo	=	month(s)
BW	=	body weight	in.	=	inch(es)	µg	=	microgram(s)
cm	=	centimeter(s)	IU	=	international		=	.001 mg
CP	=	crude protein			unit(s)	N	=	nitrogen
cwt	=	100 lb	kg	=	kilogram(s)	ng	=	nanogram(s)
d	=	day(s)	Kcal	=	kilocalorie(s)		=	.001 µg
DM	=	dry matter	lb	=	pound(s)	no.	=	number
°F	=	Fahrenheit	Mcal	=	megacalorie(s)	ppm	=	parts per million
ft	=	foot(feet)	mEq	=	milliequivalent(s)	sec	=	second(s)
ft^2	=	square foot(feet)	min	=	minute(s)	wk	=	week(s)
g	=	gram(s)	mg	=	milligram(s)	wt	=	weight(s)
gal	=	gallon(s)	ml	=	cc (cubic centimeters)	yr	=	year(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 10% Mn, 10% Fe, 10% Zn, 4% Ca, 1% Cu, .4% K, .3% I, .2% Na, and .1% Co.

Vitamin premix: each lb of premix contains vitamin A, 1,000,000 IU; vitamin D_3, 100,000 IU; vitamin E, 4,000 IU; menadione, 400 mg; riboflavin, 1,000 mg; pantothenic acid, 2,500 mg; niacin, 5,500 mg; choline, 100,000 g; and vitamin B_{12}, 5 mg.

Selenium premix: each lb of premix contains 272.4 mg Se.

NOTICE

Kansas State University makes no endorsement, expressed or implied, of any commercial product. Trade names are used in this publication only to ensure clarity of communication.

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.

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.

EFFECTS OF THE INTERRELATIONSHIP BETWEEN DIETARY LYSINE AND LITTER SIZE ON SOW AND LITTER PERFORMANCE[1]

J. L. Laurin, J. L. Nelssen, R. D. Goodband, M. D. Tokach, and R. D. Anderson

Summary

One hundred and forty-three lactating primiparous sows were used in a study to determine the influence of four different litter sizes on the dietary lysine requirement as measured by sow and litter performance. At farrowing, sows were randomly assigned to one of three corn-soybean meal diets (.67, .94, or 1.22 % lysine) and one of four litter sizes (8, 9, 10, or 11 pigs). Sows were fed 7.7, 9.9, and 12.1 lb/d of their respective diet for the first, second, and third week of lactation. This provided an average daily lysine intake of 30.1, 42.2, or 54.8 g/d throughout the 21-day lactation period. Ratio of other amino acids relative to lysine were kept constant to ensure that lysine was first limiting, and all diets contained 5% soybean oil to increase the energy density. Sows were fed twice daily, and feed disappearance was recorded each day. Litters were adjusted to their treatment size within 72 h after farrowing. If a pig died during the lactation period, a pig of similar age and weight was used as a replacement. Sows and litters were weighed weekly, and average backfat was measured at farrowing and weaning (d 21). There were no interactions between litter size and lysine intake for litter weight gain. Litter weight gain was increased by increasing litter size. Increasing dietary lysine tended to improve litter weight gain. A dietary lysine × litter size interaction was observed for sow weight loss. Sow weight loss was increased as litter size increased. However, increased dietary lysine reduced sow weight loss. Sow backfat loss was not affected by litter size or dietary lysine. In conclusion, it appears that sows require approximately 42.5 g/d lysine to maximize 21-d litter weight gain. Surprisingly, litter size did not influence the sows lysine requirement. Increasing litter size increased sow weight loss, but this response was minimized by increasing dietary lysine.

(Key Words: Sows, Lysine, Reproductive Performance, Litter Size.)

Introduction

In recent years, there has been tremendous interest in the feeding strategies used for high producing sows. Development and identification of genetically superior white line sows for the breeding herd are primarily responsible for the renewed interest in nutritional requirements. Although the average swine producer in the U.S. weans only eight pigs per litter, several studies have shown excellent responses to increased dietary lysine from sows nursing litters with more than nine pigs. Therefore, the objective of this study was to take into account a wide range of litter sizes (8, 9, 10, or 11 pigs) and also a wide range of daily lysine intakes. This information will be used to construct a statistical model that would be used to predict lysine requirements based on week of lactation and number of pigs nursed by the sow. This requirement would meet two major criteria: 1) to maximize sow productivity in terms of milk production and litter weight gain and 2)

[1]The authors would like to thank Nutri-Quest, Inc. and BioKyowa for partial funding of this study and supplying amino acids.

to minimize sow weight loss and reduce nonproductive sow days.

Procedures

At farrowing, sows were randomly assigned to one of three experimental diets (.67, .94, or 1.22% lysine; Table 1) and one of four litter sizes (8, 9, 10, or 11 pigs). The corn-soybean meal ratio in the diets was adjusted to achieve the desired level of dietary lysine. Ratios of other amino acids relative to lysine were kept constant to ensure that lysine was first limiting (Table 2), and all diets contained 5% soybean oil to increase the energy density. All diets were pelleted through a 3/16 × 2 in. die to help maximize feed intake. Litters were adjusted to their treatment size within 72 h after farrowing. If a pig died during the lactation period, a pig of similar age and weight was used as a replacement. During the first week of lactation, sows were fed 7.7 lb/d of each diet. This provided sows with 23.4, 32.8, or 42.6 g/d lysine. During the second week of lactation, feed was increased to 9.9 lb/d, providing 30.1, 42.2, or 54.8 g/d lysine. Finally, during the third week of lactation feed intake was increased to 12 lb/d providing 36.8, 51.6, and 67.0 g/d lysine. Thus, the average daily lysine intakes throughout the 21 d lactation period were 30.1, 42.2, and 54.8 g/d lysine. Feed disappearance was measured daily and individual sow feed consumption was used in the statistical modeling of daily lysine intake to litter weight gain. Sows and litters were weighed on d 1, 7, 14, and at weaning. Average backfat was measured on d 1 and at weaning.

Results and Discussion

Increasing litter size resulted in increased litter weight on d 7 and 14 and at weaning ($P<.01$). Increasing dietary lysine resulted in increased litter weight gain and d 21 litter weight ($P<.10$). Surprisingly, no dietary lysine × litter size interaction was observed for litter weight gain. This indicates that, regardless of litter size, sows require approximately 42 to 46 g/d dietary lysine to maximize litter weaning weight. A dietary lysine × litter size interaction ($P<.06$) was observed for sow weight loss. Sow weight loss was increased as litter size increased ($P<.08$). However, increased dietary lysine reduced sow weight loss ($P<.01$). Sow backfat loss was not affected by litter size or dietary lysine.

One possible explanation for the response observed between dietary lysine and litter size is the influence of amino acids contributed by sows' tissue catabolism. For example, litter weight gain increased linearly for sows nursing 8 or 9 pigs, whereas sow weight loss was not affected. However, for sows nursing 11 pigs, sow weight loss increased dramatically when sows were not allowed to consume sufficient lysine. Thus, sows in this study may have buffered increased milk production (litter weight gain) by depleting body tissue stores.

The information gathered in this study is currently being used to construct a statistical model that will predict the weekly lysine requirements of lactating sows based upon litter size. Preliminary regression analysis using lysing intake and litter size to predict litter weight gain and sow weight loss is presented in Figures 1 and 2, respectively. In conclusion, these data suggest that sows require at least 42 g/d lysine regardless of litter size to maximize litter weight gain. Improved litter weight gain and reduced sow weight loss increase sow productivity during lactation and should help reduce the nonproductive sow days associated with returning to estrus.

Table 1. Composition of Experimental Diets

	Lysine intake g/d		
Ingredient, %	30.1	42.2	54.8
Corn	75.48	66.20	56.42
Soybean meal (48.5 % CP)	15.17	24.69	34.23
Soybean oil	5.00	5.00	5.00
Monocalcium phosphate (21% P)	2.33	2.16	2.00
Limestone	.97	.90	.93
Salt	.50	.50	.50
Vitamin premix	.36	.36	.36
Trace mineral premix	.18	.18	.18
Amino acid mix	.01	.02	.44
Total	100.00	100.00	100.00
Calculated analysis			
CP, %	13.93	17.73	21.61
Lysine, %	.67	.94	1.22
Ca, %	.90	.90	.90
P, %	.80	.80	.80
Metabolizable energy, Mcal/lb	1,568	1,565	1,565

Table 2. Calculated Amino Acid Levels in Experimental Diets, %

		Lysine intake g/d		
Amino acid	Ratio[a]	30.1	42.2	54.8
Lysine	100	.67	.94	1.22
Arginine	131	.88	1.24	1.54
Histidine	58	.39	.47	.56
Isoleucine	88	.59	.76	.93
Leucine	216	1.45	1.68	1.68
Met & Cys	77	.52	.62	.81
Phe & Tyr	185	1.24	1.54	1.83
Threonine	79	.53	.74	.96
Tryptophan	22	.15	.21	.27
Valine	110	.74	1.04	1.34

[a]Amino acids at 110 % of 1988 NRC recommended levels relative to lysine.

Table 3. The Effect of Dietary Lysine and Litter Size (8 - 11 Pigs) on Sow and Litter Performance

	Lysine intake g/d											
	30.1				42.2				54.8			
Item	8	9	10	11	8	9	10	11	8	9	10	11
No. sows	12	12	10	12	11	13	14	12	12	10	12	12
Litter weight												
D 0[a]	25.7	26.8	28.6	33.0	24.5	28.8	29.7	31.6	23.6	26.0	31.8	32.3
D 7[a]	48.6	53.0	50.3	58.4	47.8	53.8	57.3	58.8	47.9	50.0	57.2	60.5
D 14[a]	79.7	87.1	80.0	96.8	81.0	90.3	96.7	99.4	79.7	83.8	92.0	123.9
Weaning[ab]	100.5	107.3	102.7	121.7	105.6	114.5	115.4	125.5	100.4	110.6	116.6	121.6
Litter gain[ab]	74.7	80.4	74.0	88.6	81.0	85.6	85.6	93.9	76.7	84.6	84.8	89.3
Lactation												
Length, d	20	19	21	20	21	20	19	20	20	20	19	
Sow performance												
Weight loss, lb[abc]	14.7	21.6	15.8	45.8	10.1	17.1	19.2	23.1	8.3	24.8	16.2	20.5
Backfat change, mm	-1.5	0.2	0.1	- 4.8	- 3.3	2.1	0.3	- 2.7	- 1.6	-2.7	- 0.2	- 2.0

[a]Linear litter size effect (P<.01).
[b]Linear dietary lysine effect (P<.10).
[c]Dietary lysine × litter size effect (P<.06).

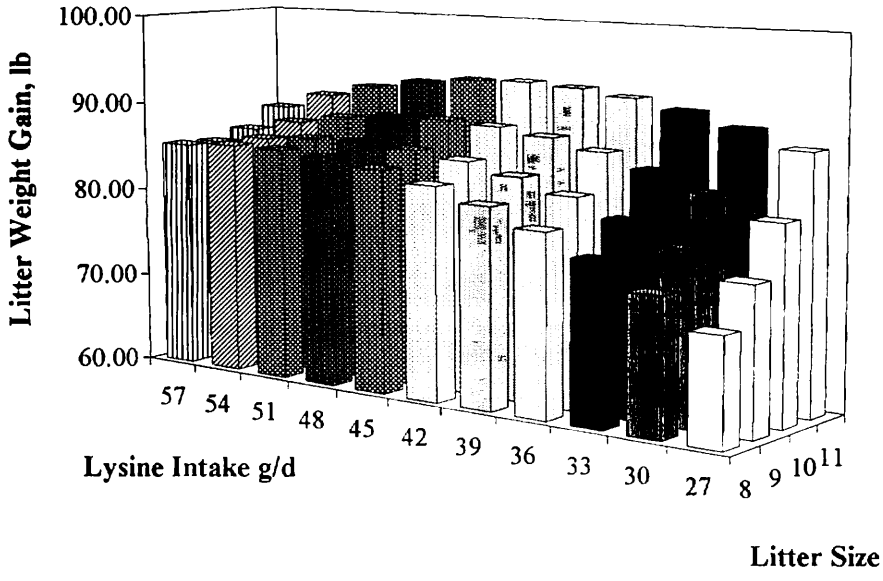


Figure 1. Regression Analysis of Effects of Daily Lysine Intake on Litter Weight Gain

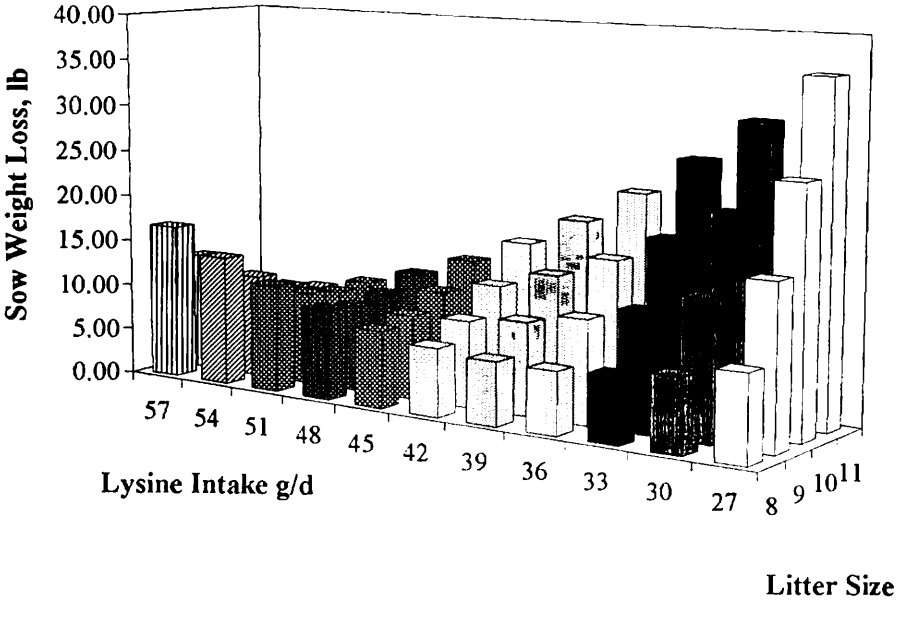


Figure 2. Regression Analysis of Effects of Daily Lysine Intake on Sow Weight Loss

REDUCTION OF CORN PARTICLE SIZE IN LACTATION DIETS IMPROVES SOW AND LITTER PERFORMANCE

K. J. Wondra, J. D. Hancock, G. A. Kennedy,[1]
R. H. Hines, and K. C. Behnke[2]

Summary

One hundred primiparous sows were used to determine the effects of corn particle size in lactation diets on sow and litter performance. Sows were fed corn-soybean meal-based diet with the corn ground to 1,200, 900, 600, or 400 µm. Particle size of corn had no influence on sow weight or backfat loss, or piglet survivability. However, feed intake and digestibilities of DM, N, and GE were increased (6, 5, 7, and 7%, respectively) as particle size was reduced from 1,200 to 400 µm. The combination of increased feed intake and improved digestibilities resulted in increased intake of digestible nutrients. DE intake was increased 14% (13.72 to 15.60 Mcal/d) as corn particle size was reduced from 1,200 to 400 µm. Intakes of digestible DM and N were also increased (11 and 14%, respectively). The increased intake of digestible nutrients resulted in a 11% increase in litter weight gain. Reducing particle size increased severity of keratinization and lesions in the esophageal region of the stomach although all treatment averages were low to moderate, and the change was not associated with reduced sow performance. In conclusion, our data indicate that nutrient intake of sows and litter weight gains can be increased by grinding corn for lactation diets to particle sizes of 600 to 400 µm.

(Key Words: Process, Particle Size, Sow, Lactation, Stomach Ulcers.)

Introduction

A primary objective in sow nutrition is to maximize feed intake during lactation, thus improving litter performance and preventing excessive sow weight loss. In the 1991 KSU Swine Day Report (page 56), Healy et al. reported that reducing particle size of corn and sorghums from 900 to 500 µm improved efficiency of gain by 6% in nursery pigs and 5% in broiler chicks. Those improvements suggested greater energy value of diets as particle size was reduced well below a more typical fineness of 800 to 1,000 µm. However, little is known about optimum processing of ingredients for sow diets. Can grinding corn to a small particle size (i.e., ≤ 600 µm) improve energy status of lactating sows? Would benefits in energy status be overshadowed by problems with palatability and(or) stomach lesions? An experiment was designed to determine the effects of particle size of corn on sow and litter performance, intake of digestible energy and protein, and changes in stomach morphology of primiparous sows.

Procedures

On d 110 of gestation, 100 primiparous sows were randomly assigned to a corn-soybean meal-based diet (Table 1) with the corn ground to one of four particle sizes. The greatest particle size (1,200 µm) was obtained with a roller mill, and the finer particle sizes (900, 600, and 400 µm) were obtained with a hammermill by grinding through 3/8, 1/8, and 3/64 in. screens, respectively. Sows were weighed and scanned ultrasonically for backfat thickness at farrow-

[1]Department of Veterinary Diagnosis.
[2]Department of Grain Science and Industry.

ing and d 21 of lactation to determine weight and backfat loss. Litter size was standardized by d 2 of lactation, and pig weights were recorded at farrowing and weaning. The sows were allowed ad libitum access to feed and water, and feed intake was recorded weekly. On d 18, fecal samples were collected from each sow, and subsequently dried, ground, and analyzed for Cr, DM, N, and GE. At weaning, 35 sows were slaughtered and their stomachs were scored for severity of ulcers and keratinization. The remaining sows were moved to an environmentally controlled gestation facility for estrus detection and breeding. Thus, response criteria included changes in sow weight and backfat during lactation, nutrient intake and digestibility, litter performance, and rebreeding data. All data were analyzed with sow as the experimental unit, and polynomial regression was used to characterize linear or quadratic effects of particle size reduction.

Table 1. Composition of Basal Diet[a]

Ingredient	% of diet
Corn	74.37
Soybean meal	21.04
Lysine-HCl	.05
Monocalcium phosphate	2.18
Limestone	1.11
Salt	.50
Vitamins and minerals[b]	.50
Chromic oxide[c]	.25
Total	100.00

[a]The basal diet was formulated to .85% lysine, .9% Ca, .8% P, and 1.5 Mcal DE/lb.

[b]KSU vitamin, mineral, and Se mixes with added biotin (200 g/ton) and folic acid (1.5 g/ton).

[c]Used as an indigestible marker.

Results and Discussion

Physical characteristics of the corn and diets are given in Table 2. Actual particle sizes of the corn were very close to the targeted particle sizes for all treatments. Particle sizes of the diets were larger than those of corn, probably because of the large particle size of other ingredients such as soybean meal. Variation in particle size (Sgw) decreased as the corn was milled to smaller mean particle sizes. Although the effects of particle size uniformity are not fully understood, another study (p. 126) indicated that increased particle uniformity results in increased nutrient digestibility.

Sow and litter performance is given in Table 3. Postfarrowing sow weight, weaning sow weight, postfarrowing backfat thickness, and weaning backfat thickness were similar for all treatments. Thus, sow weight and backfat losses during lactation were not affected by particle size of corn in the diet ($P>.30$). Daily feed intake increased ($P<.05$) as corn particle size was decreased from 1,200 to 400 µm (9.23 and 9.76 lb/d, respectively). This indicated that no palatability problems were caused by finely ground corn.

Equalizing litters ensured no difference ($P>.30$) in number or weight of pigs at initiation of the experiment. Also, number of pigs weaned and survivability were similar ($P>.30$) among treatments. However, a numerical increase occurred in litter weight at weaning (from 103.4 to 110.5 lb) as particle size was reduced. Consequently, litter weight gain was increased by 11% as particle size was reduced ($P<.05$) from 1,200 to 400 µm. Increased litter weight gain can probably be attributed not only to increased ADFI for sows fed the 400 µm treatment, but also to increased digestibility of DM, N, and GE ($P<.001$). Digestible energy value of the diet with 400 µm corn was 7% greater than DE of the diet with 1,200 µm corn. As a result, intake of DE was increased 14% (from 13.72 to 15.60 Mcal/d) as corn particle size was reduced from 1,200 to 400 µm ($P<.001$). Sows fed the 400 µm diet also had 14% greater intake of digestible N than sows fed the 1,200 µm diet. With increased

digestibilities of nutrients comes decreased excretion of nutrients. DM excretion was reduced 22% by reducing corn particle size from 1,200 to the 400 µm. In addition, N excretion from sows fed the 400 µm treatment was 31% lower than N excretions from sows fed the 1,200 µm treatment.

Although numerical variability occurred in percentage of the sows returning to estrus and days to estrus, no significant differences or trends were observed in the data. However, reducing particle size from 1,200 to 400 µm increased the severity of stomach lesions and stomach keratinization. No negative effects on animal health or well-being were noted in this experiment, but gastric ulceration in swine seems to be influenced greatly by genetics and stressful environmental conditions. Thus, interactions with those factors may affect the extent to which particle size of lactation diets can be reduced.

In conclusion, our results indicate that intake of digestible nutrients is increased and excretion of DM and N as feces is reduced as particle size of lactation diets is reduced. Furthermore, litter performance was enhanced by grinding lactation diets to a particle size of 600 to 400 µm.

Table 2. Characteristics of Corn and Diets

	Particle size treatment, µm			
Item	1,200	900	600	400
Grain characteristics				
Hammermill screen size, in.	— [a]	3/8	1/8	3/64
Mean particle size, µm	1,268	885	597	408
Variation in particle size, Sgw	2.17	2.29	1.87	1.45
Diet characteristics				
Mean particle size, µm	1,298	925	619	476
Variation in particle size, Sgw	2.16	2.24	1.95	1.76

[a]The 1,200 µm treatment was milled through a roller mill.

Table 3. Effects of Corn Particle Size on Sow and Litter Performance[a]

	Particle size, µm				
Item	1,200	900	600	400	CV
Sow wt postfarrowing, lb	383.8	385.9	380.2	386.6	7.0
Sow wt at weaning, lb	360.7	362.7	364.3	368.4	7.8
Lactation wt loss, lb	23.1	23.2	15.9	18.2	129.4
Fat depth postfarrowing, in.	1.14	1.23	1.20	1.15	13.8
Fat depth at weaning, in.	1.02	1.09	1.08	1.04	15.4
Lactation fat loss, in.	.12	.13	.12	.11	78.7
ADFI, lb[b]	9.23	9.35	9.69	9.76	10.7
Apparent nutrient digestibility, %					
DM[d]	84.17	85.08	86.39	88.31	2.2
N[d]	83.22	85.27	86.85	89.06	2.9
GE[d]	83.80	85.30	87.08	89.97	2.4
Dig DM intake, lb/d[d]	6.98	7.16	7.54	7.77	10.3
Dig N intake, lb/d[d]	.204	.212	.224	.232	10.0
DE intake, Mcal/d[d]	13.72	14.13	14.95	15.60	10.3
DM excretion, lb/d[d]	1.34	1.26	1.20	1.04	20.7
N excretion, lb/d[d]	.042	.037	.034	.029	26.1
Litter performance					
Initial litter size	9.7	10.1	10.1	10.1	14.6
Pigs weaned	9.1	9.0	9.5	8.9	11.8
Survivability, %	93.4	90.9	93.9	89.7	9.5
Initial litter wt, lb	26.5	26.5	27.0	25.4	15.8
Final litter wt, lb	103.4	107.3	111.4	110.5	15.6
Litter wt gain, lb[b]	76.9	80.8	84.3	85.1	17.3
Return to estrus, %[g]	84.5	87.6	64.9	89.7	47.5
Days to estrus[h]	5.8	5.0	5.2	5.8	63.1
Stomach keratinization[cef]	.2	1.1	.5	1.7	29.2
Stomach lesions[cef]	.3	.4	1.7	.9	29.3

[a]100 primiparous sows (21 to 29 sows/trt).
[b,c,d]Linear effect of particle size reduction (P<.05, P<.01, and P<.001, respectively).
[e]Quadratic effect of particle size reduction (P<.01).
[f]Scored on a scale of 0 to 3 (0 = normal and 3 = severe).
[g]Percentage of sows returning to estrus within 30 d of weaning.
[h]Days for sows returning to estrus within 30 d of weaning.

COMPUTERIZATION OF SOW FEEDING AND ESTROUS DETECTION — TESTS UNDER LOW-INVESTMENT HOUSING CONDITIONS IN KANSAS[1]

R. M. Blair, D. A. Nichols, and D. L. Davis

Summary

In Exp. 1, weight change, backfat thickness, and litter size were compared for gilts fed individually or with a computer-controlled electronic sow feeder provided by Osborne Ind., Inc. and NEDAP-Poiesz, B.V. Twenty gilts were fed by each method, and no treatment effects were observed. In Exp. 2, electronic monitoring of visits to a boar were studied to evaluate the potential of the data to predict time of estrus. A very good correlation between boar visitation and estrous behavior was obtained. The data indicate that gilts can be fed with computer-controlled equipment under outside housing conditions in Kansas. Further, there is potential for developing a computer controlled system to electronically detect estrus in pigs.

(Key Words: Pig, Electronic Feeding, Reproduction, Estrus.)

Introduction

This project's goal was to evaluate the ability of computer-controlled equipment provided by Osborne Ind., Inc. and NEDAP-Poiesz, B.V. to provide feed for, and detect estrus in, gilts when installed in outside lots in Kansas. The test conditions are similar to those used on many Kansas swine farms.

The Electronic Estrous Detection (EED) system is not presently marketed in the U.S., and equipment from the Osborne/Porcode feeding station was adapted to estimate the amount of time gilts spent visiting a boar.

Procedures

Exp. 1. Electronic Sow Feeding

The first experiment compared gilts housed in outside lots and fed either individually in a feeding stall (once/d) or with the Electronic Sow Feeder (ESF) system. A representation of the pens is provided in Fig. 1. Gilts were each fed 4.3 lb/d of a complete sorghum grain-soybean meal diet that met or exceeded all Kansas State University and National Research Council recommendations for breeding/gestating gilts. The weights of feed delivered with each auger turn by the ESF were .215 lb and .219 lb during pretrial testing 27 days and 15 days before the start of the experiment and .214 lb at 31 days after the start of the experiment. The software was programmed as delivering .215 lb/auger turn. Therefore, 20 auger turns were required to deliver 4.3 lb. Control gilts were fed once/d with a scoop that contained, when full, 4.3 lb of the same diet.

Training gilts to use the ESF. Training procedures were those recommended by Osborne/Porcode. On the first day, gilts were coaxed into the feeding station with feed sprinkled on the floor of the ESF. On subsequent days, only gilts that had not used the station were assisted. Individual gilts varied in the speed with which they began using the

[1]The authors appreciate funding for these experiments provided by Osborne Industries, Inc., Osborne, KS 67473, NEDAP-Poiesz, B.V., Heneglo, The Netherlands, and the Kansas Technology Enterprise Corporation, Topeka, KS 66603.

ESF without assistance. The majority began using the station by 3 days, and all but 1/20 (5%) gilts were trained by 7 days. The remaining gilt required 16 days before she routinely used the ESF unassisted.

Data collection. Gilts (20/treatment) were weighed when 30 to 35 days pregnant and moved to either the ESF or control pen. A collar with exponder that provided electronic identification was placed around the neck of each gilt assigned to the ESF pen. After 7 days (training period), all gilts were weighed a second time and probed ultrasonically for backfat depth at the last rib. Gilts were moved as a group to individual farrowing stalls on d 93 to 111 of gestation and fed individually 4 lb/d (1.8 kg) of the gestation diet until farrowing.

Replacement of lost collars. Gilts were checked each day for lost collars. All lost collars were found, although some were not found for a few days. Therefore, extra collars were available and placed on gilts whose collar could not be immediately found. Collars were occasionally lost in mud puddles and were later recovered by pigs rooting in the mud. Collars were lost on 44 occasions during the trial. Collar loss predominantly occurred for a few gilts, and in subsequent trials with sows, hardly any collar loss occurred. The relatively high incidence in this trial might be attributable to use of gilts or differences in collar adjustment by the different personnel conducting the two experiments.

Exp. 2. Electronic Estrous Detection

These studies were conducted to evaluate the efficacy of electronic monitoring of visits to the boar, a key behavior exhibited by estrous sows and gilts. The pen was arranged as depicted in Fig. 1 according to recommendations provided by Osborne Ind. An initial group of 18 sows was placed in the pen at weaning. A boar was placed in the estrous detection area on the third day after weaning, and data were recorded using a 12-h cycle. Sows were also checked for estrus once/d. These initial data indicated a close relationship between the first detection of estrus and the amount of time visiting the boar. For estimating boar visitation, an antenna identical to that used in the feeding station was installed at the only place sows could see the boar. The feed interval was set at 6 sec, the calibration at .1 lb/dispense and the total feed at 10.0 lb. Therefore, even though no feed delivery equipment was present at this station, the computer reported a feed balance that could be converted to minutes visiting the boar.

To gain more insight into the diurnal pattern of boar visitation, we next set the feed cycle at 6 h to provide a report every 6 h. Estrus was checked once/d.

Results and Discussion

Weight and backfat data are presented in Table 1. Twenty gilts were initially assigned to each treatment. One gilt in each treatment returned to estrus and was removed from the experiment. There were no ($P > .4$) treatment effects on gilt weight or backfat depth.

Farrowing and litter traits are presented in Table 2. No treatment effects were detected ($P > .80$). Individual pig birth weights and the deviation from the mean birth weight for each pig (Levine's test) are given in Table 3. No treatment effects ($P > .80$) on pig birth weight were observed. The deviations in birth weight may represent a trend ($P = .13$) for decreased deviations in birth weight for litters farrowed by ESF gilts. However the difference is small (.09 lb). An experiment to demonstrate statistical significance with the variation observed in this experiment would require 50 to 60 litters/treatment. Therefore, no conclusions about the uniformity of birth weights can be drawn from this experiment.

Results for the second and third estruses after weaning are represented in Figs. 2 and 3, respectively. Data are centered on 12:00 h of the day when estrus was first detected.

There is an obvious correlation between visitation time and estrus. Fig. 5 illustrates the variation in boar visitation among sows by providing data on extremes in boar visitation. Inspection of the data suggests a correlation between the amounts of boar visiting at second estrus and at third estrus. That is, a sow tended to spend similar amounts of time visiting the boar at the two estruses. This should be evaluated further to gain insight into estrous behavior as reflected in the EED data. Perhaps the sows that only visit the boar for a few minutes show only a low intensity of estrous behavior, or perhaps these particular sows didn't like the boar penned in the detection pen. The possibility of competition for access to the boar pen should be evaluated, also.

Work is required to evaluate the fertility of gilts or sows mated based on their electronically detected boar visiting. Data so far suggest that sows might be considered in estrus when the accumulated boar visiting exceeds 9 min per day. Mating on that day and the subsequent days until the boar is no longer accepted might achieve good fertility. However, it is clear that sows begin visiting the boar before they are in estrus; therefore, some sows might not be in estrus when first scheduled for mating by the rule suggested above. Therefore, if a sow doesn't accept the boar even though she has accumulated 9 min of boar visiting, she could be rechecked at 24-h intervals until she accepts the boar and then mated at 24-h intervals until she no longer accepts the boar.

In conclusion, electronic Sow Feeding and Estrous Detection were tested under low-investment, outside housing in Kansas. Both systems performed well. Further monitoring of the ESF in outside lots with a variety of production systems and environmental conditions should be undertaken to determine the full application possibilities. EED should receive more in-depth evaluation. It may be the first real innovation in estrous detection for handmating and could significantly impact swine production systems.

Table 1. Weight and Backfat Depth of Gilts Fed with an Electronic Sow Feeder (ESF) or with a Scoop

		Weight, lb			Backfat depth, in	
Treatment	n	Initial	After training	Before farrowing	After training	Before farrowing
Control	19	297	296	375	.86	.92
ESF	19	299	294	379	.81	.87
Pooled standard error		4.1	3.5	5.3	.04	.04

Table 2. Farrowing and Litter Traits for Gilts Fed with an Electronic Sow Feeder (ESF) or a Scoop

			Total pigs farrowed		Live pigs farrowed	
Treatment	No. of pregnant gilts assigned[a]	No. of gilts farrowing	No.	Litter wt, lb	No.	Litter wt, lb
Control	20	19	9.3	28.0	8.7	26.0
ESF	20	19	9.1	26.6	8.8	26.1
Pooled standard error	—	—	.62	1.7	.59	1.6

[a]Assigned on d 30 to 35 of pregnancy.

Table 3. Birth Weights of Pigs Farrowed by Sows Fed with an Electronic Sow Feeder (ESF) or Scoop during Gestation

Treatment	No. of litters	Birth weight, lb	Deviation from mean birth weight for the litter, lb
Control	19	2.94	.43
ESF	19	2.96	.34
Pooled standard error	—	.11	.04

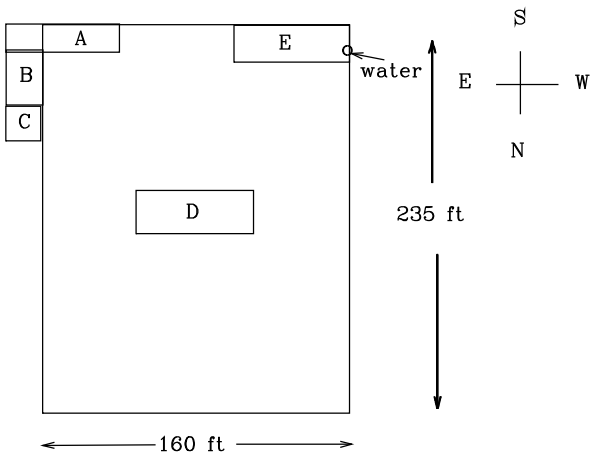


Figure 1. The configuration of the pen used for testing the Electronic Sow Feeder (ESF) and Electronic Estrous Detector (EED). A. Estrous detection pen (11.5 × 54 ft); B. Boar pen (9.2 × 11.5 ft) equipped with antenna for EED; C. Boar house (6 × 9.2 ft); D. Cement pad with 2, 11 × 18 ft houses for gilts; E. Cement pad (18 × 43 ft) with ESF station. The ESF station is covered by a two-sided shed, open to the east and south.

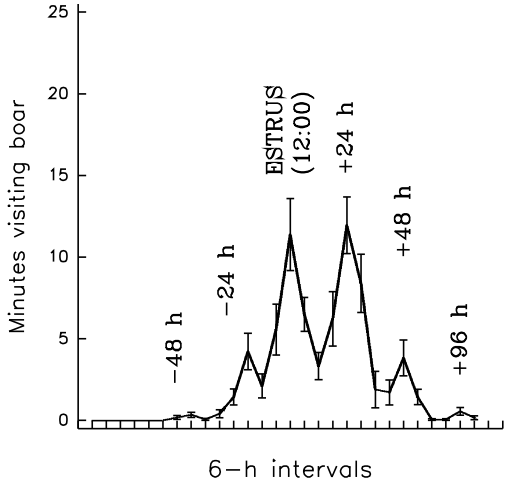


Figure 2. Boar visitation during the second post-weaning estrus. Data are centered on 12:00 h of the first day of estrus. The x-axis represents 7 d in 6-h intervals.

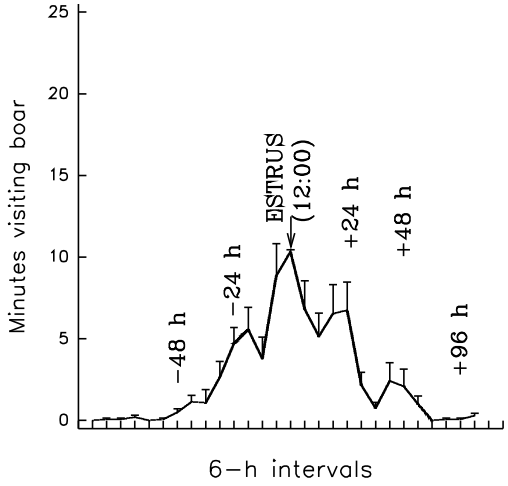


Figure 3. Boar visitation during the third post-weaning estrus. Data are centered on 12:00 h of the first day of estrus. The x-axis represents 7 d in 6-h intervals.

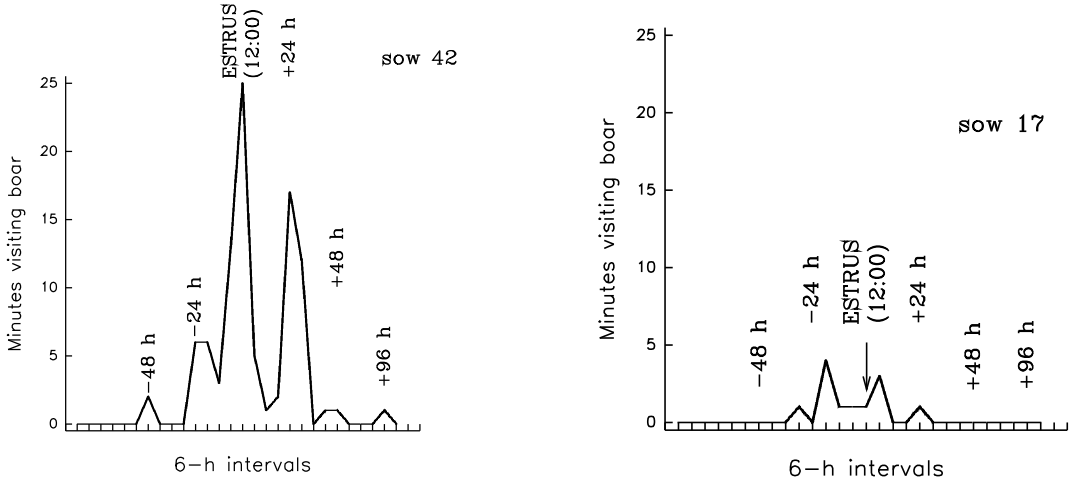


Figure 4. Boar visitation by two sows that illustrate the most (sow 42) and least (sow 17) amount of visiting. Data are centered on 12:00 h of the first day of estrus. The x-axis represents 7 d in 6-h intervals.

INFLUENCE OF WEANING WEIGHT AND GROWTH DURING THE FIRST WEEK POSTWEANING ON SUBSEQUENT PIG PERFORMANCE[1]

M. D. Tokach, R. D. Goodband, J. L. Nelssen, and L. J. Kats

Summary

A total of 1,350 pigs was used in three growth trials to determine the influence of weaning weight and average daily gain during the first week postweaning on subsequent growth performance. Average initial weight and age were 13.7 lb and 21 d, respectively. Pigs were weighed on d 0, 7, 28, and 56 postweaning in all three trials. Pigs were also weighed at market in trial 1. Weaning weight influenced postweaning growth performance such that each additional pound at weaning translated into approximately 2 lb by d 56 postweaning and 4 lb at market. These results indicate the importance of maximizing milk production during lactation to increase litter weaning weights. Average daily gain during the first week postweaning also had a major impact on subsequent growth performance. Pigs that gained greater than .5 lb/d during the first week postweaning were 17 lb heavier at market than pigs that lost weight during the first week postweaning. These results provide further evidence that nutritional programs designed to increase starter pig performance also influence performance during the subsequent grower and finisher phases.

(Key Words: Starter, Performance.)

Introduction

Pig throughput has a major impact on profitability of modern swine confinement operations. Several swine specialists have discussed the importance of obtaining heavier weaning weights to improve pig performance from weaning to market. However, few attempts have been made to determine the influence of weaning weight on subsequent growth.

Management and nutrition of the newly weaned pig also are thought to influence subsequent performance. However, little information is available to accurately characterize the impact of initial growth in the nursery on subsequent growth performance. Therefore, this trial was conducted to determine the influence of weaning weight and weight gain during the first week postweaning on subsequent growth performance.

Procedures

A total of 1,350 pigs was used in three growth trials to determine the influence of weaning weight and average daily gain during the first week postweaning on subsequent growth performance. Average initial weight was 13.7 lb with a range of 10 to 20 lb. Average initial age was 21 d with a range of 17 to 25 d. Pigs were weighed on d 0, 7, 28, and 56 postweaning in all three trials. Pigs were also weighed at market in trial 1.

Pigs were housed in an environmentally controlled nursery from d 0 to 28 postweaning. On d 28, pigs were moved to an environmentally controlled grower where they were housed from d 28 to 56 postweaning. Pigs were housed in a modified open-front

[1]The authors wish to thank Dale Keesecker and Keesecker Agribusiness, Washington, KS, for use of facilities and animals in this experiment.

finishing building from d 56 postweaning to market. Pigs were housed 12 to 14 per pen in the nursery and grower and 24 to 30 per pen in the finisher.

Pigs used in this trial were involved simultaneously in three nutrition trials with different experimental diets. However, general diet sequence was to feed a high nutrient density diet containing 10% plasma protein and 20% dried whey for the first 7 d postweaning. Pigs were then fed a corn-soybean meal diet containing 10% dried whey and 2.5% spray-dried blood meal from d 7 to 28. Simple milo-soybean meal diets were fed from d 28 postweaning until market. Pigs were allowed ad libitum access to feed and water.

Data was examined in a retrospective manner. Pigs were categorized by weaning weight and weight gain during the first week postweaning for the statistical analyses. Weaning weight was used as a covariate to examine the influence of weight gain during the first week postweaning on subsequent performance.

Results and Discussion

Weaning weight influenced (P<.001) postweaning growth performance such that each additional pound at weaning transmitted into approximately 2 lb by d 56 postweaning and 4 lb at market (Table 1). These results indicate the importance of maximizing milk production during lactation to increase litter weaning weights. Producers should consider several management options to increase milk production, including selecting a genetic background of high production, maintaining proper body condition, and maximizing intake of a properly formulated diet during lactation.

Average daily gain during the first week postweaning had a major impact (P<.001) on subsequent growth performance (Table 2). Pigs that gained > .5 lb per day during the first week were 3.5 lb heavier on d 7 postweaning than pigs that did not gain any weight during the first week postweaning. This weight advantage increased to 10 lb by d 56 postweaning and to 17 lb at market (d 156 postweaning). The 17 lb translates to market advantage of 10 d (marketed at 240 lb).

Other research has demonstrated that including milk products or spray-dried blood meal in the starter diet increases subsequent growth performance. These results provide further evidence that nutritional programs designed to increase starter pig performance also influence performance during the subsequent grower and finisher phases.

Figure 1 combines the influence of weaning weight and ADG during the first week postweaning on subsequent growth. This figure indicates that ADG during the first week postweaning has an influence on pig weight on d 56 postweaning for both light and heavy pigs. However, a fast start in the nursery appears to be especially important for pigs that are lighter at weaning.

In conclusion, these data indicate the importance of properly formulated three-phase starter programs and high-producing sows to maximize throughput in modern swine operations.

Table 1. Influence of Weaning Weight on Pig Performance[a]

	Wt (lb) on postweaning d			
Weaning wt, lb	28	56	156	d to market
10 - 11	27.1	60.8	- - -	- - -
12 - 13	30.6	66.5	236.2	181.3
14 - 15	33.3	70.0	240.4	179.2
16 - 17	35.7	74.6	248.6	174.1
18 - 20	37.9	77.8	250.4	171.8

[a]Pigs were weaned at an average age of 21 d with a range of 17 to 25 d. Data for d 28 and 56 are from 1350 pigs. Market weight data (d 156) are from 566 pigs.

Table 2. Influence of Weight Gain During the First Week Postweaning on Subsequent Performance[a]

	Wt (lb) on postweaning d			
Wk 1 ADG, lb	28	56	156	d to market
≤ 0	32.4	66.3	232.2	183.3
0 - .33	35.3	70.2	238.4	179.2
.33 - .50	37.3	71.6	245.1	175.2
> .50	40.1	76.6	249.8	173.0

[a]Pigs were weaned at an average age and wt of 21 d and 13.7 lb, respectively. Data for d 28 and 56 are from 1350 pigs. Market weight data (d 156) are from 566 pigs.

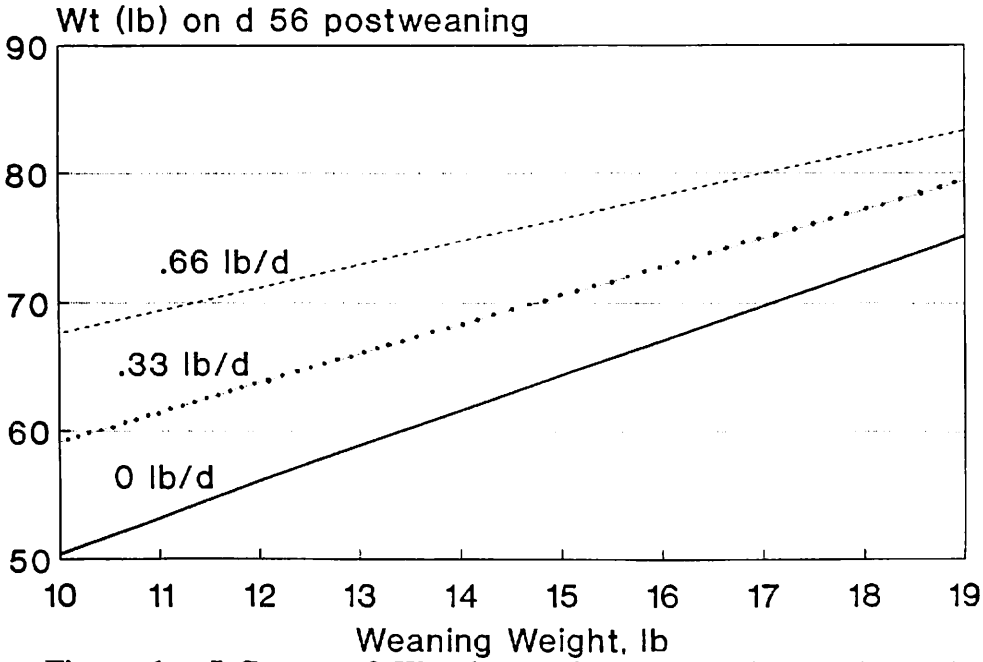


Figure 1. Influence of Weaning Weight and Weight Gain during the First Week Postweaning (0, .33, or .66 lb/d) on Weight on D 56 Postweaning.

EFFECTS OF SPRAY-DRIED PORCINE PLASMA IN THE HIGH NUTRIENT DENSITY DIET[1]

L. J. Kats, R. D. Goodband, J. L. Nelssen, M. D. Tokach, K. G. Friesen, J. A. Hansen, and S. S. Dritz

Summary

A total of 740 weanling pigs was used in three separate experiments to evaluate the effects of additions of spray-dried porcine plasma in the HNDD starter diet. In Trial 1, 534 weanling pigs (initially 14.1 lb and 21 d of age) were used to evaluate various levels of spray-dried porcine plasma. Pigs were assigned to one of six experimental diets with either 0, 2, 4, 6, 8, or 10% spray-dried porcine plasma replacing dried skim milk. Pigs were fed this diet for the first 14 days postweaning, when they were switched to a common phase II diet (d 14 to 28). During phase I (d 0 to 14), linear and quadratic improvements occurred in average daily gain and average daily feed intake. No significant differences occurred in feed efficiency for any phase of the experiment. In Trial 2, 68 weanling pigs (12.7 lb and 21 d of age) were used to determine if supplemental methionine is needed for diets containing high levels of spray-dried porcine plasma. Pigs were fed identical diets containing 20% dried whey, 7.5% spray-dried porcine plasma, and 1.75% spray-dried blood meal except that one diet contained 2 lb/ton supplemental DL-methionine. Pigs receiving diets containing supplemental methionine had improved average daily gain and average daily feed intake during the first week postweaning. Feed efficiency also was improved for the overall trial. In Trial 3, 144 weanling pigs (initially 12.6 lb and 19 d of age) were used in a 21-d growth trial to evaluate two different sources of spray-dried porcine plasma. Pigs were assigned one of two diets containing 20% dried whey and 10% spray-dried porcine plasma. Pigs receiving the diet containing spray-dried porcine plasma obtained from source 1 had improved average daily gain for all phases of the experiment and increased average daily feed intake for d 0 to 14 and d 0 to 21 compared to pigs fed the diet containing spray-dried porcine plasma from source 2. There were no differences in feed efficiency. In conclusion, these trials demonstrate three key points concerning spray-dried porcine plasma: 1) starter pig performance is improved linearly with increasing levels of spray-dried porcine plasma through 10% of the diet; 2) DL-methionine must be added to diets containing high levels of spray-dried porcine plasma to obtain optimal performance; and 3) there are differences in commercially available sources of spray-dried porcine plasma.

(Key Words: Starter, Spray-dried Porcine Plasma, Performance.)

Introduction

Previous research conducted at Iowa State University has shown the optimum level of spray-dried porcine plasma in the phase I high nutrient density diet to be 6 to 8%. However, spray-dried porcine plasma replaced soybean meal in those experiments without holding methionine at a constant

[1]Appreciation is expressed to Merrick's, Inc., for donating plasma protein and providing partial financial support for trial 3. The authors wish to thank Dale Keesecker and Keesecker Agribusiness, Washington, KS, and Steve Eichman and Eichman Farms, St. George, KS, for use of facilities and animals in these experiments.

level. Recommendations by the NRC (1988) suggest that methionine becomes the first-limiting amino acids in diets containing greater than 6% spray-dried porcine plasma. Therefore, it is possible that starter pigs would respond to a higher level of spray-dried porcine plasma, if sufficient synthetic methionine were added to the diet. In addition, multiple sources of spray-dried porcine plasma are available to the swine industry. These sources may vary in quality for use in starter pig diets. Therefore, three experiments were conducted to: 1) determine the optimal level of spray-dried porcine plasma in the phase I diet; 2) evaluate the need for supplemental methionine in diets containing high levels of spray-dried porcine plasma; and 3) compare different sources of spray-dried porcine plasma in the phase I diet.

Procedures

Trial 1. A total of 534 weanling pigs (initially 14.1 lb and 21 d of age) was used on a commercial operation to evaluate various levels of spray-dried porcine plasma in the phase I diet. Pigs were blocked by weight and sex to the six experimental treatments. Pigs were housed 14 or 15 pigs per pen (six pens per treatment) in an environmentally controlled nursery with metal flooring and allowed ad libitum access to feed and water. Pigs and feeders were weighed on d 7, 14, 21, and 28 after weaning to determine ADG, ADFI, and F/G.

Experimental diets (Table 1) were formulated to contain either 0, 2, 4, 6, 8, or 10% spray-dried porcine plasma. Spray-dried porcine plasma replaced dried skim milk in the diet to maintain a constant level of soybean meal in all diets. Lactose also was added to the diet as skim milk was removed to maintain the same lactose level. All diets were formulated to contain 1.5% lysine, .41% methionine, .9% Ca, and .8% P. Methionine was held constant by adding DL-methionine to the diets containing spray-dried porcine plasma. Pigs were fed the experimental diets for the first 14 days postweaning, when they were switched to a common phase II (d 14 to 28) diet. The phase II diet contained 10% dried whey and 2.5% spray-dried blood meal and was formulated to 1.25% lysine.

Trial 2. A total of 68 weanling pigs (initially 12.7 lb and 21 d of age) was used to determine if supplemental methionine was limiting in a diet containing high levels of spray-dried porcine plasma. Pigs were allotted by sex, weight, and ancestry to pens containing five to six pigs per pen. Pens were assigned to one of two diets (Table 2) that contained 20% dried whey, 7.5% spray-dried porcine plasma, and 1.75% spray-dried blood meal and were formulated to contain 1.5% lysine. Diets were identical except for the inclusion of 2 lb/ton supplemental DL-methionine in one diet. Pigs were fed the same diet for the entire 21-d trial. Pigs and feeders were weighed on d 7, 14, and 21 postweaning to evaluate ADG, ADFI, and F/G.

Trial 3. A total of 144 weanling pigs (initially 12.6 lb and 19 d of age) was used to evaluate two different sources of spray-dried porcine plasma in the phase I diet. Pigs were allotted by weight to pens containing eight to nine pigs per pen. Pens were randomly assigned to one of two diets (Table 2) containing either a spray-dried porcine plasma from source 1 or source 2. Diets were formulated with 20% dried whey and 10% spray-dried porcine plasma and were formulated to contain 1.5% lysine with the only difference being the source of plasma. Pigs received this diet for the entire 21-d trial. Pigs and feed disappearance were measured on d 7, 14, and 21 postweaning to evaluate ADG, ADFI, and F/G.

Results and Discussion

Trial 1. During phase I (d 0 - 14 postweaning) linear ($P<.01$) and quadratic ($P<.11$) improvements occurred in ADG, with pigs receiving diets containing 10% spray-dried porcine plasma having the greatest performance (Table 3). Average daily feed intake also improved linearly ($P<.01$) and

quadratically (P<.04) during phase I, with pigs receiving 8% and 10% spray-dried porcine plasma consuming the most feed. During the overall period, ADG also followed a linear (P<.01) trend, with pigs receiving 10% spray-dried porcine plasma having the greatest performance. No significant differences occurred in feed efficiency (F/G) for any phase of the trial. Results of this trial indicate that starter pig performance is improved linearly as spray-dried porcine plasma increases from 0 to 10% of the diet. These results contradict earlier research at Iowa State University that indicated that pig performance was maximized at the 6% plasma level. The major difference between this experiment and the Iowa State trials was the methionine level in the diets. Synthetic methionine must be added to diets containing greater than 6% spray-dried porcine plasma to maintain the methionine:lysine ratio above the ratio suggested by NRC (1988). Therefore, the Iowa State research may have reflected the point where methionine becomes deficient rather than the optimal plasma level.

Trial 2. Pigs receiving the diet containing supplemental methionine had improved (P<.05) ADG during the first week of the trial (Table 4). This improvement in performance led to the slight improvement (P<.15) in ADG for the overall trial. Average daily feed intake was increased (P<.05) from d 0 to 7 for pigs receiving supplemental methionine. Feed efficiency also was improved for d 0 to 14 (P<.11) and the overall trial (P<.05).

These results provide evidence that diets containing high levels of spray-dried porcine plasma are deficient in methionine unless DL-methionine is added to the diet. This evidence supports the conclusions discussed for trial 1.

Trial 3. During the first week (d 0 to 7), pigs receiving diets containing spray-dried porcine plasma from source 2 had improved ADG (P<.001), ADFI (P<.02), and F/G (P<.15) compared to pigs fed porcine plasma from source 1 (Table 5). Pigs receiving diets containing plasma from source 2 also had improved (P<.01) ADG and ADFI for d 0 to 14. A similiar trend was seen for the overall trial with increased (P<.02) ADG and a slight improvement (P<.12) in ADFI.

Although large differences in pig performance would not normally be expected when dietary treatments were nearly identical, these results indicate a very important factor to take into consideration. Differences in the handling and processing of spray-dried porcine plasma can be very influential in affecting performance. Quality control of spray-dried porcine plasma or any other feed ingredient used in diet formulation can play a major role in optimizing performance and should be considered when purchasing ingredients for use in swine diets.

Table 1. Diet Composition (Trial 1)[a]

	Spray-dried porcine plasma, %						
Item, %	0	2	4	6	8	10	Phase II
Corn	30.66	30.66	30.66	30.66	30.66	30.56	-
Milo	-	-	-	-	-	-	55.89
Soybean meal (48.5% CP)	19.52	19.52	19.52	19.52	19.52	19.52	24.08
Dried whey, edible grade	20.00	20.00	20.00	20.00	20.00	20.00	10.00
Spray-dried porcine plasma	-	2.00	4.00	6.00	8.00	10.00	-
Dried skim milk	20.00	16.00	12.00	8.00	4.00	-	-
Lactose	-	2.00	4.00	6.00	8.00	10.00	
Soy oil	5.00	5.00	5.00	5.00	5.00	5.00	3.00
Spray-dried blood meal	-	-	-	-	-	-	2.50
Monosodium phosphate (18% P)	1.52	1.24	1.00	.76	.29	-	
Limestone	1.22	1.12	1.04	.96	.75	.65	.82
Antibiotic[b]	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Monocalcium	-	.47	.90	1.32	2.00	2.48	1.92
Salt	.30	.20	.10	-	-	-	
Vitamin premix	.25	.25	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15	.15	.15
L-Lysine HCl	.15	.12	.098	.072	.046	.021	.15
Vitamin E premix	.10	.10	.10	.10	.10	.10	.10
Copper sulfate	.075	.075	.075	.075	.075	.075	.075
Selenium premix	.050	.050	.050	.050	.050	.050	
D-L Methionine	-	.024	.049	.075	.10	.12	.050

[a]Diets were formulated to contain 1.50% lysine, .41% methionine, .9% Ca, and .8% P in phase I and 1.25% lysine in phase II.
[b]Provided 150 g/ton Apramycin in phase I and 50 g/ton Carbadox in phase II.

Table 2. Diet Composition (Trial 2 and 3)

Item, %	Trial 2[a]	Trial 3[a]
Corn	44.23	45.47
Soybean meal, 48.5% CP	16.43	15.96
Dried whey, edible grade	20.00	20.00
Spray-dried porcine plasma	10.00	7.50
Spray-dried blood meal	-	1.75
Soy oil	5.00	5.00
Monocalcium phosphate, 18% P	1.92	1.91
Antibiotic[b]	1.00	1.00
Limestone	.69	.69
Vitamin premix	.25	.25
Trace mineral premix	.15	.15
L-Lysine HCL	.10	.10
D-L Methionine[c]	.10	.10
Copper sulfate	.075	.075
Selenium premix	.05	.050

[a]Diet was fed for the entire 21 d trial and was formulated to contain 1.5% lysine.
[b]Provided 150 g/ton Apramycin.
[c]Methionine replaced corn in Trial 2 in the + methionine diet.

Table 3. Performance of Pigs Fed Various Levels of Spray-Dried Porcine Plasma (Trial 1)[a]

	Spray-dried Porcine Plasma, %						
Item	0	2	4	6	8	10	CV
d 0 - 14							
ADG, lb[bc]	.36	.45	.47	.52	.54	.56	13.64
ADFI, lb[bd]	.45	.53	.56	.63	.66	.66	9.64
F/G	1.26	1.19	1.18	1.21	1.22	1.19	7.85
d 0 - 28							
ADG, lb[b]	.64	.72	.68	.73	.71	.72	6.67
ADFI, lb[be]	.90	.99	.95	1.03	1.01	1.01	5.34
F/G	1.40	1.38	1.38	1.40	1.41	1.39	5.21

[a]534 weanling pigs were used (initially 14.1 lb and 21 d of age), 14 to 15 pigs/pen with 6 pens/treatment.
[b]Linear response ($P < .01$).
[c]Quadratic response ($P < .11$).
[d]Quadratic response ($P < .04$).
[e]Quadratic response ($P < .08$).

Table 4. Growth Performance of Pigs Fed Supplemental Methionine in a High Nutrient Density Diet Containing Spray-Dried Porcine Plasma (Trial 2)[a]

Item	+ Methionine	Control	CV
d 0 - 7			
ADG, lb[b]	.55	.46	11.68
ADFI, lb[c]	.57	.48	9.88
F/G	1.02	1.02	4.34
d 0 - 14			
ADG, lb	.68	.61	11.68
ADFI, lb	.77	.75	7.36
F/G[d]	1.13	1.23	7.52
d 0 - 21			
ADG, lb	.83	.75	9.46
ADFI, lb	.99	.97	7.64
F/G[b]	1.19	1.28	5.46

[a]68 weanling pigs were used (initially 12.7 lb and 21 d of age), 5-6 pigs/pen.
[b]$P < .05$
[c]$P < .03$
[d]$P < .11$

Table 5. Growth Performance of Pigs Fed Different Sources of Spray-Dried Porcine Plasma (Trial 3)[a]

Item	Source 1	Source 2	CV
d 0 - 7			
ADG, lb[b]	.37	.44	14.86
ADFI, lb[b]	.53	.60	8.83
F/G	1.48	1.35	12.24
d 0 - 14			
ADG, lb[c]	.55	.64	7.94
ADFI, lb[b]	.70	.78	8.31
F/G	1.27	1.22	5.52
d 0 - 21			
ADG, lb[b]	.75	.81	6.28
ADFI, lb[d]	.94	.99	6.36
F/G	1.26	1.21	5.28

[a]144 weanling pigs were used (initially 12.6 lb and 19 d of age), 8-9 pigs/pen.
[b]$P<.02$.
[c]$P<.001$.
[d] $P<.12$.

A COMBINATION OF SPRAY-DRIED PORCINE PLASMA AND SPRAY-DRIED BLOOD MEAL OPTIMIZES STARTER PIG PERFORMANCE[1]

L. J. Kats, M. D. Tokach, J. L. Nelssen, R. D. Goodband, and J. L. Laurin

Summary

A total of 298 weanling pigs (initially 12.1 lb and 19 d of age) was used in a 25-d growth trial to examine the influence of various combinations of spray-dried porcine plasma (SDPP) and spray-dried blood meal (SDBM) in a high nutrient density diet on starter pig performance. Pigs were allotted by weight to eight replicates of five treatments with seven to eight pigs per pen. Pigs were assigned to one of five dietary treatments with 0, 25, 50, 75, or 100% of the SDPP replaced with SDBM on an equal lysine basis. Therefore, diets contained 10, 7.5, 5.0, 2.5, or 0% SDPP combined with 0, 1.63, 3.25, 4.8, or 6.5% SDBM, respectively. All phase I diets were formulated to contain 20% dried whey, 1.50% lysine, .81% isoleucine, and .37% methionine. These diets were fed from d 0 to 14 postweaning. On d 14, all pigs were switched to a common phase II diet containing 10% dried whey and 2.5% SDBM and was formulated to 1.25% lysine. Pigs were fed this diet for the remainder of the trial (d 14 to 25 postweaning). A quadratic response occurred for average daily gain and feed efficiency during phase I, with pigs fed a combination of spray-dried porcine plasma and spray-dried blood meal having superior performance compared to pigs fed diets containing only spray-dried plasma or spray-dried blood. Maximum performance was seen with the combination of 7.5% spray-dried porcine plasma and 1.63% spray-dried blood meal. Therefore, the results of this trial show that phase I diet cost can be reduced and performance improved by formulating the diet with a combination of spray-dried porcine plasma and spray-dried blood meal rather than spray-dried plasma alone.

(Key Words: Starter, Porcine Plasma, Blood Meal.)

Introduction

Previous research at Kansas State University has compared spray-dried porcine plasma, spray-dried blood meal, and dried skim milk as protein sources in the phase I high nutrient density diet for the early weaned pig. Results of these trials indicated that spray-dried porcine plasma (SDPP) was superior to spray-dried blood meal (SDBM) and dried skim milk in average daily gain (ADG) and average daily feed intake (ADFI). However, in those trials, each protein source was a total substitution for dried skim milk on an equal lysine basis. Combinations of SDPP and SDBM have not been investigated. Because SDBM is approximately 25% of the cost of SDPP, a combination of SDPP and SDBM would dramatically reduce the cost of the phase I diet. Therefore, the objective of this experiment was to evaluate the effectiveness of various combinations of SDPP and SDBM in the phase I diet on starter pig performance.

[1]The authors wish to thank Steve Eichman and Eichman Farms, St. George, KS for use of facilities and animals for this experiment.

Procedures

A total of 298 weanling pigs (initially 12.1 lb and 19 d of age) was used in a 25 d growth trial to examine the influence of varying combinations of SDPP and SDBM on starter pig performance. Pigs were allotted by weight to eight replicates of five treatments with seven to eight pigs per pen. Pigs were assigned to one of five dietary treatments with 0, 25, 50, 75, or 100% of the SDPP replaced with SDBM on an equal lysine basis (Table 1). Therefore, diets contained 10, 7.5, 5.0, 2.5, or 0% SDPP and 0, 1.63, 3.25, 4.8, or 6.5% SDBM, respectively. All phase I diets were formulated to contain 20% dried whey, 1.50% lysine, .81% isoleucine, and .37% methionine. These diets were fed from d 0 to 14 postweaning. On day 14, all pigs were switched to a common phase II diet containing 10% dried whey and 2.5% SDBM and was formulated to 1.25% lysine. Pigs were fed this diet for the remainder of the trial (d 14 to 25 postweaning). Pigs were housed in an environmentally controlled nursery and were allowed ad libitum access to feed and water. Pigs were weighed and feed disappearance was measured on days 7, 14, and 25 postweaning to determine average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G).

Results and Discussion

Quadratic responses occurred for ADG ($P<.06$) and F/G ($P<.09$) during phase I (Table 2), with pigs fed combinations of SDPP and SDBM having superior performance compared to pigs fed diets containing SDPP and SDBM alone. Maximum performance was achieved when the diet contained 7.5% SDPP and 1.63% SDBM. Phase I treatment had no influence on phase II and overall performance, with similar pig performance on all treatments for the 25-d trial. However, a numeric improvement occurred in phase II performance for pigs that received a diet containing some blood meal in phase I. Therefore, if SDBM is used in the phase II diet, it may be beneficial to include blood meal in the phase I diet. In addition, decreasing the amount of SDPP in the phase I diet from 10% to 7.5% with SDBM results in a $60/ton reduction in diet cost. In conclusion, diet cost can be decreased in phase I and performance increased by replacing a portion of the SDPP with SDBM. Optimum performance in this trial was achieved with 7.5% SDPP and 1.63% SDBM.

Table 1. Diet Composition[a]

	Plasma:blood combinations					
Item, %	100:0	75:25	50:50	25:75	0:100	Phase II
Corn	43.88	44.86	45.80	46.79	47.73	58.92
Soybean meal (48% CP)	18.98	18.89	18.84	18.76	18.67	21.03
Dried whey,edible grade	20.00	20.00	20.00	20.00	20.00	10.00
Porcine plasma, spray-dried	10.00	7.50	5.00	2.50	-	-
Blood meal, spray-dried	-	1.63	3.25	4.88	6.51	2.50
Soybean oil	3.00	3.00	3.00	3.00	3.00	3.00
Monocalcium phosphate (21% P)	1.85	1.83	1.81	1.79	1.77	1.97
Limestone	.69	.69	.69	.69	.69	.83
Antibiotic[b]	1.00	1.00	1.00	1.00	1.00	1.00
Vitamin premix	.25	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15	.15
Copper sulfate	.075	.075	.075	.075	.075	.075
DL-Methionine	.061	.057	.052	.048	.045	.061
Selenium premix	.05	.05	.05	.05	.05	.05
Isoleucine	-	-	-	.005	.04	-
L-Lysine HCl	-	-	-	-	-	.15
Total	100.00	100.00	100.00	100.00	100.00	100.00

[a]Diets were formulated to contain 1.50% lysine, .81% isoleucine, and .37% methionine in phase I and 1.25% lysine in phase II.
[b]Provided 150 g/ton Apramycin in phase I and 50 g/ton Carbadox in phase II.

Table 2. Growth Performance of Pigs Fed Various Combinations of Spray-dried Porcine Plasma and Spray-dried Blood Meal[a]

	Plasma:blood meal combinations					
Item	100:0	75:25	50:50	25:75	0:100	CV
d 0 - 14						
ADG, lb[b]	.51	.57	.53	.54	.51	8.8
ADFI, lb	.63	.67	.64	.62	.62	6.9
F/G[c]	1.23	1.16	1.20	1.15	1.22	6.6
d 0 - 25						
ADG, lb	.72	.76	.74	.75	.73	5.5
ADFI, lb[c]	1.01	1.08	1.06	1.04	1.04	5.1
F/G	1.41	1.41	1.43	1.39	1.39	3.2

[a]298 weanling pigs were used (initially 12.1 lb and 19 d of age), 14-15 pigs per pen with 4 pens per treatment.
[b]Quadratic response (P<.06).
[c]Quadratic response (P<.09).

OPTIMUM LEVEL OF SPRAY-DRIED BLOOD MEAL IN PHASE II DIET[1]

L. J. Kats, J. L. Nelssen, M. D. Tokach, and R. D. Goodband

Summary

A total of 744 pigs (initially 12.8 lb and 22 d of age) was used in a 28 d trial to determine the effects of increasing levels of blood meal in the phase II (d 7 to 28) diet. Pigs were allotted by sex and weight and placed in pens containing 13 to 14 pigs each. A common phase I diet was fed for the first 7 days postweaning. The phase I diet contained 37.5% dried whey and 7.5% porcine plasma and was formulated to contain 1.5% lysine. After the phase I period, pigs were assigned to one of six dietary treatments that contained 10% dried whey and either 0, 1, 2, 3, 4, or 5% spray-dried blood meal. These diets were fed for the entire phase II period (d 7 to 28 postweaning). Phase II diets were formulated to contain 1.25% lysine and a minimum of .68% isoleucine and .30% methionine. During phase I (d 0 to 7), average daily gain, average daily feed intake, and feed efficiency (F/G) were .34 lb, .38 lb, and 1.28, respectively. During phase II (d 7 to 28), quadratic improvements occurred in average daily gain, average daily feed intake, and feed efficiency, with optimum performance achieved at approximately the 2% inclusion rate of spray-dried blood meal. Therefore, the results of this trial indicate that the optimal level of spray-dried blood meal in the phase II diet is approximately 2%.

(Key Words: Starter, Blood Meal, Performance.)

Introduction

The advent of spray-drying various by-products has produced many effective feed ingredients that are available for use in swine diets. Previous research conducted at Kansas State University has shown that spray-dried porcine plasma is an effective ingredient to improve starter pig performance. However, spray-dried porcine plasma is not cost effective in diets other than the high nutrient density diet (phase I). Therefore, alternative products need to be evaluated for use in diets for the later stages of the nursery phase. One such ingredient has been spray-dried blood meal, which is a by-product of the meat processing industry. This particular feedstuff has been shown to be quite effective when used in the phase II diet for nursery pigs. In previous trials, 2.5% spray-dried blood meal was a superior protein source in the phase II diet compared to soy protein concentrate, extruded soy protein concentrate, and fish meal. However, in past trials, blood meal replaced 5% select menhaden fish meal on an equal lysine basis, so the ideal inclusion rate in the diet was not known. This trial was conducted to evaluate various levels of spray-dried blood meal in the phase II diet and to determine where pig performance was maximized.

Procedures

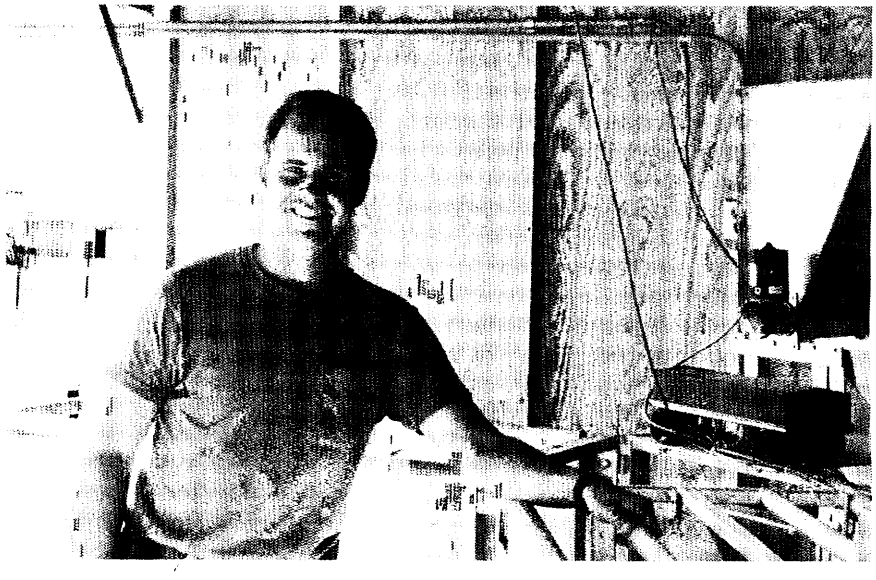
A total of 744 pigs (initially 12.8 lb and 22 d of age) was used in a 28 d trial. Pigs were allotted by sex and weight and placed in pens containing 13 to 14 pigs each. A com-

[1]Appreciation is expressed to California Spray Dry, Inc. Modesto, CA for donating the blood meal and Feed Specialties, Des Moines, IA for partial financial support. The authors wish to thank Dale Keesecker and Keesecker Agribusiness, Washington, KS for use of facilities and animals.

mon phase I diet was fed for the first 7 days postweaning. The phase I diet contained 37.5% dried whey and 7.5% porcine plasma and was formulated to 1.5% lysine. After the phase I period, pigs were assigned to one of six dietary treatments that contained 10% dried whey and either 0, 1, 2, 3, 4, or 5% spray-dried blood meal. These diets were fed for the entire phase II period (d 7 to 28 postweaning). Phase II diets (Table 1) were formulated to contain 1.25% lysine, .68% isoleucine, and .30% methionine. Pigs and feeders were weighed on d 7, 14, and 28 postweaning to evaluate average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G).

Results and Discussion

During phase I (d 0 to 7), ADG, ADFI, and F/G were .34 lb, .38 lb, and 1.28, respectively. During the first week of phase II (d 7 to 14), a linear and quadratic response ($P<.01$) in ADG occurred with the addition of blood meal to the diet (Table 2). Average daily feed intake followed a similar trend, with pigs receiving at least 2% blood meal consuming approximately .10 lb/d more than those pigs receiving no blood meal. A significant ($P<.01$) improvement in feed efficiency also occurred with the addition of blood meal during the first week of phase II. During phase II (d 7 to 28) and the overall trial, quadratic improvements ($P<.01$) occurred in ADG, ADFI, and F/G with the addition of blood meal. The optimum level of performance was achieved at the 2% blood meal level, with ADG, ADFI, and F/G being .68 lb, 1.05 lb, and 1.56, respectively, in the phase II period. The results of this trial indicate that an inclusion level of approximately 2% spray-dried blood meal in the phase II diet will optimize pig performance and cost effectiveness.



Joe Carpenter, swine herdsman, inspects the new computerized sow feeder.

Table 1. Phase II Diet Composition[a]

	Spray-dried blood meal, %					
Item, %	0	1	2	3	4	5
Corn	49.62	51.74	53.85	55.97	58.08	60.20
Soybean meal (48% CP)	33.07	29.90	26.73	23.55	20.38	17.21
Dried whey, edible grade	10.00	10.00	10.00	10.00	10.00	10.00
Blood meal	-	1.00	2.00	3.00	4.00	5.00
Soybean oil	3.00	3.00	3.00	3.00	3.00	3.00
Monocalcium phosphate (21% P)	1.76	1.81	1.87	1.93	1.98	2.04
Limestone	.81	.81	.81	.81	.81	.82
Antibiotic[b]	1.00	1.00	1.00	1.00	1.00	1.00
Vitamin premix	.25	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15	.15
Salt	.15	.15	.15	.15	.15	.15
Copper sulfate	.075	.075	.075	.075	.075	.075
Selenium premix	.05	.05	.05	.05	.05	.05
Vitamin E	.05	.05	.05	.05	.05	.05
Total	100.00	100.00	100.00	100.00	100.00	100.00

[a]Diets were formulated to contain 1.25% lysine, .9% Ca, .8% P, and at least .68% isoleucine and .30% methionine.
[b]Provided 50 g/ton Carbadox.

Table 2. Influence of Various Levels of Blood Meal in the Phase II Diet[a]

	Spray-dried blood meal, %						
Item	0	1	2	3	4	5	CV
d 7 to 14							
ADG, lb[bcd]	.26	.34	.43	.40	.42	.40	22.9
ADFI, lb[ef]	.55	.59	.64	.61	.64	.63	11.8
F/G[bcd]	2.49	1.82	1.56	1.62	1.59	1.54	22.4
d 7 to 28							
ADG, lb[cd]	.60	.66	.68	.67	.66	.66	8.6
ADFI, lb[f]	.979	1.02	1.05	1.01	1.04	1.03	7.2
F/G[bcd]	1.66	1.54	1.55	1.51	1.60	1.57	3.8

[a]Seven hundred and forty four weanling pigs were used (initially 12.8 lb and 22 d of age), 13-14 pigs/pen, 12 pens/treatment.
[be]Linear effect of blood meal (P<.01, .05, respectively).
[c]Quadratic effect of blood meal (P<.01).
[df]Control vs blood meal (P<.01, .05, respectively).

BLOOD MEAL SOURCE INFLUENCES STARTER PIG PERFORMANCE[1]

L. J. Kats, J. L. Nelssen, R. D. Goodband, M. D. Tokach, and T. L. Weeden

Summary

A total of 144 weanling pigs (initially 14.1 lb and 24 d of age) was used to compare three different blood meal sources in starter diets. The three sources included spray-dried porcine, spray-dried bovine, and flash-dried bovine blood meal. Each diet contained 10% dried whey and 2.5% of one of the three blood meal sources. Diets were formulated to contain 1.25% lysine and .31% methionine. Pigs receiving diets containing either source of spray-dried blood meal had improved average daily gain and feed efficiency during the first 2 weeks of the experiment and the overall trial compared to pigs receiving diets containing the flash-dried source. No differences occurred in pig performance between the two spray-dried sources. Therefore, no apparent effects were due to species differences but the blood meal must be spray-dried in order to optimize starter pig performance.

(Key Words: Starter, Blood Meal, Performance.)

Introduction

Recent work at Kansas State University has shown spray-dried blood meal to be an effective protein source in the starter pig diet. Also, results indicate that only 2 to 3% blood meal needs to be added to the diet to optimize performance in phase II. In addition to the flash or ring-dried products that have been available for quite some time, new sources of blood meal, such as spray-dried bovine and spray-dried porcine, have been introduced recently. Therefore, the objective of this experiment was to evaluate different sources of blood meal and determine their effects on starter pig performance.

Procedures

A total of 144 weanling pigs (initially 14.1 lb and 24 d of age) was used. Pigs were allotted by weight, sex, and ancestry in a randomized complete block design to one of three dietary treatments with eight replicates of six pigs/pen. The three blood meal sources were flash-dried bovine, spray-dried porcine, and spray-dried bovine. The blood sources varied in amino acid composition, and nutritive values provided by the individual suppliers were used in diet formulation (Table 2). Calculated values for flash-dried bovine, spray-dried porcine, and spray-dried bovine were: lysine 7.25, 9.37, 11.0; methionine .80, 1.0, 1.41; isoleucine .88, .76, .92; tryptophan 1.10, 1.62, .97; and threonine 4.07, 4.27, 4.49%, respectively. All diets contained 10% dried whey and were formulated to contain 1.25% lysine, .31% methionine, .9% Ca, and .8% P. Each diet contained 2.5% of each of the various blood meal sources. Pigs were fed this diet for the 28 d trial. Pigs were housed in an environmentally controlled nursery on raised deck flooring and had ad libitum access to feed and water. Pigs and feeders were weighed weekly to determine average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G).

[1]Appreciation is expressed to Vita Plus Corp., Madison, WI for donating the blood meal for this experiment.

Results and Discussion

Amino acid analysis was conducted on each blood meal sample (Table 1) and gave lower values than those given in company literature. Pigs consuming the diets containing the spray-dried blood meal had improved (P<.01) ADG and F/G compared to the pigs fed the diet containing flash-dried blood meal for the first 2 weeks postweaning and the overall trial (Table 3). Average daily feed intake for the overall trial tended (P<.09) to be greater for pigs fed either spray-dried protein source compared to flash-dried blood meal. No significant differences occurred between the two different sources of spray-dried blood products for any of the response criteria. Results of this trial demonstrate that processing and heat treatment of the protein sources used can affect starter pig performance. Both types of blood meals are heated at high temperatures but spray-drying involves a much shorter time period for heat treatment than does the flash-dried source. This extended heating time would affect protein quality and thereby be detrimental to starter pig performance. Therefore, spray-dried source of blood meal should be used in starter pig diets in order to optimize pig performance.

Table 1. Analyzed Composition of Blood Meal Sources[a]

Item, %	Flash-dried bovine	Spray-dried bovine	Spray-dried porcine
DM	87.9	81.9	82.5
CP	89.8	88.1	89.9
Ash	1.5	5.7	5.7
Ca	.14	.04	.05
P	.11	.12	.20
Arginine	3.97	3.26	3.45
Cystine	1.12	.97	1.01
Histidine	6.00	4.68	4.91
Isoleucine	1.04	.77	.91
Lysine	8.01	7.66	7.53
Methionine	.72	1.05	.88
Phenylalanine	5.79	5.55	5.40
Threonine	3.13	3.96	3.96
Tryptophan	.75	1.61	1.67
Tyrosine	2.45	2.53	2.48
Valine	7.55	6.84	6.91
Potassium	-	.28	.60
Sodium	-	1.17	1.17
Magnesium	-	.014	.027
Sulfur	-	.68	.64
Iron	-	.19	.19

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

Table 2. Diet Composition[a]

Item, %	Blood meal source		
	Flash-dried bovine	Spray-dried bovine	Spray-dried porcine
Corn	53.86	57.07	55.68
Soybean meal (48% CP)	26.93	23.66	25.08
Dried whey, edible grade	10.00	10.00	10.00
Blood meal	2.50	2.50	2.50
Soybean oil	3.00	3.00	3.00
Monocalcium phosphate (21% P)	1.87	1.92	1.89
Limestone	.81	.82	.82
Antibiotic[b]	.50	.50	.50
Vitamin premix	.25	.25	.25
Trace mineral premix	.15	.15	.15
Copper sulfate	.075	.075	.075
Selenium premix	.05	.05	.05
Total	100.00	100.00	100.00

[a]Diets were formulated to contain 1.25% lysine, .31% methionine, .9% Ca, and .8% P.
[b]Provided 50 g/ton Carbadox.

Table 3. Growth Performance of Pigs Fed Various Blood Meal Sources[a]

Item	Blood meal source			CV
	Flash-dried bovine	Spray-dried bovine	Spray-dried porcine	
d 0 - 14				
ADG, lb[b]	.35	.46	.44	15.87
ADFI, lb	.67	.72	.70	9.54
F/G[b]	1.87	1.57	1.61	12.65
d 0 - 28				
ADG, lb[b]	.68	.79	.74	8.5
ADFI, lb[c]	1.20	1.27	1.23	5.48
F/G[b]	1.75	1.60	1.65	5.42

[a]144 weanling pigs were used (initially 14.1 lb and 24 d of age), 6 pigs/pen, 8 pens/treatment.
[b]Flash-dried vs spray-dried ($P<.01$).

[c]Flash-dried vs spray-dried (P<.09).

COMPARISON OF AVIAN AND BOVINE SPRAY-DRIED BLOOD MEAL AND WHEY LEVELS IN STARTER PIG DIETS

S. S. Dritz, M. D. Tokach, J. L. Nelssen, R. D. Goodband, and L. J. Kats[1]

Summary

A total of 420 weanling pigs was used in a growth trial having two objectives. Objective 1 was to compare spray-dried avian blood meal and spray-dried bovine blood meal as protein sources in the phase II diet (d 7-21 postweaning). Objective 2 was to determine the appropriate level of dried whey for a phase II diet containing 2.5% spray-dried bovine blood meal. During phase I (d 0-7 postweaning), all pigs were fed a common high nutrient density pelletized diet containing 1.5% lysine, 20% dried edible grade whey, 7.5% spray-dried porcine plasma, and 1.75% spray-dried bovine blood meal. All phase II diets were formulated to 1.25% lysine, .9% Ca, and .8% P. In the comparison of avian and bovine spray-dried blood meals, the diets contained 2.5% blood meal and 10% whey. No significant differences occurred in average daily gain (ADG), average daily feed intake (ADFI), or feed to gain ratio (F/G) with use of avian and bovine spray-dried blood meal. The phase II diets comparing different whey levels contained 2.5% spray-dried bovine blood meal and whey levels of 5, 10, 15, or 20% substituted for corn and soybean meal on a protein basis. Linear and quadratic improvements occurred in performance with increasing whey levels for the 21 d growth period. However, linear and quadratic increases in the cost per pound of gain also occurred. In conclusion, avian and bovine blood meal appear to be comparable sources of protein for the phase II diet. Current economics indicate that approximately 10% whey is the optimal inclusion rate in phase II starter pig diets containing 2.5% spray-dried blood meal.

(Key Words: Starter Pigs, Whey, Spray-Dried Blood Meal.)

Introduction

Previous research at Kansas State University has shown spray-dried blood meal to be the protein source of choice for the phase II starter pig diet. Since changing the recommended protein source to spray-dried blood meal, there have been questions as to the appropriate level of whey to include in the phase II diet for starter pigs. Previous research at Kansas State University also has compared bovine and porcine spray-dried blood meal as a protein source for the phase II diet. Results indicated that porcine and bovine spray-dried blood meal were comparable. Therefore, the two objectives of this experiment were to determine the optimal level of dried whey inclusion in the phase II diet and to compare avian and bovine spray-dried blood meal as protein sources for the phase II diet.

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[1]Appreciation is expressed to California Spray Dry Inc., Modesto, California to partial financial support and donation of spray-dried blood meal. The authors also wish to thank Dale Keesecker and the employees of Keesecker Agribusiness, Washington, KS for use of facilities and animals.

Procedure

A growth trial utilizing 420 weaned pigs (initially 13.7 lb and 21 d of age) was conducted. At weaning, pigs were blocked by weight and sex to the five experimental treatments with 13 or 15 pigs per pen (6 pens per treatment). During phases I (0 to 7 d postweaning) and II (7 to 28 d postweaning), pigs were housed in an environmentally controlled nursery with woven wire flooring and allowed ad libitum access to feed and water. Feed consumption and individual pig weights were recorded on d 0, 7, 14, and 28 to determine ADG, ADFI and F/G. Pigs were reallotted after day 7 postweaning within replicates to equalize pen weights.

During phase I (0 to 7 d postweaning), all pigs were fed a common high nutrient density diet (Table 1). The phase I diet was formulated to contain 1.5% lysine, .9% calcium, and .8% phosphorus and was in the pellet (1/8 inch) form. Pigs were switched to phase II diets on d 7 postweaning. All phase II diets were formulated to contain 1.25% lysine, .9% calcium, and .8% phosphorus and were fed in the meal form. In the comparison of avian and bovine spray-dried blood meal, both diets contained 10% whey. For the comparison of whey levels, increasing levels of whey were substituted for corn and soybean meal on a protein basis (Table 1).

Results and Discussion

Phase I. During phase I, pigs gained .33 lb/d, consumed .42 lb feed/day, and had a feed to gain ratio of 1.29.

Phase II avian vs bovine spray-dried blood meal. No statistical differences in ADG, ADFI, or F/G occurred between the diets containing either avian or bovine spray-dried blood meal for either the 7 to 14 d postweaning or 7 to 28 d postweaning periods (Table 2). However, numeric differences occurred in ADG, ADFI, and F/G for the 7 to 14 d period. Therefore, a follow-up trial was conducted comparing avian and bovine spray-dried blood meal beginning at d 0 postweaning. This trial indicated no significant differences between spray-dried bovine and avian blood meals as protein sources for phase II. In conclusion, research at Kansas State University indicates that porcine, bovine and avian blood meal are interchangeable as protein sources in the phase II diet, as long as they are spray-dried.

Phase II whey levels. For the 7 to 14 d postweaning period, linear ($P<.001$) and quadratic ($P<.05$) improvements occurred in ADG and ADFI, and a linear ($P<.05$) improvement in F/G (Table 3). For the entire 7 to 28 d postweaning period, linear ($P<.001$) and quadratic ($P<.001$) improvements occurred in ADG, ADFI, and F/G. However, linear ($P<.001$) and quadratic ($P<.001$) increases in cost per pound of gain also occurred. Maximum ADG and ADFI occurred with inclusion of 20% whey in the phase II diet, but cost per pound of gain was minimized using a 10% whey inclusion rate. Prices used for the cost per pound of gain analysis were corn, $2.18 per bushel; soybean meal, $180 per ton; and spray-dried edible grade whey, $.33 per pound. Although performance was maximized with 20% dried whey inclusion in the diets, current economics dictate 10% whey as the optimal inclusion rate in phase II starter pig diets containing 2.5% spray-dried blood meal.

Table 1. Composition of Diets, %

		Phase II treatment					
	Phase	Blood meal		Dried whey %			
Item	I	Avian	Bovine[a]	5	10[a]	15	20
Corn	45.47	58.06	58.06	61.66	58.06	54.46	50.86
Soybean meal (46.5%)	16.00	21.87	21.87	23.14	21.87	20.61	19.35
Dried whey, edible grade	20.00	10.00	10.00	5.00	10.00	15.00	20.00
Spray-dried porcine plasma	7.50						
Spray-dried avian blood meal		2.50					
Spray-dried bovine blood meal	1.75		2.50	2.50	2.50	2.50	2.50
Soybean oil	5.00	3.00	3.00	3.00	3.00	3.00	3.00
Monocalcium phosphate (18%P)	1.91	1.96	1.96	2.06	1.96	1.87	1.77
Limestone	.69	.82	.82	.88	.82	.78	.73
Mecadox	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Vitamin premix[b]	.25	.25	.25	.25	.25	.25	.25
Trace mineral premix[c]	.15	.15	.15	.15	.15	.15	.15
L-lysine	.10	.15	.15	.15	.15	.15	.15
DL-methionine	.10	.05	.05	.05	.05	.05	.05
Copper sulfate	.08	.08	.08	.08	.08	.08	.08
Vitamin E premix[d]		.05	.05	.05	.05	.05	.05
Selenium premix[e]		.05	.05	.05	.05	.05	.05
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[a]The 10% whey and bovine spray-dried blood meal diets were the same treatment.

[b]Phase I each pound contains vitamin A, 2,000,000 IU; vitamin D_3, 200,000 IU; vitamin E, 8,000 IU; menadione, 800 mg; vitamin B_{12}, 6 mg; riboflavin, 1,500 mg; pantothenic acid, 5,200 mg; niacin, 9,000 mg; choline, 30,000 mg. Phase II each pound contains vitamin A, 1,000,000 IU; vitamin D_3, 100,000 IU; vitamin E, 4,000 IU; menadione, 400 mg; vitamin B_{12}, 5 mg; riboflavin, 1,000 mg; pantothenic acid, 2,500 mg; niacin, 5,500 mg; choline, 100,000 mg.

[c]In phase I each pound contains Zn, 50 g; Fe, 50 g; Mn, 12 g; Cu, 5 g; I, 90 mg; Se, 90 mg. In phase II each pound contains Zn, 45 g; Fe, 45 g; Mn, 45 g; Cu, 4.5 g; I 90 mg.

[d]Each pound contains 20,000 IU vitamin E.

[e]Each pound contains 272.4 mg Se.

Table 2. Comparison of Spray-dried Blood Meal Sources in the Phase II Starter Pig Diet[a,b]

	Spray-Dried Blood Meal Source		
Item	Avian	Bovine	CV, %
d 7 to 14			
ADG, lb	.39	.44	17.5
ADFI, lb	.74	.78	7.0
F/G	2.18	1.87	19.6
d 7 to 28			
ADG, lb	.81	.82	4.9
ADFI, lb	1.26	1.28	4.4
F/G	1.55	1.54	3.0

[a]All pigs were fed a common diet from day 0 to 7 (phase I) postweaning. Each value is the mean of six pens containing 13 or 15 pigs per pen.
[b]No significant treatment effects.

Table 3. Comparison of Dried Whey Levels for the Phase II Starter Pig Diet Containing 2.5% Spray-dried Blood Meal[a]

	Spray-dried Whey %				
Item	5	10	15	20	CV, %
d 7 to 14					
ADG, lb[b,c]	.38	.44	.46	.55	17.5
ADFI, lb[b,c]	.70	.78	.79	.84	7.0
F/G[d]	2.01	1.87	1.71	1.58	19.6
d 7 to 28					
ADG, lb[b,e]	.66	.82	.85	.90	4.9
ADFI, lb[b,e]	1.17	1.28	1.26	1.35	4.4
F/G[b,e]	1.76	1.56	1.50	1.50	3.0
Diet Cost/Ton, $[f]	209	235	260	286	
Cost/lb gain, $[b,e]	.184	.184	.192	.215	3.1

[a]All pigs were fed a common diet from day 0 to 7 postweaning. Each value is the mean of six pens containing 13 or 15 pigs per pen.
[b,d]Linear effect P<.001 and P<.05, respectively.
[c,e]Quadratic effect P<.05 and P<.001, respectively.
[f]Ingredient costs used were corn, $2.18 per bushel; soybean meal, $180 per ton; spray-dried edible whey, $.33 per pound.

COMPARISON OF SPRAY-DRIED BLOOD MEAL AND FISH BY-PRODUCTS IN THE PHASE II STARTER PIG DIET[1]

L. J. Kats, M. D. Tokach, J. L. Nelssen, R. D. Goodband, and J. L. Laurin

Summary

A total of 311 weanling pigs (initially 10.9 lb and 17 d of age) was used to compare fish by-products, spray-dried blood meal and combinations of spray-dried blood meal and fish by-products in the phase II (d 7 to 25) diet. Pigs were allotted by weight to one of five experimental treatments with 8 to 11 pigs/pen and seven replications. Pigs were placed on a common phase I diet (d 0 to 7 postweaning) that contained 7.5% spray-dried porcine plasma, 1.75% spray-dried blood meal, and 20% dried whey. The phase I diet was formulated to contain 1.5% lysine, .9% Ca, and .8% P. Pigs were then randomly assigned to one of five dietary treatments. All phase II diets (d 7 to 25 postweaning) contained 10% dried whey and were formulated to contain 1.25% lysine and .36% methionine. The control diet contained 2.5% spray-dried blood meal (SDBM) and 10% dried whey. Select menhaden fish meal (SMFM) and spray-dried fish hydrolysate (SDFH) replaced SDBM on an equal lysine basis at 5% and 4.8%, respectively, and 2.5% SMFM + 1.25% SDBM and 2.0% SDFH + 1.25% SDBM were used in combinations to form the other four dietary treatments. Average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G) were improved with the addition of SDBM in the first week (d 7 to 14) of phase II. No differences were observed in ADG and ADFI for the overall phase II period. Pigs fed SDBM had poorer F/G (d 7 to 25) compared to pigs fed either SMFM or SDFH. However, SDBM was the most cost effective protein source in this experiment.

(Key Words: Starter Pig, Fish By-Products, Blood Meal.)

Introduction

Previous research has shown that spray-dried blood meal is a cost effective replacement for select menhaden fish meal in the nursery diet for the early-weaned pig. However, other fish by-products are also available. One such product is spray-dried fish protein hydrolysate, which is a by-product derived from fish filleting plants. The fish meal by-product is processed, all bones are removed, and then it is spray-dried. This product is high in lysine and offers an alternative to select menhaden fish meal in the nursery diet. Therefore, the objective of this trial was to compare spray-dried blood meal (SDBM), select menhaden fish meal (SMFM), spray-dried fish hydrolysate (SDFH), and combinations of spray-dried blood meal and the fish by-products in the phase II diet.

Procedures

A total of 311 weanling pigs (initially 10.9 lb and 17 d of age) was allotted by weight to one of five experimental treatments with 8 to 11 pigs per pen with seven replica-

[1]Appreciation is expressed to California Spray Dry, Inc., Modesto, CA, for donating feed ingredients and providing partial financial support and Zapata Haynie Corp,. Reedville, VA, for donating the select menhaden fishmeal. The authors also wish to thank Steve Eichman and Eichman Farms, St. George, KS, for use of facilities and animals in this experiment.

tions per treatment. Pigs were placed on a common phase I diet (d 0 to 7 postweaning) that contained 7.5% spray-dried porcine plasma, 1.75% spray-dried blood meal, and 20% dried whey (Table 1). The phase I diet was formulated to contain 1.5% lysine, .9% Ca, and .8% P. On d 7, pigs were randomly assigned to one of five dietary treatments. All phase II diets (d 7 to 25 postweaning) contained 10% dried whey and were formulated to contain 1.25% lysine and .36% methionine. The various protein sources were added on an equal lysine basis with inclusion rates of 2.5% SDBM, 5.0% SMFM, 4.18% SDFH, 2.5% SMFM + 1.25% SDBM, and 2.0% SDFH + 1.25% SDBM to form the five treatments. Pigs were fed these diets from d 7 to 25 postweaning. Pigs were housed in an environmentally controlled nursery with metal flooring and were allowed ad libitum access to feed and water. Pigs were weighed and feed disappearance was measured on d 7, 14, and 25 to evaluate average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G).

Results and Discussion

During phase I (d 0 to 7 postweaning), ADG, ADFI, and F/G were .40 lb, .49 lb, and 1.20, respectively. During the first week of phase II (d 7 to 14 postweaning), pigs fed the SDBM diet gained faster than pigs fed diets containing SMFM ($P<.01$), SDFH ($P<.03$), and SMFM + SDBM ($P<.06$). Average daily feed intake also was improved ($P<.01$) in the first week of phase II, with pigs receiving SDBM having greater feed intake than those receiving SDFH. Pigs fed SDBM also were more efficient ($P<.02$) during the first week of phase II compared to those receiving SMFM. Spray-dried blood meal appears to a superior protein source in the transition from a phase I diet containing spray-dried porcine plasma and SDBM.

For the overall phase II period (d 7 to 25 postweaning), there were no differences in ADG. Average daily feed intake was improved for pigs receiving SDBM compared to those receiving SDFH ($P<.01$) and SMFM + SDBM ($P<.03$). However, when comparing feed efficiency, pigs receiving SDBM were less efficient than those receiving SMFM ($P<.05$), SDFH ($P<.01$), and SMFM + SDBM ($P<.02$) for the phase II period. In conclusion, spray-dried fish hydrolysate and combinations of fish by-products and spray-dried blood meal appear to be effective protein sources in the phase II diet. However, because of the lower inclusion rate, SDBM is still the most cost effective protein source in the phase II starter diet.

Table 1. Diet Composition[a]

		Phase II treatment[c]				
Item, %	Phase I[b]	SDBM	SMFM	SDFH	SMFM + SDBM	SDFH + SDBM
Corn	45.47	58.94	57.46	57.33	58.21	58.13
Soybean meal (48% CP)	15.96	21.03	21.03	21.03	21.03	21.03
Dried whey	20.00	10.00	10.00	10.00	10.00	10.00
Soybean oil	5.00	3.00	3.00	3.00	3.00	3.00
Spray-dried blood meal	1.75	2.50	-	-	1.25	1.25
Select menhaden fish meal	-	-	5.02	-	2.51	-
Spray-dried fish hydrolysate	-	-	-	4.18	-	2.09
Spray-dried porcine plasma	7.50	-	-	-	-	-
Monocalcium phosphate (21% P)	1.91	1.97	1.34	1.93	1.65	1.95
Limestone	.69	.83	.48	.86	.65	.85
Antibiotic[d]	1.00	1.00	1.00	1.00	1.00	1.00
Vitamin premix	.25	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15	.15
L-Lysine HCl	.10	.15	.15	.15	.15	.15
Copper sulfate	.075	.075	.075	.075	.075	.075
DL-methionine	.1	.061	-	.002	.031	.032
Selenium premix	.05	.05	.05	.05	.05	.05
Total	100.00	100.00	100.00	100.00	100.00	100.00

[a]Diets were formulated to contain 1.5% lysine, .9% Ca and .8% P in phase I (d 0 to 7) and 1.25% lysine, .9% Ca, .8% P, and .36% methionine in phase II (d 7 to 25).
[b]Pigs received a common phase I (d 0 to 7) diet.
[c]SDBM = spray-dried blood meal, SMFM = select menhaden fish meal, and SDFH = spray-dried fish hydrolysate.
[d]Provided 150 g/ton Apramycin in phase I and 50 g/ton Carbadox in phase II.

Table 2. Growth Performance of Pigs Fed Spray-dried Blood Meal and Fish By-products during Phase II (d 7 to 25 Postweaning)[a]

	Phase II treatment[b]					
Item	SDBM	SMFM	SDFH	SMFM + SDBM	SDFH + SDBM	CV
d 7 - 14						
ADG, lb[cde]	.59	.51	.52	.53	.55	10.80
ADFI, lb[f]	.90	.86	.80	.85	.89	7.94
F/G[c]	1.53	1.76	1.59	1.64	1.69	10.46
d 7 - 25						
ADG, lb	.90	.91	.88	.89	.91	5.53
ADFI, lb[fg]	1.12	1.09	1.04	1.05	1.11	5.02
F/G[fgh]	1.47	1.41	1.38	1.39	1.45	4.42

[a]Three hundred and eleven weanling pigs (initially 10.9 lb and 17 days of age), 8 to 11 pigs/pen, 5 pens/treatment.
[b]SDBM = spray-dried blood meal, SMFM = select menhaden fish meal, and SDFH = spray-dried fish hydrolysate.
[c]SDBM vs SMFM (P<.02).
[d]SDBM vs SDFH (P<.03).
[e]SDBM vs SMFM + SDBM (P<.06).
[f]SDBM vs SDFH (P<.01).
[g]SDBM vs SMFM + SDBM (P<.02).
[h]SDBM vs SMFM (P<.05).

EFFECTS OF WHEAT GLUTEN ON NURSERY PIG PERFORMANCE

B. T. Richert, J. D. Hancock, and J. L. Morrill

Summary

One hundred eighty weanling pigs, averaging 23 d of age and 12.6 lb initial weight, were used to evaluate spray-dried wheat gluten (WG) in phase 1 (d 0 to 14) and(or) phase 2 (d 14 to 37) nursery diets. Phase 1 treatments were 1) dried skim milk-soybean meal-dried whey-based control (DSM-SBM), 2) Diet 1 with WG and lactose used to replace the DSM (WG-SBM), and 3) Diet 1 with WG used to replace the SBM (DSM-WG). Phase 2 treatments were 1) corn-SBM-dried whey-based control and 2) WG and lactose used to replace the dried whey. During phase 1, diets with WG supported average daily gain (ADG), average daily feed intake (ADFI), and feed/gain (F/G) similar to the DSM-SBM control. Pigs fed the diet with DSM-WG had improved F/G compared to pigs fed WG-SBM. Diets with WG had increased DM and N digestibilities but caused increased serum urea N compared to the DSM-SBM control. In the first week of phase 2 (d 14 to 21), pigs previously fed WG-SBM and DSM-WG had improved F/G and DM and N digestibilities compared to those previously fed the DSM-SBM control. Pigs previously fed the WG-SBM treatment had improved ADG, ADFI, and F/G compared to pigs previously fed DSM-WG. Overall (d 0 to 37), pigs fed WG in phase 1 had improved ADG and F/G compared to pigs fed the DSM-SBM control, and pigs fed WG-SBM during phase 1 had greater ADG and ADFI than pigs fed DSM-WG. As for the phase 2 diet treatments, dried whey supported improved ADG, ADFI, and F/G from d 14 to 21 compared to WG and lactose. However, for the entire phase 2 period (d 14 to 37) and overall (d 0 to 37), pigs fed WG in phase 2 had similar ADG and improved F/G compared to those fed dried whey. In conclusion, pigs fed WG in place of DSM during phase 1 had improvements of 13% in ADG, 9% in ADFI, and 4% in F/G for the entire nursery period.

(Key Words: Dried Skim Milk, Wheat Gluten, Nursery.)

Introduction

Wheat gluten (WG) is a product produced in Kansas that is used primarily by the baking industry to improve the protein concentration of poor quality flours. However, research published in the 1991 KSU Swine Day Report (Report of Progress No. 641, page 74) indicated increases of 10 to 20% in average daily gain (ADG) and average daily feed intake (ADFI) for the overall nursery phase when pigs were fed spray-dried WG vs dried skim milk from d 0 to 14 postweaning. Those data suggested an alternative for swine producers wishing to improve growth performance of their weanling pigs without use of rendered animal products. In an effort to further elucidate the growth enhancing effects of WG, an experiment was designed to determine the effects of feeding spray-dried WG in place of milk products during phase 1 (d 0 to 14), phase 2 (d 14 to 37), and for the entire nursery period.

Procedures

One hundred eighty weanling pigs, averaging 23 d of age and 12.6 lb initial weight, were used in a 37-d experiment to determine the effects of feeding spray-dried WG in phase 1 and(or) phase 2 on growth perfor-

mance and nutrient digestibility. At weaning, the pigs were allotted to treatment based on initial weight, sex, and ancestry. The experiment was a randomized complete block with treatments arranged as a 3 × 2 factorial. Treatments for phase 1 were 1) dried skim milk-soybean meal-dried whey-based control (DSM-SBM), 2) Diet 1 with WG and lactose used to replace the DSM (WG-SBM), and 3) Diet 1 with WG used to replace the SBM (DSM-WG). On d 14, pigs were changed to phase 2 treatments that were 1) corn-SBM-dried whey-based control and 2) WG and lactose used to replace the dried whey. Phase 1 diets had 1.4% lysine and 25% lactose (Table 1). Phase 2 diets had 1.2% lysine and 15% lactose. All diets were pelleted. Each pen had three barrows and three gilts, with five pens per treatment. Pens were 4 ft × 5 ft with a self-feeder and nipple waterer to allow ad libitum consumption of feed and water.

Fecal samples were collected from four pigs per pen on d 14 and 21; dried; pooled within pen; and analyzed for DM, N, and Cr concentrations to determine apparent nutrient digestibilities. On d 13 and 20, feeders were removed for 3 h and blood was collected from four pigs per pen for determination of serum urea N concentrations.

Results and Discussion

Crude protein concentrations of the protein sources ranged from 13.3% for the dried whey to 74.3% for the spray-dried WG (Table 2). Of particular importance were the differences in lysine concentrations. When expressed as a percentage of CP, dried skim milk, dried whey, soybean meal, and WG had 7.6, 7.1, 6.3, and 1.7% lysine. Thus, it should be noted that use of WG to replace the protein from DSM or SBM in phase 1 starter diets will necessitate use of crystalline lysine (i.e., 10 to 12 lb/ton).

During phase 1, pigs fed WG-SBM and DSM-WG had similar performance (P>.15) to pigs fed the DSM-SBM control, although pigs fed the DSM-WG diet (without soybean meal) tended to have the greatest ADG and superior F/G (Table 3). Pigs fed WG-SBM had greater ADFI (P<.01) but poorer F/G (P<.001) compared to pigs fed DSM-WG. Pigs fed DSM-SBM had the lowest serum urea N concentrations, and pigs fed DSM-WG had the greatest. Normally, we would anticipate lower serum urea N concentrations to be associated with superior amino acid balance and, therefore, improved growth performance. In the present experiment, serum urea N was not an adequate predictor of nutritional status, because pigs with the greatest growth performance also had the greatest serum urea N. Diets with WG had greater DM and N digestibilities than the DSM-SBM control (P<.001), and the DSM-WG diet had greater DM and N digestibilities than the WG-SBM diet (P<.001). Comparison of the DSM-SBM control diet to the DSM-WG diet indicated 4 and 9% improvements in digestibilities of DM and N, respectively, when WG was used to replace SBM.

Growth performance, nutrient digestibilities, and serum urea N were determined for the first 7 d of phase 2 (d 14 to 21) to evaluate the response of pigs to a diet change. For d 14 to 21, there were carryover effects of phase 1 treatment, with pigs fed WG in phase 1 having improved F/G (P<.01), DM (P<.01), and N (P<.001) digestibilities compared to pigs fed the DSM-SBM control diet in phase 1 (Table 4). Pigs fed WG-SBM in phase 1 had improved ADG (P<.001), ADFI (P<.001), and F/G (P<.05) compared to those fed DSM-WG. Thus, the advantage of using WG to formulate diets without SBM in phase 1 was lost when the pigs were changed to a phase 2 diet with SBM.

For d 14 to 37 and overall (d 0 to 37), pigs fed WG in phase 1 had improved ADG (P<.06) and F/G (P<.01) compared to pigs fed DSM-SBM. Also, pigs fed WG-SBM in phase 1 had greater ADG (P<.001) and ADFI (P<.001) and improved F/G (P<.01) in phase 2 compared to those fed DSM-WG, demonstrating again that using WG to replace the

DSM in phase 1 diets is of more benefit than replacing the SBM. The diet with WG-SBM supported 18, 11, and 6% improvements in ADG, ADFI, and F/G in phase 2, and 13, 9 and 4% improvements in ADG, ADFI, and F/G overall when compared to the DSM-SBM control. These values are similar to those reported in the 1991 KSU Swine Day Report, which indicated overall improvements of 10 to 20% in ADG and ADFI for pigs fed spray-dried WG vs those fed DSM during phase 1.

Regarding phase 2 treatments, pigs consuming dried whey had improved ADG ($P<.01$), ADFI ($P<.05$), and F/G ($P<.05$) compared to pigs fed WG and lactose for d 14 to 21 (the first 7 d of phase 2). However, WG and lactose supported better F/G ($P<.05$) for the entire phase 2 period. Serum urea N was greater ($P<.001$) for pigs fed diets with WG in phase 2.

In conclusion, using spray-dried WG and lactose to replace DSM in diets for early-weaned pigs resulted in greater growth performance during the nursery phase with lower diet costs. However, our data do not support use of spray-dried wheat gluten to formulate nonsoybean meal diets for phase 1 or to replace dried whey in phase 2 diets.

Table 1. Diet Composition, %

	Phase 1[ab]			Phase 2[c]	
Item	DSM-SBM	WG-SBM	DSM-WG	Whey	WG
Corn	33.96	32.78	33.92	45.10	45.49
Soybean meal (48%)	19.85	19.85	—	28.85	28.85
Dried whey (edible)	20.00	20.00	20.00	20.00	—
Dried skim milk	20.00	—	20.00	—	—
Spray-dried WG	—	9.20	13.00	—	3.50
Lactose	—	10.40	—	—	14.90
Lysine-HCl	—	.50	.58	—	.18
Cornstarch	—	—	6.00	—	—
Soybean oil	3.00	3.00	3.00	3.00	3.00
Monocalcium phosphate	1.20	2.20	1.70	1.30	2.05
Limestone	.34	.42	.15	.60	.63
Vitamins and minerals[d]	.65	.65	.65	.65	.65
Salt	—	—	—	—	.25
Antibiotic[e]	1.00	1.00	1.00	.50	.50
Total	100	100	100	100	100

[a]Phase 1 diets were formulated to 1.4% lysine, 22% CP, 25% lactose, .9% Ca, and .8% P.
[b]DSM = dried skim milk; SBM = soybean meal, and WG = spray-dried wheat gluten.
[c]Phase 2 diets were formulated to 1.2% lysine, 20% CP, 15% lactose, .8% Ca, and .7% P.
[d]KSU vitamin mix (.25%), KSU mineral mix (.15%), Se mix (.05%), copper sulfate (.10%), and chromic oxide (.10% as an indigestible marker).
[e]Phase 1 antibiotic supplied 200 g furazolidone, 100 g oxytetracycline, and 90 g arsanilic acid per ton of diet; phase 2 antibiotic supplied 100 g chlortetracycline, 100 g sulfathiazole, and 50 g penicillin per ton of diet.

Table 2. Chemical Composition of Protein Sources, %

Item	Dried skim milk[a]	Whey[a]	Soybean meal[b]	Spray-dried wheat gluten[b]
CP	33.3	13.3	45.84	74.34
Amino acids				
Arginine	1.16	.33	3.97	2.56
Histidine	.86	.17	1.15	1.38
Isoleucine	2.18	.78	1.96	2.15
Leucine	3.30	1.18	3.62	4.73
Lysine	2.54	.94	2.91	1.27
Methionine	.90	.19	.75	2.45
Phenylalanine	1.57	.35	1.83	3.43
Threonine	1.57	.89	1.84	2.37
Tryptophan	.43	.18	.59	.61
Valine	2.29	.67	1.84	2.19

[a]From NRC (1988) Nutrient Requirements for Swine.
[b]Analyzed values.

Table 3. Phase 1 Growth Performance of Weanling Pigs Fed Spray-Dried Wheat Gluten[a]

	Phase 1 treatments (d 0 to 14)			
Item	DSM-SBM[b]	WG-SBM	DSM-WG	CV
d 0 to 14				
ADG, lb	.65	.64	.66	7.4
ADFI, lb[e]	.64	.66	.60	6.2
F/G[f]	.98	1.03	.91	5.7
Apparent digestibility (d 14), %				
DM[c,f]	87.1	87.5	90.7	1.0
N[c,f]	82.6	83.9	89.7	1.5
Serum urea N (d 13), mg/dL[c,d]	7.4	11.4	12.6	12.2

[a]A total of 180 pigs (six pigs/pen and five pens/treatment) with an average initial wt of 12.6 lb.
[b]DSM = dried skim milk, WG = spray-dried wheat gluten, and SBM = soybean meal.
[c]DSM-SBM vs WG-SBM and DSM-WG (P<.001).
[def]WG-SBM vs DSM-WG (P<.05, P<.01, and P<.001, respectively).

Table 4. Phase 2 Growth Performance of Weanling Pigs Fed Spray-Dried Wheat Gluten[a]

	DSM-SBM[b]		WG-SBM		DSM-WG		
Item	Whey	WG	Whey	WG	Whey	WG	CV
d 14 to 21							
ADG, lb[h,j]	.80	.70	1.00	.84	.76	.68	11.7
ADFI, lb,[h,i]	1.22	1.14	1.32	1.20	1.09	1.05	7.5
F/G[d,f,i]	1.53	1.63	1.32	1.43	1.43	1.54	8.3
d 14 to 37							
ADG, lb[c,h]	1.04	1.00	1.21	1.20	.97	1.02	9.5
ADFI, lb[h]	1.64	1.54	1.80	1.72	1.52	1.55	7.9
F/G[d,g,j]	1.58	1.54	1.49	1.43	1.57	1.52	3.2
d 0 to 37							
ADG, lb[c,h]	.89	.86	1.00	.98	.85	.89	7.4
ADFI, lb[h]	1.26	1.20	1.37	1.32	1.17	1.19	6.6
F/G[d,i]	1.42	1.40	1.37	1.35	1.38	1.34	2.7
Apparent digestibility (d 21), %							
DM[d]	83.6	82.4	85.6	85.4	85.5	84.5	2.4
N[e]	79.2	79.0	81.6	82.6	80.4	81.4	2.6
Serum urea N (d 20),							
mg/dL[k,l]	11.4	12.7	11.3	14.0	9.8	13.7	10.2

[a]A total of 180 pigs (six pigs/pen and five pens/treatment) with an average initial wt of 12.6 lb.
[b]DSM = dried skim milk, WG = spray-dried wheat gluten, and SBM = soybean meal. Note that DSM-SBM, WG-SBM, and DSM-WG were phase 1 treatments fed from d 0 to 14 only.
[cde]DSM-SBM vs WG-SBM and DSM-WG (P<.06, P<.01, and P<.001, respectively).
[fgh]WG-SBM vs DSM-WG (P<.05, P<.01, and P<.001, respectively).
[ijk]Whey vs WG (P<.05, P<.01, and P<.001, respectively).
[l]DSM-SBM vs WG-SBM and DSM-WG × whey vs WG (P<.04).

USE OF WHEY PROTEIN CONCENTRATE, DRIED BUTTERMILK, AND PORCINE PLASMA PROTEIN TO REPLACE DRIED SKIM MILK IN DIETS FOR WEANLING PIGS

B. T. Richert, J. D. Hancock, and R. H. Hines

Summary

One hundred thirty-two weanling pigs, with an average age of 19 d and average weight of 8.4 lb, were used in a 28-d growth assay to determine the effects of replacing dried skim milk (DSM) with dried whey protein concentrate (WPC), dried buttermilk (DBM), and spray-dried porcine plasma (SDPP). Treatments were 1) 20% DSM-20% dried whey-based control, 2) WPC used to replace the DSM of Diet 1, 3) DBM used to replace the DSM of Diet 1, and 4) SDPP and lactose used to replace the DSM of Diet 1. All diets were formulated to 1.4% lysine, 25% lactose, 5% fat, .9% Ca, and .8% P. These diets were fed from d 0 to 14 with a corn-soybean meal - dried whey - fish meal - based diet fed to all pigs from d 14 to 28. For d 0 to 14, pigs fed the alternative protein sources (WPC, DBM, and SDPP) had average daily gain (ADG), average daily feed intake (ADFI), and feed/gain (F/G) similar to pigs fed DSM. Pigs fed SDPP had the greatest ADG and ADFI but poorer F/G than pigs fed WPC and DBM. Pigs fed WPC had greater ADFI than pigs fed DBM. There were no differences among treatments for DM or N digestibilities. For d 14 to 28, there were no differences in ADG or ADFI among treatments. However, pigs fed WPC and DBM had numerically greater ADG than pigs fed SDPP (.99 vs .95 lb/d) corresponding closely with the 5% improvement in F/G. Overall (d 0 to 28), there were no differences in ADG among treatments. However, pigs fed SDPP consumed more feed and had poorer F/G compared to pigs fed WPC and DBM. Considering overall pig performance, WPC, DBM, and SDPP are acceptable substitutes for DSM in diets for early-weaned pigs.

(Key Words: Whey Protein Concentrate, Dried Buttermilk, Porcine Plasma, Skim Milk, Nursery.)

Introduction

Use of dried skim milk (DSM) in diets for early-weaned pigs has been a common practice during the last decade. It has allowed producers to reduce weaning age and maintain acceptable pig performance. However, DSM is expensive, and alternative protein sources are needed that reduce diet cost without loss of pig performance. With these concerns in mind, an experiment was conducted to determine the effects of replacing DSM with whey protein concentrate (WPC), dried buttermilk (DBM), and spray-dried porcine plasma (SDPP) in diets for weanling pigs.

Procedures

One hundred thirty-two weanling pigs, with an average age of 19 d and average weight of 8.4 lb, were used in a 28-d growth assay. Treatments were 1) 20% DSM-20% dried whey-based control, 2) WPC used to replace the DSM of Diet 1, 3) DBM used to replace the DSM of Diet 1, and 4) SDPP and lactose used to replace the DSM of Diet 1. These diets were formulated to 1.4% lysine, .9% Ca, and .8% P and fed in pelleted form (Table 1). For d 14 to 28, all pigs were given a corn-soybean meal-dried whey-fish meal-based diet formulated to 1.2% lysine, .8% Ca, and .7% P and fed in meal form.

Pigs were housed in 3.5 ft × 5 ft pens with rubber coated, expanded metal flooring. Room temperatures were 90, 86, 82, and

78°F for wk 1 to 4, respectively. Each pen had a self-feeder and nipple waterer to allow ad libitum consumption of feed and water. Pigs and feeders were weighed weekly to allow calculation of average daily gain (ADG), average daily feed intake (ADFI), and feed/gain (F/G). Fecal samples were collected on d 13 to allow calculation of apparent DM and N digestibilities.

Results and Discussion

Whey protein concentrate was similar to DSM for CP concentration (Table 2). However, lysine concentration (especially when expressed as a percentage of CP) was greater for WPC than DSM. Perhaps the most appealing characteristic of WPC was that its average cost was less than half the cost of DSM during the past year. Dried buttermilk was similar to DSM in CP and lysine concentrations, but had 6% milk fat, which should be readily utilized by weanling pigs. Spray-dried plasma protein had the greatest CP and lysine concentrations with only slightly lower lysine as a percentage of CP compared to WPC. Thus, the high cost of SDPP is deceiving because when 166 lb of spray-dried plasma protein was blended with 200 lb of lactose to replace DSM in the control diet, the cost was $1.05/lb for the blend.

For d 0 to 14, pigs fed the alternative protein sources (WPC, DBM, and SDPP) had similar (P>.10) ADG, ADFI, and F/G compared to pigs fed DSM (Table 3). Pigs fed SDPP had greater ADG (P<.01) and ADFI (P<.001) but poorer F/G (P<.01) than pigs fed WPC and DBM. These results are consistent with reports from Iowa State University, Kansas State University, Oklahoma State University, and others that indicate greater ADG and ADFI, and only slight losses in efficiency of gain in weanling pigs fed SDPP. Pigs fed WPC had greater ADFI (P<.06) than pigs fed DBM. There were no differences (P>.12) among protein sources in DM and N digestibilities at d 13.

For d 14 to 28, there were no differences (P>.10) in ADG, ADFI, and F/G for DSM vs the alternative protein sources (WPC, DBM, and SDPP). However, within the alternative protein sources, pigs fed WPC and DBM tended to have the greatest ADG and had improved F/G (P<.01) compared to those fed SDPP.

Overall, ADG was similar among treatments. Pigs fed SDPP had greater overall ADFI (P<.06) resulting from greater appetite from d 0 to 14, and inferior F/G compared to pigs fed WPC and DBM (P<.06). The tendency for greater rates and efficiencies of growth during d 14 to 28 for pigs fed WPC and DBM vs DSM and SDPP from d 0 to 14 indicates carryover effects for the protein sources. Indeed, other research in this booklet indicates that choice of protein source from d 0 to 14 will determine if advantages from feeding SDPP from d 0 to 14 are lost or maintained. Such research to identify complementary protein sources (if any) for WPC and DBM is yet to be conducted.

In conclusion, WPC, DBM, and SDPP can effectively replace DSM in diets for the early-weaned pig. Furthermore, considering overall performance, WPC was a cost effective alternative to DSM when all pigs were changed to a corn-soybean meal-dried whey-fish meal-based diet for d 14 to 28 of the nursery phase.

Table 1. Diet Composition[a]

Item	DSM	WPC	DBM	SDPP
Corn	33.96	35.63	34.91	34.49
Soybean meal (48% CP)	19.85	19.85	19.85	19.85
Dried skim milk	20.00	—	—	—
Whey protein concentrate	—	16.15	—	—
Dried buttermilk	—	—	20.00	—
Spray-dried porcine plasma	—	—	—	8.30
Whey	20.00	20.00	20.00	20.00
Lactose	—	1.75	—	10.00
Lysine-HCl	—	—	.06	—
DL-methionine	—	—	—	.10
Soybean oil	3.00	2.70	2.00	3.00
Dicalcium phosphate	1.20	1.82	1.25	2.25
Limestone	.34	.45	.28	.36
Vitamins and minerals[b]	.65	.65	.65	.65
Antibiotic[c]	1.00	1.00	1.00	1.00
Total	100	100	100	100

[a]These diets were fed from d 0 to 14. All diets were formulated to 1.4% lysine, .9% Ca, and .8% P. All pigs were fed a corn-soybean meal-dried whey-fish meal-based diet from d 14 to 28 (formulated to 1.2% lysine, .8% Ca, and .7% P).

[b]KSU vitamin premix (.25%), KSU trace mineral premix (.15%), Se premix (.05%), copper sulfate (.10%), and chromic oxide (.10%).

[c]Day 0 to 14 antibiotic supplied 200 g furazolidone, 100 g oxytetracycline, and 90 g arsanilic acid per ton of diet. Day 14 to 28 antibiotic supplied 100 g chlortetracycline, 100 g sulfathiazole, and 50 g penicillin per ton of diet.

Table 2. Chemical Composition of Protein Sources

Item	Dried skim milk	Whey protein concentrate	Dried buttermilk	Spray-dried porcine plasma
Crude protein, %	33.3	34.5	32.0	70
Lysine, % of sample	2.54	3.12	2.28	6.10
Lysine, % of CP	7.6	9.0	7.1	8.7
Methionine, %	.62	.75	.55	.53
Fat, %	1.1	3.0	6.0	2.0
Lactose, %	52.0	52.6	51.5	—
Cost, $/cwt[a]	105	45	90	190

[a]Average cost for the last 12 months.

Table 3. Effects of Replacing DSM with Alternative Protein Sources[a]

	Protein sources (for d 0 to 14)				
Item	DSM[b]	WPC	DBM	SDPP	CV
d 0 to 14					
ADG, lb[d]	.53	.54	.50	.61	11.6
ADFI, lb[e,f]	.54	.55	.48	.66	9.4
F/G[d]	1.02	1.02	.96	1.08	5.9
Apparent digestibilities (d 13), %					
DM	89.8	90.3	90.1	88.8	2.1
N	84.8	84.5	85.5	81.6	5.0
d 14 to 28					
ADG, lb	.96	1.00	.98	.95	6.4
ADFI, lb	1.52	1.53	1.49	1.52	7.2
F/G[d]	1.58	1.53	1.52	1.60	2.9
d 0 to 28					
ADG, lb	.74	.77	.74	.78	7.6
ADFI, lb[c]	1.03	1.04	.98	1.09	7.0
F/G[c]	1.39	1.35	1.32	1.40	3.0

[a]132 weanling pigs with an average age of 19 d and average weight of 8.4 lb.
[b]DSM = dried skim milk, WPC = whey protein concentrate, DBM = dried buttermilk, and SDPP = spray-dried porcine plasma protein.
[cde]SDPP vs WPC and DBM (P<.06, P<.01 and P<.001, respectively).
[f]WPC vs DBM (P<.06).

INFLUENCE OF PROTEIN SOURCE FED TO THE EARLY-WEANED PIG DURING PHASE I (D 0 - 9) ON THE RESPONSES TO VARIOUS PROTEIN SOURCES FED DURING PHASE II (D 9 - 28)[1]

L. J Kats, M. D. Tokach, J. L. Nelssen, R. D. Goodband, and J. A. Hansen

Summary

A total of 468 weanling pigs (initially 13.2 lb and 21 d of age) was used in a 28 d growth assay to determine the influence of protein source fed during phase I (d 0 to 9) on the response to various protein sources fed during phase II (d 9 to 28). Phase I diets contained 20% dried whey, 10% lactose, and either 10.3% spray-dried porcine plasma or 15.2% moist-extruded soy protein concentrate and formulated to contain 1.5% lysine. On d 9, pigs were switched to diets containing 10% dried whey and either 3.9% spray-dried porcine plasma, 2.5% spray-dried blood meal, or 5.7% moist-extruded soy protein concentrate and formulated to contain 1.25% lysine. During phase I, pigs fed spray-dried porcine plasma had improved average daily gain (.30 vs .16 lb), average daily feed intake (.40 vs .29 lb), and feed efficiency (1.35 vs 2.08) compared to pigs fed moist-extruded soy protein concentrate. During phase II, pigs fed diets containing spray-dried porcine plasma had increased average daily gain and average daily feed intake compared with pigs fed diets containing spray-dried blood meal and higher average daily feed intake than pigs fed extruded soy protein concentrate. There were no interactive effects between phase I and phase II protein sources; therefore, growth responses observed during phase I apparently are additive with those observed during phase II.

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

Introduction

Previous research has shown spray-dried porcine plasma to be an effective protein source in the high nutrient density diet for the early-weaned pig. However, interest in using a soy protein-based product in these diets has increased because of the potential for decreasing diet cost. In the phase II diet, spray-dried blood meal has been shown to be a very effective protein source to replace a portion of the soybean meal. With various ingredient options available to the producer, the consequences of using protein sources in a certain sequence could be important for obtaining maximum pig performance. Therefore, the objective of this experiment was to evaluate the influence of various protein sources fed in the phase I period on subsequent performance in the phase II period when pigs were either fed the same protein source or switched to a different protein source to determine any interactive effects.

Procedures

A total of 468 weanling pigs (initially 13.2 lb and 21 d of age) was used in a 28 d growth trial to determine the influence of protein source fed during phase I (d 0 to 9) on the response to various protein sources fed during phase II. Pigs were allotted by weight and sex to six replicates with 13 pigs/pen. The trial was arranged in a 2 × 3 factorial based on protein sources fed in the phase I (spray-dried porcine plasma or moist-extruded soy protein concentrate) and II (spray-dried

[1]The authors wish to thank Dale Keesecker and Keesecker Agribusiness, Washington, KS, for use of facilities and animals.

porcine plasma, spray-dried blood meal, or moist-extruded soy protein concentrate) starter diets. Phase I diets contained 20% dried whey, 10% lactose, and either 10.3% spray-dried porcine plasma or 15.2% moist-extruded soy protein concentrate and were formulated to contain 1.5% lysine (Table 1). On d 9 postweaning, pigs were switched to one of three diets containing 10% dried whey and either 3.9% spray-dried porcine plasma, 2.5% spray-dried blood meal, or 5.7% moist-extruded soy protein concentrate. All phase II diets were formulated to contain 1.25% lysine. Thus, pigs fed plasma diets in phase I continued on a blood source diet or switched to a soy-based diet in phase II. Similiarly, pigs fed a soy-based diet in phase I either continued on a soy-based diet or switched to a blood source diet in phase II. Therefore, the possibility of complementary effects of protein source fed in the phase I diet on subsequent performance in phase II could be evaluated. All experimental protein sources were substituted on an equal lysine basis. Pigs were housed in an environmentally controlled nursery and were allowed ad libitum access to feed and water. Pigs and feeders were weighed on d 9, 16, and 28 postweaning to evaluate average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G).

Results and Discussion

During phase I, pigs fed spray-dried porcine plasma had improved (P<.001) ADG (.30 vs .16 lb), ADFI (.40 vs .29 lb), and F/G (1.35 vs 2.08) compared to pigs fed moist-extruded soy protein concentrate (Table 2). Phase I protein source did not influence phase II performance, and no interactions occurred between protein sources fed during phases I and II. During phase II, pigs fed diets containing spray-dried porcine plasma had improved (P<.02) ADG and ADFI compared with pigs fed diets containing spray-dried blood meal and higher (P<.03) ADFI than pigs fed diets containing moist-extruded soy protein concentrate (Table 3). Although there were no interactive effects, protein sources in both phases I and II influenced (P<.05) pig weight at the end of the starter period (d 28). Pigs receiving spray-dried porcine plasma during phases I and II had the greatest final weight. These results indicate that growth responses attributed to protein source in phases I and II are additive. Therefore, when planning a nursery phase feeding system, it is important to keep in mind the protein sources you will be using in order to take advantage of this additive effect for optimizing pig performance and reducing cost/lb of gain.

Table 1. Diet Composition

	Phase I[a]		Phase II[b]		
Item, %	SDPP[c]	ESPC[d]	SDPP	SDBM[e]	ESPC
Corn	32.58	27.79	52.28	53.71	50.54
Soybean meal, (48% CP)	19.34	19.34	25.23	25.23	25.23
Dried whey, edible grade	20.00	20.00	10.00	10.00	10.00
Spray-dried porcine plasma	10.28	-	3.90	-	-
Extruded soy protein concentrate	-	15.2	-	-	5.77
Spray-dried blood meal	-	-	-	2.50	-
Lactose	10.00	10.00	-	-	-
Soybean oil	3.00	3.00	4.00	4.00	4.00
Monocalcium phosphate (21% P)	2.47	2.01	1.95	1.92	1.78
Limestone	.65	.76	.81	.81	.86
Antibiotic[f]	1.00	1.00	1.00	1.00	1.00
Salt	-	.30	.25	.25	.25
Vitamin premix	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15
Copper sulfate	.10	.10	.075	.075	.075
Vitamin E	.05	.05	.05	.05	.05
Selenium premix	.05	.05	.05	.05	.05
DL-methionine	.078	.003	.007	-	-
Total	100.00	100.00	100.00	100.00	100.00

[a]Phase I diets were fed from d 0 - 9 and were formulated to contain 1.5% lysine.
[b]Phase II diets were fed from d 9 - 28 and were formulated to contain 1.25% lysine.
[c]Spray-dried porcine plasma.
[d]Extruded soy protein concentrate.
[e]Spray-dried blood meal.
[f]Provided 200 g furazoladone, 100 g oxytetracycline, and 90 g arsenilic acid per ton.

Table 2. Phase I (d 0 - 9) Growth Performance[a]

Item	SDPP[b]	ESPC[c]
d 0 - 9		
ADG, lb[d]	.30	.16
ADFI, lb[d]	.40	.30
F/G[d]	1.35	2.08

[a]Four hundred sixty eight pigs were used (initially 13.2 lb and 21 d of age), 13 pigs/pen.
[b]Spray-dried porcine plasma.
[c]Extruded soy protein concentrate.
[d] P<.001.

Table 3. Growth Performance of Pigs Fed Various Protein Sources in Phases I and II[a]

	I:SDPP			I:ESPC			
Item	II:SDPP	SDBM	ESPC	II:SDPP	SDBM	ESPC	CV
d 9 - 28							
ADG, lb[b]	.74	.64	.67	.73	.65	.70	10.6
ADFI, lb[bc]	.95	.87	.92	1.03	.85	.88	10.8
F/G	1.29	1.37	1.37	1.41	1.31	1.26	8.5
d 0 - 28							
ADG, lb	.59	.53	.56	.55	.49	.52	9.9
ADFI, lb	.77	.72	.74	.79	.67	.69	10.7
F/G	1.31	1.37	1.33	1.45	1.37	1.33	5.8
d 28 wt[d]	30.2	28.4	28.9	28.9	27.4	28.7	4.0

[a]468 weanling pigs were used (initially 13.2 lb and 21 d of age), 13 pigs/pen.
[b]Spray-dried porcine plasma vs spray-dried blood meal (P<.02).
[c]Spray-dried porcine plasma vs extruded soy protein concentrate (P<.03).
[d]P<.05.

THE EFFECT OF DIETARY SOYBEAN MEAL LEVEL IN PHASE I ON SUBSEQUENT PHASE II GROWTH PERFORMANCE

K. G. Friesen, R. D. Goodband, J. L. Nelssen, M. D. Tokach, and L. J. Kats

Summary

One hundred and four pigs (initially 11.7 lb and 21 d of age) were used to determine the effect dietary soybean meal has on growth performance in the early-weaned pig. Pigs were fed one of four diets from d 0 to 14 postweaning. Diets were formulated to 1.5% lysine and 24.4% lactose with either 0, 7.5, 15.0, or 22.5% soybean meal. Soybean meal and lactose replaced dried skim milk to maintain equal lysine and lactose levels. From d 14 to 35 postweaning, all pigs were fed a common (1.25% lysine) corn-soybean meal diet containing 10% dried whey and 4% select menhaden fish meal. Growth performance (ADG, ADFI, and F/G) was not influenced by dietary soybean meal level fed from d 0 to 14 postweaning. From d 14 to 35 postweaning, ADG was not influenced by dietary soybean meal level during d 0 to 14. Average daily feed intake was decreased linearly during d 14 to 35 as dietary soybean meal (d 0 to 14) increased. Conversely, feed efficiency during d 14 to 35 improved linearly as dietary soybean meal increased (d 0 to 14). Cumulative (d 0 to 35) ADG was not affected by the amount of dietary soybean meal (7.5, 15.0, or 22.5%) fed from d 0 to 14 postweaning, whereas ADFI decreased linearly and feed efficiency was improved linearly. These data suggest that soybean meal can be included in a high nutrient dense starter diet at levels up to 22.5% without impairing phase I (d 0 to 14 postweaning) growth performance and overall growth performance. The phase I diet must contain soybean meal for optimal subsequent performance.

(Key Words: Starter Pigs, Soybean Meal, Dried Skim Milk.)

Introduction

Previous research at Kansas State University has suggested that decreased growth performance during the first week postweaning can be attributed to an immune (allergic) reaction to soybean meal in the small intestine. This immune response impairs nutrient absorption, resulting in decreased growth performance. Further research indicates that feeding early-weaned pigs a corn-soybean meal diet following a diet without soybean meal from d 0 to 14 postweaning also results in a similar depression in growth performance. These data suggest that the early-weaned pig requires soybean meal during phase I to become acclimated to soy protein as it matures. Thus, the objective of this experiment was to determine the amount of dietary soybean meal necessary during phase I to acclimate the early-weaned pig to soy protein without impairing growth performance throughout the nursery phase.

Procedures

A total of 104 pigs averaging 11.7 lb and 21 ± 1 d of age was used to determine the optimal level of soybean meal to be included in starter diets for the early-weaned pig. From d 0 to 14, pigs were fed experimental diets containing 0, 7.5, 15.0, and 22.5% soybean meal (Table 1). Soybean meal and purified lactose replaced dried skim milk to provide the three soybean meal diets. The experimental diets were formulated to contain 1.5% lysine, and purified lactose was supplemented in the soybean meal diets to ensure that all four diets were equal in lactose content. From d 14 to 35 postweaning, pigs

were placed on a common, 1.25% lysine diet containing 10% dried whey and 4% select menhaden fish meal. Pigs were housed in 4 ft × 5 ft pens, with four or five pigs per pen and six replicate pens per treatment. Each pen was equipped with a self-feeder and a nipple waterer to provide *ad libitum* access to feed and water. Weekly pig weights and feed consumption were collected to determine ADG, ADFI, and F/G.

Results and Discussion

Increasing soybean meal in diets for early-weaned pigs did not affect (P>.10) ADG, ADFI, and F/G from d 0 to 14 postweaning (Table 2). The performance during d 0 to 14 in this study suggests that the maximum inclusion rate of soybean meal in the starter pig diet was not detected. A previous high nutrient dense diet included 21.4% soybean meal, which is similar to the highest soybean meal inclusion rate of this experiment. Initially, the high nutrient dense diet contained a high concentration of milk products (dried skim milk and dried whey) to increase diet palatability and digestibility. Recent research from Kansas State University has suggested that spray-dried porcine plasma improves ADFI and feed efficiency, resulting in increased ADG when fed to the early-weaned pig. The high level of feed consumption in this experiment can be explained by the inclusion of spray-dried porcine plasma in the diet. This may hasten the development of immune tolerance to soy protein by increasing soybean meal intake during the starter phase and allow higher levels of SBM in the phase I diet.

From d 14 to 35, all pigs were placed on a common diet. Average daily gain was not affected (P>.10) in the final 3 weeks of the experiment (Table 2). However, from d 14 to 21, ADG tended (P<.11) to linearly decrease in pigs that had been fed low levels of soybean meal compared to pigs that had been fed a 22.5% soybean meal diet from d 0 to 14. The response was not prolonged, because ADG was not different (P>.10) from d 21 to 28 postweaning. Average daily feed intake during d 14 to 35 was decreased linearly (P<.05) and quadratically (P<.05) with increased soybean meal levels fed from d 0 to 14 postweaning.

Cumulative (d 0 to 35) ADG was not affected (P>.10) by soybean meal inclusion in the starter diet. However, as the level of soybean meal increased in the starter diet, ADFI was decreased (quadratic, P<.05). Feed efficiency from d 0 to 35 showed a quadratic (P<.05) improvement, with F/G maximized in pigs fed a 15% soybean meal diet from d 0 to 14 postweaning. Simple corn-soybean meal diets are not typically utilized for the early-weaned pig because of decreased nutrient digestibility; thus, the use of high nutrient dense diets has been proposed to increase feed intake and ADG in conjunction with improved feed efficiency. Including spray dried porcine plasma in the diets increased feed consumption, potentially masking the immune response for pigs fed higher levels of soybean meal (22.5%) on d 0 to 14 postweaning. This experiment indicates that soybean meal can be included at levels up to 22.5% from d 0 to 14 postweaning without depressing ADG or F/G. The phase I starter diet must contain soybean meal for optimal F/G during phase II.

Table 1. Composition of Diets, %[a]

	Soybean meal, %				
Item	0	7.5	15	22.5	Phase II
Corn	35.21	31.83	28.40	24.99	55.83
Soybean meal (48% CP)		7.50	15.00	22.50	22.71
Dried skim milk	26.71	17.81	8.91	—	—
Dried whey	20.00	20.00	20.00	20.00	10.00
Lactose		4.45	8.90	13.35	—
Fish meal					4.00
Spray dried porcine plasma	8.94	8.94	8.94	8.94	—
Soybean oil	6.00	6.00	6.00	6.00	4.00
					.15
Monocalcium phosphate (21% P)	1.47	1.76	2.05	2.33	1.46
Limestone	.14	.19	.26	.28	.55
Vitamin premix	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15
Copper sulfate	.07	.07	.07	.07	—
Salt	.05	.05	.05	.05	.25
Antibiotic[b]	1.00	1.00	1.00	1.00	.50
Total	100.00	100.00	100.00	100.00	100.00

[a]Phase I diets were formulated to contain 1.5% lysine, .90% Ca, .80% P, and 24.40% lactose. The Phase II diet was formulated to
[b]CSP-250 provided the following per lb of complete diet (g): chlortetracycline, .11, sulfathiazole, .11; penicillin, .055.

Table 2. The Effect of Soybean Meal Level on Weanling Pig Growth Performance[a]

	Soybean meal inclusion, %				
Item	0	7.5	15.0	22.5	CV
d 0 to 14					
ADG, lb	.80	.78	.76	.77	11.2
ADFI, lb	.81	.86	.77	.83	10.6
F/G	1.01	1.10	1.01	1.08	6.8
d 14 to 35					
ADG, lb	1.04	1.03	1.03	1.05	8.9
ADFI, lb[bc]	1.82	1.72	1.64	1.69	5.8
F/G[b]	1.75	1.67	1.59	1.61	5.9
d 0 to 35					
ADG, lb	.95	.93	.92	.94	5.7
ADFI, lb[c]	1.42	1.37	1.29	1.35	5.2
F/G[b]	1.49	1.47	1.40	1.44	4.1

[a]A total of 104 pigs, initial weight = 11.7 lb, 4-5 pigs/treatment, 6 pens/treatment.
[b]Linear effect of soybean meal (P<.05).
[c]Quadratic effect of soybean meal (P<.05).

MOIST EXTRUSION OF SOY PRODUCTS INFLUENCES GROWTH PERFORMANCE AND NUTRIENT UTILIZATION IN THE EARLY-WEANED PIG

K. G. Friesen, J. L. Nelssen, K. C. Behnke[1], and R. D. Goodband

Summary

One hundred and seventy pigs (initially 12.8 lb and 21 d of age) were used to determine the effect of moist extrusion on soybean products when fed to the early-weaned pig. Dietary treatments, including a positive control, fed d 0 to 14 postweaning were arranged in a 2 × 3 factorial. Pigs were fed one of the seven diets: 1) control diet (milk): corn+dried skim milk+dried whey+casein; 2 and 3) corn+defatted soy flakes with or without moist extrusion; 4 and 5) corn+toasted soy flour with or without moist extrusion; and 6 and 7) corn+soy protein concentrate with or without moist extrusion. The diets were formulated to 1.4% dietary lysine and 24.4% lactose, with soy products and purified lactose replacing the milk products on an isolysine and isolactose basis. From d 14 to 35 postweaning, all pigs were fed a common (1.25% lysine) corn-soybean meal diet containing 10% dried whey and 4% select menhaden fish meal. Pigs fed extruded soy products had improved ADG, ADFI, and F/G compared to pigs fed nonextruded soy products, with the largest improvement in pigs fed extruded soy flakes and flour. Dry matter and N digestibilities also were greater in pigs fed extruded soy products compared to pigs fed nonextruded soy products. When pigs were fed a common diet (d 14 to 35), ADFI and F/G were improved in pigs fed a nonextruded soy product from d 0 to 14 than in pigs fed an extruded soy product. Cumulative (d 0 to 35) ADG, ADFI, and F/G were improved in pigs fed extruded soy products compared to pigs fed nonextruded products. These data suggest that growth performance of early-weaned pigs fed less refined soy products (soy flakes and soy flour) processed by moist extrusion can be comparable to that of pigs fed highly refined soy products (soy protein concentrate).

(Key Words: Pigs, Soy Protein, Moist Extrusion, Nutrient Digestibility.)

Introduction

A common practice in the swine industry is to decrease the age of weaning in order to increase sow productivity. However, by decreasing the weaning age to 21 d, the young pig is often subject to a postweaning growth depression. Prior to weaning, the young pig receives sow's milk, a highly palatable, readily digestible diet. At weaning, the young pig is often fed a dry, complex carbohydrate, plant protein-based diet that is not readily utilized. Research has indicated that the early-weaned pig suffers from an immune (allergic) response to soy protein in the small intestine. This response results in intestinal damage, decreasing nutrient absorption, and, ultimately, poor growth performance. Previous research at Kansas State University suggests that moist extrusion processing can be used to increase digestibility and reduce the antigenicity of less refined soy products. Thus, the objective of this experiment was to further assess the effect of moist extrusion on soy products for inclusion in starter pig (phase I) diets.

[1]Department of Grain Science.

Procedures

One hundred and seventy pigs averaging 21 ± 1 d of age (initially 12.8 lb) were used to determine the effect moist extrusion has on soybean products when fed to the early-weaned pig. The experiment was designed as a randomized complete block with treatments arranged as a 2 × 3 factorial plus a positive control. Treatments were arranged to assess the main effects of soy product and extrusion processing. At weaning, pigs were allotted to one of seven dietary treatments based upon weight, gender, and ancestry. Treatments included were: 1) control diet: corn+dried skim milk+dried whey+casein, 2 and 3) corn+defatted soy flakes with or without moist extrusion, 4 and 5) corn+toasted soy flour with or without moist extrusion, and 6 and 7) corn+soy protein concentrate with or without moist extrusion. Experimental diets were formulated to contain 1.4% lysine, 24.4% lactose, .9% Ca, and .8% P (Table 1). The positive control diet was formulated with predominately milk protein sources. The soy products replaced milk products (dried skim milk, dried whey, and casein) on a lysine basis. Chromic oxide was included in the experimental diets as an undigestible marker to determine apparent nutrient digestibility. Experimental diets were fed from d 0 to 14 postweaning. All pigs were fed a common corn-soybean meal diet (1.25% lysine) containing 10% dried whey and 4% select menhaden fish meal from d 14 to 35 postweaning. Pigs were housed in an environmentally controlled nursery with wire mesh flooring. Each pen contained a self feeder and a nipple waterer to provide ad libitum access to feed and water. There were five pigs per pen (4 ft × 5 ft) and five replicate pens per treatment. Weekly pig weights and feed consumption were collected to calculate ADG, average daily feed intake (ADFI), and F/G.

A single screw extruder (Wenger X-20, Wenger Mfg. Sebetha, KS) equipped with a high shear screw, barrel, and die arrangement was used to moist extrude all soy products. Operating conditions were held constant between soy products. Slight alterations were made during the process, if machine stability was not maintained. Steam and water were added to the extruder to facilitate processing and to prevent burning of the soy product. The extruded product (approximately 30% moisture) was dried in a double pass, gas-fired dryer to approximately 12% moisture. After extrusion, the dried product was ground through a 1/16 in. hammermill screen and mixed into the experimental diets.

Results and Discussion

Moist extrusion of soy flakes and soy flour decreased trypsin inhibitor concentrations by 26.5 and 31.2 mg/g protein, respectively. Trypsin inhibitor concentrations were similar among all three soy products following extrusion processing. Glycinin and β-conglycinin concentrations of soy products were reduced to nondetectable levels after moist extrusion. Protein dispersibility index was decreased in extruded soy flakes and flour but increased in extruded soy protein concentrate.

Average daily gain, ADFI, and F/G were improved ($P<.01$) in pigs fed a milk-based diet compared to pigs fed a soy-based diet (Table 2). Diets with moist extruded soy flakes, soy flour, and soy protein concentrate improved ADG, ADFI, and F/G ($P<.01$) from d 0 to 14 postweaning. An interaction ($P<.05$) between moist extrusion and soy product source was observed, with pigs fed extruded soy flakes and flour having larger improvements in ADG, ADFI, and F/G than pigs fed extruded soy protein concentrate. Pigs fed nonextruded soy protein concentrate had improved ($P<.05$) ADG, ADFI, and F/G compared to pigs fed either nonextruded soy flakes or soy flour from d 0 to 14 postweaning. Apparent DM and N digestibilities (Table 2) were increased ($P<.01$) on d 13 postweaning in pigs fed extruded soy products and were highest in pigs fed a milk diet ($P<.01$). On d 14 postweaning, a soy protein source by extrusion processing interaction ($P<.05$) was observed for serum urea N, with

pigs fed extruded soy flakes and soy flour having the largest decrease in urea N concentration. Urea N concentration was lowest (P<.01) in pigs fed a milk diet from d 0 to 14 postweaning.

From d 14 to 35 postweaning, when pigs were fed a common corn-soybean meal diet, ADG was not different (P>.10), regardless of d 0 to 14 protein source. Feed consumption and F/G from d 14 to 35 were maximized (P<.01) in pigs fed a milk diet from d 0 to 14 and increased in pigs fed extruded soy flakes and flour compared to nonextruded soy flakes and flour from d 0 to 14 postweaning.

Cumulative (d 0 to 35) ADG, ADFI, and F/G were lowest (P<.05) in pigs fed a milk diet from d 0 to 14 postweaning. Again, an interaction (P<.05) between moist extrusion and soy product existed, with greater improvements in ADG, ADFI, and F/G detected in pigs fed extruded soy flakes and flour. Moist extruded soy flakes and flour in the starter diet (d 0 to 14), improved ADG and ADFI (P<.01) from d 0 to 35 postweaning.

These data suggest that moist extrusion can be used to improve less refined soy products for use in starter pig diets. Average daily feed intake and feed efficiency were improved in pigs fed moist extruded soy products, resulting in increased ADG. In conjunction, moist extrusion of soy flakes and flour increased apparent nutrient digestibility and amino acid utilization, resulting in improved ADG and feed efficiency from d 0 to 14 and for the entire 35 d trial. Therefore, moist extrusion offers an alternative processing method to improve the nutritional value of soy products for the early-weaned pig.

Table 1. Composition of Diets d 0 to 14 Postweaning (Exp. 2)

Ingredient, %	Milk[a]	Soy flakes	Soy flour	Soy protein concentrate	d 14 to 35 Common diet[b]
Corn	43.56	24.07	27.13	34.41	55.83
Soy protein	--	40.85	37.74	31.33	
Soybean meal (48% CP)	--	--	--	--	22.71
Fish meal, select menhaden	--	--	--	--	4.00
Dried whey, edible grade	20.00	--	--	--	10.00
Dried skim milk	20.00	--	--	--	--
Casein	7.41	--	--	--	--
Lactose	--	24.40	24.40	24.40	--
L-Lysine-HCL	.15	--	--	--	--
Soybean oil	6.00	6.00	6.00	6.00	4.00
Monocalcium phosphate (21% P)	1.24	2.17	2.23	2.15	1.46
Limestone	.49	1.07	1.05	1.01	.55
Vitamin premix	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15
Copper sulfate	.10	.10	.10	.10	.10
Selenium premix	.05	.05	.05	.05	.05
Salt	--	.30	.30	.30	.30
Antibiotic[c]	.50	.50	.50	.50	.50
Chromic oxide	.10	.10	.10	.10	--
Total	100.00	100.00	100.00	100.00	100.00

[a]Diets contained 1.4% lysine, 24.4% lactose, .9% Ca, and .8% P.
[b]Diet contained 1.25% lysine, 7.2% lactose, .9% Ca, and .8% P.
[c]CSP-250 provided the following per lb of complete diet (g): oxytetracycline, .11; sulfathiazole, .11; penicillin .055.

Table 2. Growth Performance, Apparent Nutrient Digestibility, and Serum Urea Nitrogen of Weanling Pigs Fed Soy Proteins with or without Moist Extrusion[a]

Item	Milk	Soy flakes	Extruded soy flakes	Soy flour	Extruded soy flour	Soy protein concentrate	Extruded soy protein concentrate	CV
d 0 to 14								
ADG, lb[bcdef]	.64	.14	.50	.15	.44	.44	.46	18.3
ADFI, lb[bcde]	.66	.42	.59	.43	.58	.54	.55	9.4
F/G[bcdef]	1.03	3.00	1.18	2.87	1.32	1.23	1.20	30.8
d 14 to 35								
ADG, lb	1.09	.99	1.04	.99	1.12	1.06	1.00	7.5
ADFI, lb[bcd]	1.78	1.46	1.72	1.47	1.74	1.62	1.59	6.3
F/G[bcd]	1.63	1.47	1.65	1.48	1.55	1.53	1.59	3.8
d 0 to 35								
ADG, lb[bcdef]	.91	.65	.83	.65	.85	.81	.79	7.1
ADFI, lb[bcd]	1.34	1.04	1.27	1.06	1.28	1.19	1.18	5.8
F/G[bcdef]	1.47	1.60	1.53	1.63	1.51	1.47	1.49	3.4
d 13 digestibility								
DM dig., %[bd]	92.1	84.7	89.9	85.3	89.3	89.3	90.6	2.1
N dig., %[bd]	93.3	71.7	86.2	71.6	86.8	86.5	88.8	4.7
Serum urea N, mg/dL[bcd]	2.9	23.0	17.9	21.0	16.5	17.7	17.4	12.5

[a]A total of 170 pigs, average initial weight = 5.8 kg, 5 pigs/pen, 5 pens/treatment.
[b]Milk vs soy protein (P<.01).
[c]Moist extrusion processing × protein source interaction (P<.05).
[d]Extruded soy protein vs nonextruded soy protein (P<.01).
[e]Soy flakes vs soy protein concentrate (P<.05).
[f]Soy flour vs soy protein concentrate (P<.05).

THE EFFECT OF MOIST AND DRY EXTRUSION PROCESSING ON GROWTH PERFORMANCE AND NITROGEN DIGESTIBILITY IN THE EARLY-WEANED PIG

K. G. Friesen, J. L. Nelssen, R. D. Goodband, K. C. Behnke[1], and L. J. Kats

Summary

One hundred pigs (initially 13.0 lb and 21 d of age) were used to assess the differences between moist and dry extruded soybean meal in diets for early-weaned pigs. Dietary treatments included: 1) corn+dried skim milk+dried whey+casein, 2) corn+soybean meal, 3) corn+dry extruded soybean meal, and 4) corn+moist extruded soybean meal. The diets were formulated to contain 1.4% lysine and 24.4% lactose. Soybean meal (with or without extrusion processing) replaced milk protein on an equal lysine basis. Experimental diets were fed for the entire 28 d experiment. On d 14, fecal samples were collected to determine apparent DM and N digestibilities by feeding chromic oxide as an undigestible marker. Average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G) were improved (P<.05) in pigs fed the predominately milk diet from d 0 to 14 postweaning compared to pigs fed soybean meal with or without extrusion processing. For the entire trial (d 0 to 28), ADG was increased in pigs fed the milk based diet compared to pigs fed a soybean meal-based diet. Pigs fed moist extruded soybean meal had a similar ADG to pigs fed the milk diet and had an increased ADG compared to pigs fed dry extruded soybean meal. Average daily feed intake (d 0 to 28) was increased in pigs fed soybean meal (with or without moist extrusion) compared to pigs fed the milk based diet. Pigs fed the milk based diet had improved feed efficiency compared to pigs fed soybean meal with or without extrusion processing. Dry matter and N digestibilities were similar between dietary treatments. These data suggest that extrusion processing can be used to improve soybean meal quality for use in starter pig diets. Moist extrusion produces a superior product compared to dry extrusion for starter pig diets as indicated by increased ADG and improved feed efficiency.

(Key Words: Starter Pigs, Extrusion, Soybean Meal.)

Introduction

The postweaning "lag" frequently detected in the early-weaned pig has been attributed to an immune (allergic) response to soy protein. Previous research at Kansas State University suggests that moist extrusion processing can be used to process less refined soy products for inclusion in starter pig diets, decreasing the potential for a postweaning lag. Further research has also indicated that dry extrusion can be used to process soybean meal for complex starter diets. During extrusion, the protein structure of the soy product is altered, decreasing the antagonistic properties and increasing the surface area exposed for protein digestion. However, whether or not moist and dry extrusion processing can produce comparable products remains to be answered. Thus, the objective of this experiment was to assess the differences between soybean meal quality when processed by either moist or dry extrusion.

[1]Department of Grain Science and Industry.

Procedures

The experiment was designed as a randomized complete block using 100 pigs (initially 13.0 lb and 21 ± 1 d of age), randomly allotted to one of four treatments based upon weight, gender, and ancestry. Dietary treatments included: 1) corn+dried skim milk+dried whey+casein, 2) corn+soybean meal, 3) corn+dry extruded soybean meal, and 4) corn+moist extruded soybean meal. The diets (Table 1) were formulated to contain 1.4% lysine and 24.4% lactose. Soybean meal (with or without extrusion processing) replaced milk protein on an equal lysine basis. Experimental diets were fed for the entire 28 d experiment. On d 14, fecal samples were collected to determine apparent DM and N digestibilities by feeding chromic oxide as an undigestible marker.

Pigs were housed in an environmentally controlled nursery (five pigs/pen, five pens/treatment). Each pen (4 × 5 ft) contained a self feeder and a nipple waterer to provide *ad libitum* access to both feed and water. Weekly pig weights and feed consumption were collected to determine ADG, ADFI, and F/G ratio.

Soybean meal from the same lot was used in all diets. Soybean meal was moist extrusion with a single screw extruder (Wenger X-20, Wenger Mfg. Sebetha, KS) equipped with a high shear screw, barrel, and die arrangement. Steam and water were added to the extruder to facilitate processing and to prevent burning. The extruded product (approximately 30% moisture) was dried in a double pass, gas-fired dryer (Wenger Mfg. Sebetha, KS) to approximately 12% moisture. Dry extrusion was accomplished by utilizing a single screw extruder (Insta-Pro, Tripple F Feeds Inc., Des Moines, IA). Moisture was not added during this process. After extrusion, the dried product was ground through a Fitz Mill (Fitzpatrick Co., Elmhurst, IL) equipped with a 1/8 in. hammermill screen and mixed into the experimental diets.

Results and Discussion

Trypsin inhibitor concentrations were less than l mg/g in unprocessed soybean meal and soybean meal processed by either moist or dry extrusion (.43, .56, and .32 mg/g, respectively). These levels of trypsin inhibitor are below concentrations that typically reduce growth performance. Protein dispersibility index of soybean meal (27.37%) was decreased by using both moist and dry extrusion (15.02% and 15.89%, respectively), suggesting similar amounts of protein denaturization in both processing methods.

Moist and dry extrusion were compared to determine the superior processing method for soy products to be included in starter pig diets. Milk-fed pigs had the greatest (P<.05) ADG, ADFI, and F/G compared to pigs fed the soy-based diets (Table 2). Pigs fed extruded soybean meal (moist or dry extrusion) had improved (P<.05) ADG, ADFI, and F/G compared to pigs fed a corn-soybean meal diet from d 0 to 14. Nitrogen and DM digestibilities (d 14) were similar between pigs fed moist and dry extruded soybean meal, with pigs fed a milk diet having the greatest (P<.05) nutrient digestibilities.

Cumulative (d 0 to 28) ADG was similar between pigs fed a milk-based diet and pigs fed a moist extruded soybean meal diet, with pigs fed a dry extruded soybean meal diet having decreased (P<.05) ADG. Pigs fed a nonextruded soybean meal diet had the poorest (P<.05) ADG. Average daily feed intake was increased (P<.05) in pigs fed either a moist or dry extruded soybean meal diet compared to the nonextruded soybean meal diet from d 0 to 28 postweaning, with pigs fed a soybean meal based diet having the lowest (P<.05) ADFI. Feed efficiency was optimized (P<.05) in pigs fed a milk diet from d 0 to 28 compared to pigs fed soybean meal diets. Similar F/G was detected in pigs fed either a moist or dry extruded soybean meal.

Both methods of extrusion processing improved growth performance and nutrient

digestibility compared to nonextruded soybean meal. The product quality (trypsin inhibitor and protein dispersibility index) was similar for both moist and dry extrusion processing. Overall ADG was improved by 11.5%, and feed efficiency was improved by 7% in pigs fed moist extruded soybean meal compared to pigs fed dry extruded soybean meal. These data suggest that moist extrusion produces a superior soy product for starter pig diets. The difference between moist and dry extrusion can potentially be explained by differences in protein denaturization and degree of product burning. With moist extrusion of soybean meal, processing methods can be controlled more effectively, resulting in improved product quality.

Table 1. Diet Composition, %

Ingredient	Milk	Soybean meal
Corn	43.56	19.98
Soybean meal (48% CP)	-	45.00
Dried whey, edible grade	20.00	--
Dried skim milk	20.00	--
Casein	7.41	--
Lactose	--	24.40
L-Lysine-HCl	.15	--
Soybean oil	6.00	6.00
Monocalcium phosphate (21% P)	1.24	2.09
Limestone	.49	1.08
Vitamin premix	.25	.25
Trace mineral premix	.15	.15
Copper sulfate	.10	.10
Selenium premix	.05	.05
Salt	--	.30
Antibiotic[b]	.50	.50
Chromic oxide	.10	.10
Total	100.00	100.00

[a]Soybean meal, moist extruded soybean meal, or dry extruded soybean meal was substituted at equal concentration.
[b]CSP-250 provided the following per lb of complete diet (g): oxytetracycline, .11; sulfathiazole, .22; penicillin, .055.

Table 2. The Effect of Moist or Dry Extrusion of Soybean Meal on Weanling Pig Growth Performance and Nutrient Digestibility

Item	Milk	SBM	Dry Extruded SBM	Moist Extruded SBM	CV
d 0 to 14					
ADG, g[bc]	.70	.37	.47	.52	9.8
ADFI, g[bc]	.71	.56	.60	.64	9.5
F/G[bc]	1.01	1.51	1.28	1.23	10.0
d 0 to 28					
ADG, g[bcd]	.79	.40	.69	.78	6.5
ADFI, g[c]	.92	.80	.99	1.04	7.4
F/G[bc]	1.16	2.00	1.43	1.33	8.2
Digestibility					
DM, %	94.5	89.9	91.0	90.3	1.0
N, %	91.3	86.3	89.3	89.0	1.7

[a]A total of 100 pigs initial weight = 5.9 kg, 5 pigs/pen, 5 pens/treatment.
[b]Milk protein vs soy protein (P<.05).
[c]Milk protein vs extruded soy protein (P<.05).
[d]Moist vs dry extrusion (P<.10).

EXTRUDED SORGHUM AND SOYBEANS FOR NURSERY PIGS

B. T. Richert, J. D. Hancock, and R. H. Hines

Summary

Two experiments were conducted to determine the effects of extruding sorghum and soybeans for weanling pigs. The first experiment involved 66 piglets with an average age of 19 d and average weight of 10.8 lb. Two diets were fed in meal form. Treatment 1 was ground sorghum mixed with extruded soybeans, and Treatment 2 was prepared by extruding the mixture of ground sorghum and extruded soybeans. Extrusion of the sorghum-soybeans mixture increased average daily gain (ADG) and improved feed/gain (F/G) for d 0 to 14 and overall (d 0 to 28) compared to the ground sorghum treatment. In Exp. 2, 48 piglets averaging 23 d of age and average weight 13.0 lb were used to determine the potential for increased pig performance by double extrusion of soybeans. Diets were similar to those used in Exp. 1, with treatments of 1) ground sorghum-extruded soybeans, 2) extruded mixture of ground sorghum and extruded soybeans, and 3) ground sorghum with double-extruded soybeans. The extruded sorghum-soybeans mixture and double-extruded soybeans did not affect ADG from d 0 to 14, although there was a numerical improvement in F/G compared to the ground sorghum-extruded soybeans treatment. For d 14 to 28 and overall (d 0 to 28), average daily feed intake was reduced by extrusion of the sorghum-extruded soybeans mixture and double-extruded soybeans, with no effect on ADG or F/G. Extrusion of sorghum improved growth performance of nursery-age pigs, but more information is needed to define the processing conditions and end-product characteristics that yield consistent improvements in nutritional value.

(Key Words: Sorghum, Soybeans, Extrusion, Processing, Nursery.)

Introduction

Research reported in the past two KSU Swine Day Reports (Reports of Progress No. 610 and 641) demonstrated increased nutrient digestibility and improved efficiency of gain in finishing pigs fed extruded sorghum and soybeans compared to ground sorghum and soybean meal. However, the use of extruded cereal grains in diets for nursery pigs has not been thoroughly investigated. Therefore, two experiments were conducted to determine the nutritional value of extruded sorghum and soybeans for early-weaned pigs.

Procedures

In Exp. 1, 66 weanling pigs, averaging 19 d of age and 10.8 lb initial weight, were used in a 28-d growth assay to evaluate the effects of extruded sorghum and soybeans in nursery diets. Pigs were blocked by weight and randomly allotted to treatment based on sex and ancestry. Treatments were 1) ground sorghum and extruded soybeans, and 2) extruded mixture of ground sorghum and extruded soybeans. The diets were formulated to 1.6% lysine, .9% Ca, and .8% P for d 0 to 14, and 1.3% lysine, .8% Ca, and .7% P for d 14 to 28 (Table 1). All diets were fed in meal form. Soybeans were extruded in an Insta-Pro® extruder, using a double flight screw with 6 and 6E steam locks on the barrel. The exit orifice was 5/16 in. The soybeans were processed with a barrel temperature of 326°F at 1,200 lb/hr. Ground sorghum was prepared by grinding in a Jacobson Pulverator® hammermill equipped with a

3/16 in. screen. Extruded sorghum was prepared by mixing the ground sorghum with extruded soybeans and extruding the blend using a single flight screw with a compression head and multihole plate (1/8 in. orifices). The sorghum-soybeans blend was processed with a barrel temperature of 146°F at 1,320 lb/hr.

Pigs were housed in 3.5 ft × 5 ft pens with rubber coated, expanded metal flooring. Room temperatures were 90, 86, 82, and 78°F for wk 1 to 4, respectively. Each pen had a self-feeder and nipple waterer to allow ad libitum consumption of feed and water. There were five pigs per pen in three blocks and six pigs per pen in three blocks. Pigs and feeders were weighed weekly to allow calculation of average daily gain (ADG), average daily feed intake (ADFI), and feed/gain (F/G).

In Exp. 2, 48 weanling pigs, averaging 23 d of age and 13.0 lb initial weight, were used in a 28-d growth assay to determine if benefits from extruding sorghum with soybeans in Exp. 1 resulted simply from extruding the soybeans twice. Treatments were 1) ground sorghum and extruded soybeans, 2) extruded mixture of ground sorghum and extruded soybeans, and 3) ground sorghum with double-extruded soybeans. All diets were fed in meal form. Soybeans and sorghum were extruded as in Exp. 1. For double-extruded soybeans, the extruded soybeans were re-extruded with a lower barrel temperature (245°F). The average barrel temperature while extruding the sorghum-soybeans blend was 140°F. Pigs were blocked by weight and randomly allotted to treatment based on sex and ancestry. The pigs were housed and managed as in Exp. 1, with four pigs per pen and four pens per treatment.

Results and Discussion

A major concern in nutrition of weanling pigs is to maximize feed intake, especially immediately postweaning. Thus, we were concerned that the puffing and reduced bulk density of diets with extruded sorghum could result in decreased nutrient intake. In Exp. 1, ADFI for d 0 to 14 was not reduced by extrusion of the sorghum ($P>.20$). However, ADG and F/G were improved by 20% ($P<.01$) and 13% ($P<.05$), respectively, when extruded sorghum was used in place of ground sorghum. Similar trends were noted for d 14 to 28, although not statistically significant ($P>.10$). Overall (d 0 to 28), ADFI was not affected, but ADG was improved by 12% and F/G was improved by 10% with extrusion of the sorghum ($P<.05$).

For Exp. 2, ADG and ADFI were not affected by treatment ($P>.16$) from d 0 to 14, although there was a numerical improvement in F/G for pigs fed the extruded sorghum and double-extruded soybeans treatments. For d 14 to 28, ADG and F/G were not affected by treatment ($P>.20$), but ADFI was reduced by 8% ($P<.05$) for pigs fed the extruded sorghum and double-extruded soybeans treatments compared to the ground sorghum-extruded soybeans treatment. Overall (d 0 to 28), ADG and F/G were not affected by treatment ($P>.20$), but ADFI was reduced ($P<.05$) for the extruded sorghum and double-extruded soybeans treatments compared to the ground sorghum-extruded soybeans treatment.

In conclusion, results of the two experiments were mixed, with improved rate and efficiency of gain from extrusion of sorghum in Exp. 1, but no effect on rate or efficiency of gain in Exp. 2. These findings merit further investigation, especially to identify the processing conditions, and physical and chemical characteristics of the extruded product that give consistent improvements in growth performance of nursery-age pigs.

Table 1. Diet Composition (Exp. 1 and 2)

Item, %	Phase 1[a]	Phase 2[b]
Sorghum[c]	31.15	43.06
Extruded soybeans	24.77	31.11
Spray-dried porcine plasma	10.00	—
Spray-dried blood meal	—	2.50
Dried whey (edible grade)	30.00	20.00
Lysine-HCl	.10	.10
D, L-methionine	.15	.05
Monocalcium phosphate (21% P)	1.73	1.24
Limestone	.45	.64
Vitamins and minerals[d]	.55	.55
Salt	—	.25
Antibiotic[e]	1.00	.50
Chromic oxide	.10	—
Total	100	100

[a]Diets for d 0 to 14 were formulated to 1.60% lysine, 23% CP, .9% Ca, and .8% P.
[b]Diets for d 14 to 28 were formulated to 1.30% lysine, 20% CP, .8% Ca, and .7% P.
[c]Extruded sorghum was substituted on an equal weight basis for ground sorghum.
[d]KSU vitamin mix (.25%), KSU mineral mix (.15%), Se mix (.05%), and copper sulfate (.10%).
[e]Day 0 to 14 antibiotic supplied 50 g carbadox per ton of diet. Day 14 to 28 antibiotic supplied 100 g chlortetracycline, 100 g sulfathiazole, and 50 g penicillin per ton of diet.

Table 2. Effects of Extruded Sorghum and Soybeans on Nursery Pigs (Exp. 1)[a]

Item	Ground sorghum	Extruded sorghum	CV
d 0 to 14			
ADG, lb[c]	.60	.72	8.7
ADFI, lb	.84	.88	4.6
F/G[b]	1.40	1.22	7.3
d 14 to 28			
ADG, lb	.92	.97	8.5
ADFI, lb	1.51	1.51	5.7
F/G	1.64	1.56	19.2
d 0 to 28			
ADG, lb[b]	.75	.84	6.0
ADFI, lb	1.16	1.18	5.0
F/G[b]	1.55	1.40	8.2

[a]A total of 66 pigs (five or six pigs/pen and six pens/treatment) with an average initial weight of 10.8 lb.
[bc]Ground sorghum vs extruded sorghum (P<.05 and P<.01, respectively).

Table 3. Effects of Extruded Sorghum and Soybeans on Nursery Pigs (Exp. 2)[a]

Item	G-sorghum + ESB[b]	E-sorghum + ESB	G-sorghum + double-ESB	CV
d 0 to 14				
ADG, lb	.71	.73	.72	13.7
ADFI, lb	.99	.94	.93	13.6
F/G	1.39	1.29	1.29	8.5
d 14 to 28				
ADG, lb	1.15	1.05	1.09	11.0
ADFI, lb[c]	1.85	1.65	1.75	5.1
F/G	1.61	1.57	1.61	6.8
d 0 to 28				
ADG, lb	.93	.89	.90	11.0
ADFI, lb[c]	1.42	1.25	1.34	5.1
F/G	1.53	1.40	1.49	7.0

[a]A total of 48 pigs (four pigs/pen and four pens/treatment) with an average initial weight of 13.0 lb.
[b]G-sorghum = ground sorghum, ESB = extruded soybeans, and E-sorghum = extruded sorghum.
[c]Ground sorghum-extruded soybeans vs extruded mixture of sorghum and extruded soybeans and ground sorghum-double-extruded soybeans (P<.05).

EXTRUDED CORN, SORGHUM, AND SOYBEAN MEAL FOR NURSERY PIGS

B. T. Richert, J. D. Hancock, R. H. Hines, and T. L. Gugle

Summary

Two experiments were conducted to determine the nutritional value of extruded corn, sorghum, and soybean meal (SBM) for nursery-age pigs. Experiment 1 involved 180 weanling pigs, with an average age of 22 d and average weight of 13.2 lb. Treatments were 1) corn-SBM-dried whey-based control, 2) extruded corn (Ecorn)-SBM, 3) Ecorn-extruded SBM (ESBM), 4) sorghum-SBM, 5) extruded sorghum (Esorghum)-SBM, 6) Esorghum-ESBM. Extrusion of the grains improved feed to gain (F/G) but reduced average daily feed intake (ADFI) in phase 1 (d 0 to 10). For phase 2 (d 10 to 24), phase 3 (d 24 to 38), and overall, corn supported greater average daily gain (ADG) and ADFI compared to sorghum. Extrusion of the grain reduced ADG and ADFI. Extrusion of SBM improved ADG and ADFI of pigs fed the extruded grains. Corn had greater DM and N digestibilities than sorghum, and extrusion increased DM and N digestibilities compared to ground grains. In Exp. 2, 192 pigs were used (average age of 22 d and 12.6 lb initial weight). Treatments were arranged as a 2 × 2× 2 factorial, with main effects of grain source (corn vs sorghum), processing method (grinding vs extrusion), and soybean meal treatment (SBM vs ESBM). Contrary to Exp. 1, sorghum supported greater ADG and ADFI compared to corn for phase 1. Extrusion of the grains reduced ADFI in phase 1, phase 3 and overall, and reduced ADG in phase 3 and overall. Extrusion of SBM improved ADG and ADFI with ground grains but reduced ADG and ADFI with extruded grains. Extrusion of the grains and SBM improved DM and N digestibilities. In conclusion, extruded corn and sorghum improved performance for d 0 to 10 post- weaning, but reduced growth performance if fed for the entire nursery period.

(Key Words: Extrusion, Sorghum, Soybean Meal, Corn, Process, Nursery.)

Introduction

Data in the 1990 and 1991 KSU Swine Day Reports of Progress (pages 76 and 92, respectively) indicated that extrusion of sorghum improved feed efficiency and digestibility of nutrients in finishing pigs. Thus, extrusion could improve the nutritional value of sorghum grain to a level more comparable to that of corn. This might be true especially in young pigs with their limited ability to digest proteins and carbohydrates (e.g., starch) of plant origin. Likewise, extrusion of a defatted soy flour yielded a product of greater nutritional value than toasted soybean meal for nursery pigs (1990 KSU Swine Day Report of Progress No. 610, page 37). Thus, extrusion of diet ingredients offers potential for increased nursery pig performance compared to ground grain and SBM. Therefore, two experiments were conducted to determine the effects of extruding cereal grains and SBM on growth performance and nutrient digestibility in nursery-age pigs.

Procedures

In Exp. 1, 180 weanling pigs, averaging 22 d of age and 13.2 lb initial weight, were used in a 38-d growth assay to determine the effects of extruding corn, sorghum, and SBM on growth performance and nutrient digestibility. Pigs were blocked by weight and randomly allotted to treatment based on sex

and ancestry. Treatments were 1) corn-SBM-dried whey-based control, 2) extruded corn (Ecorn) to replace the corn in Diet 1, 3) Ecorn and extruded SBM (ESBM) to replace the corn and SBM in Diet 1, 4) sorghum to replace the corn in Diet 1, 5) extruded sorghum (Esorghum) to replace the corn in Diet 1, and 6) Esorghum and ESBM to replace the corn and SBM in Diet 1. Phase 1 diets (d 0 to 10) were formulated to 1.5% lysine, .9% Ca, and .8% P. Phase 2 diets (d 10 to 24) were formulated to 1.25% lysine, .8% Ca, and .7% P, and phase 3 diets (d 24 to 38) were formulated to 1.1% lysine, .8% Ca, and .7% P (Table 1).

Ground grains were prepared by grinding through a Jacobson Pulverator® hammermill equipped with a screen having 3/16 in. openings. For the extrusion treatments, ground grains and SBM were extruded through a single-screw extruder (Insta Pro®, Model 2000). Grains and SBM were adjusted to 18% moisture prior to extrusion, and one-half the dietary oil was added to the SBM to aid in the extrusion process. Extruder barrel temperatures were 148°F for corn, 146°F for sorghum, and 183°F for SBM. Following extrusion, all products were coarsely ground through a roller mill. Phase 1 diets were pelleted through a 5/32 in. die. Phase 2 and phase 3 diets were pelleted through a 3/16 in. die.

Table 1. Diet Composition (Exp. 1 and 2), %

Item	Phase 1[a]	Phase 2[b]	Phase 3[c]
Grain source[d]	36.41	43.22	62.85
Soybean meal (48%CP)	16.60	30.58	30.23
Spray-dried porcine plasma	10.00	—	—
Dried whey (edible grade)	30.00	20.00	—
Lysine-HCl	—	.01	.02
D,L-methionine	.10	—	—
Soybean oil	3.00	3.00	3.00
Monocalcium phosphate (21% P)	1.87	1.27	1.80
Limestone	.37	.62	.75
Vitamins and minerals[e]	.55	.55	.55
Salt	—	.25	.30
Antibiotic[f]	1.00	.50	.50
Chromic oxide	.10	—	—
Total	100	100	100

[a]Phase 1 diets (d 0 to 10) were formulated to 1.50% lysine, 22% CP, .9% Ca, and .8% P.
[b]Phase 2 diets (d 10 to 24) were formulated to 1.25% lysine, 21% CP, .8% Ca, and .7% P.
[c]Phase 3 diets (d 24 to 38) were formulated to 1.10% lysine, 20% CP, .8% Ca, and .7% P.
[d]Grain sources (i.e., corn, sorghum, extruded corn, and extruded sorghum) were substituted on an equal weight basis with lysine-HCl added to the sorghum diets to equalize lysine concentrations. Soybean meal treatments (nonextruded or extruded) were added on an equal weight basis.
[e]KSU vitamin premix (.25%), KSU mineral premix (.15%), Se premix (.05%), and copper sulfate (.10%).
[f]Phase 1 antibiotic supplied 200 g furazolidone, 100 g oxytetracycline, and 90 g arsanilic acid per ton of diet. Phases 2 and 3 antibiotic supplied 100 g chlortetracycline, 100 g sulfathiazole, and 50 g penicillin per ton of diet.

Pigs were housed in 4 ft × 5 ft pens with wire-mesh flooring. Room temperatures were 87, 84, 80, and 75°F for wk 1 to 5, respectively. Each pen had a self-feeder and nipple waterer to allow ad libitum consumption of feed and water. There were six pigs per pen with five pens per treatment. Pigs and feeders were weighed on d 10, 24, and 38 to allow calculation of ADG, ADFI, and F/G. On d 9, fecal samples were collected from four pigs per pen; dried; pooled; and analyzed for Cr, DM, and N to allow calculation of apparent nutrient digestibilities.

In Exp. 2, 192 weanling pigs, averaging 22 d of age and 12.6 lb, were used in a 38-d experiment to determine the effects of feeding Ecorn and Esorghum, with and without ESBM, on growth performance of weanling pigs. At weaning, pigs were blocked by weight and randomly allotted to treatment based on sex and ancestry. Treatments were 1) corn-SBM-dried whey-control, 2) Ecorn to replace the corn in Diet 1, 3) ESBM to replace the SBM in Diet 1, 4) Ecorn and ESBM to replace the corn and SBM in Diet 1, 5) sorghum to replace the corn in Diet 1, 6) Esorghum to replace the corn in Diet 1, 7) sorghum and ESBM to replace the corn and SBM in Diet 1, and 8) Esorghum and ESBM to replace the corn and SBM in Diet 1. Nutrient concentrations were the same as in Exp. 1 (Table 1).

The grains and SBM were processed as in Exp. 1, but barrel temperatures varied somewhat (i.e., 151°F for corn, 133°F for sorghum, and 140°F for SBM). Phase 1 diets were pelleted through a 5/32 in. die and phase 2 and 3 diets were fed in meal form.

Pigs were housed and managed as in Exp. 1, with four pens per treatment. Fecal samples were collected and analyzed as in Exp. 1. Blood samples were collected on d 9 and analyzed for serum urea N concentrations and antisoy antibody titers.

Results and Discussion

For Exp. 1 (Table 2), phase 1 treatment did not affect ADG (P>.10). Extrusion of corn and sorghum resulted in decreased ADFI (P<.06) and improved F/G (P<.001). Apparent digestibilities of DM and N were greater for corn than sorghum (P<.001), and extruded grains had greater DM (P<.05) and N (P<.05) digestibilities than ground grains.

In phase 2, diets with corn supported improved ADG (P<.001), ADFI (P<.001), and F/G (P<.01) compared to diets with sorghum. Extrusion of the grains decreased ADG and ADFI (P<.001) compared to diets with ground grains. However, adding ESBM to diets with extruded grains improved ADG (P<.001) to levels similar to those of the ground grain-SBM diets and improved efficiencies of gain compared to other treatments.

For phase 3 and overall, pigs fed corn had greater ADG (P<.001) and ADFI (P<.001) than those fed sorghum. In contrast with phase 1 effects, extrusion of corn and sorghum resulted in decreased ADG (P<.01) compared to grinding the grains. Use of ESBM in diets with the extruded grains improved (P<.001) ADG and ADFI, but not to levels comparable to the ground grain-SBM treatments.

For Exp. 2, sorghum supported greater (P<.01) ADG and ADFI compared to corn during phase 1 (Table 3). Also, diets with sorghum had greater DM digestibility (P<.05) than diets with corn. Extrusion of corn gave improved F/G (P<.05); however, F/G was not changed by extrusion of the sorghum. Furthermore, pigs fed extruded grains had increased serum urea N (P<.001) with reduced ADFI, suggesting that extruding the grain may have complexed some of the amino acids (e.g., lysine) in an undigestible form, creating a less desirable amino acid balance. Extrusion of SBM increased DM (P<.05) and N (P<.01) digestibilities, especially in diets with corn. However, extrusion of the SBM did not reduce serum

antisoy antibody titers compared to SBM (P>.10).

During Phase 2, pigs fed extruded grains had improved F/G (P<.06) compared to pigs fed ground grains. However, there was an interaction between the effects of ESBM and grain source, i.e., when ESBM was fed with corn, it gave a trend for improved ADG (P<.06) and F/G (P<.08), but when fed with sorghum, it gave poorer ADG and F/G. During phase 3 and overall, ADG (P<.01) and ADFI (P<.001) were reduced by extrusion of the grains. Use of ESBM increased ADG (P<.05) and ADFI (P<.01), but only when fed with ground grains and not with extruded grains.

In conclusion, extrusion of corn and sorghum improved diet utilization for the initial postweaning period (d 0 to 10), but was of no benefit from d 10 to 38. Extrusion of SBM improved growth performance of pigs fed extruded grains in Exp. 1 and pigs fed ground grains in Exp. 2, but the inconsistencies in response necessitate further investigation before this application of extrusion technology can be recommended.

Table 2. Effects of Extruded Grain and Soybean Meal on Nursery Pigs (Exp. 1)[a]

Item	Corn-SBM[b]	Ecorn-SBM	Ecorn-ESBM	Sorg-SBM	Esorg-SBM	Esorg-ESBM	CV
d 0 to 10							
ADG, lb	.58	.59	.56	.52	.52	.57	15.4
ADFI, lb[e]	.65	.60	.56	.59	.52	.57	13.5
F/G[g]	1.12	1.02	1.00	1.13	1.00	1.00	4.1
d 10 to 24							
ADG, lb[dfi]	.98	.65	.93	.77	.49	.80	14.4
ADFI, lb[dgi]	1.39	1.06	1.30	1.19	.87	1.22	10.1
F/G[ci]	1.42	1.63	1.40	1.55	1.78	1.53	10.3
d 24 to 38							
ADG, lb[dgi]	1.46	.95	1.24	1.13	.88	1.05	12.0
ADFI, lb[dgi]	2.27	1.56	1.93	1.83	1.37	1.66	8.7
F/G	1.55	1.64	1.56	1.62	1.56	1.58	8.2
d 0 to 38							
ADG, lb[dgi]	1.03	.74	.93	.82	.63	.82	10.2
ADFI, lb[dgi]	1.48	1.10	1.30	1.24	.94	1.19	7.9
F/G[h]	1.44	1.49	1.40	1.51	1.49	1.45	5.3
Digestibilities (d 9), %							
DM[dej]	92.1	91.4	92.4	88.3	90.6	90.5	1.4
N[de]	87.9	88.4	90.0	82.1	85.8	84.7	2.7

[a]A total of 180 pigs (six pigs/pen and five pens/treatment) with an average initial weight of 13.2 lb.
[b]SBM=soybean meal, Ecorn=extruded corn, ESBM=extruded soybean meal, Sorg=sorghum, and Esorg=extruded sorghum.
[cd]Corn vs sorghum (P<.01 and P<.001, respectively).
[efg]Ground grain vs extruded grain (P<.06, P<.01, and P<.001, respectively).
[hi]Extruded grain vs extruded grain with extruded SBM (P<.05 and P<.001, respectively).
[j]Corn vs sorghum × ground grain vs extruded grain (P<.02).

Table 3. Effects of Extruded Grain and Soybean Meal on Nursery Pigs (Exp. 2)[a]

	Corn[b]		Ecorn		Sorghum		Esorghum		
Item	SBM	ESBM	SBM	ESBM	SBM	ESBM	SBM	ESBM	CV
d 0 to 10									
ADG, lb[dk]	.57	.52	.58	.47	.63	.66	.52	.63	11.5
ADFI, lb[dek]	.59	.57	.58	.47	.63	.67	.56	.61	8.8
F/G[im]	1.04	1.10	1.00	1.00	1.00	1.02	1.08	.97	5.3
d 10 to 24									
ADG, lb[jm]	.60	.70	.73	.72	.71	.71	.76	.58	14.7
ADFI, lb[im]	1.06	1.17	1.22	1.12	1.22	1.17	1.14	.96	9.0
F/G	1.77	1.67	1.67	1.56	1.72	1.65	1.50	1.66	9.8
d 24 to 38									
ADG, lb[em]	1.11	1.26	1.16	.96	1.23	1.27	1.01	.95	12.0
ADFI, lb[fn]	1.82	2.07	1.88	1.65	2.03	2.18	1.77	1.66	9.1
F/G	1.64	1.64	1.62	1.72	1.65	1.72	1.75	1.75	6.1
d 0 to 38									
ADG, lb[ein]	.78	.86	.85	.74	.88	.90	.79	.73	8.6
ADFI, lb[fin]	1.22	1.34	1.29	1.14	1.36	1.41	1.22	1.13	7.2
F/G	1.56	1.56	1.52	1.54	1.55	1.57	1.54	1.55	3.9
Digestibilities (d 9), %									
DM[cglo]	90.9	93.8	91.3	92.8	93.9	92.0	92.8	93.2	.9
N[hl]	86.0	91.8	86.3	91.1	90.8	87.6	88.9	90.1	2.4
Serum urea N (d 9),									
mg/dL[f]	8.3	7.8	9.4	9.4	8.0	6.7	10.7	9.7	14.2
Antisoy titers (d 9),									
$\log_2$	10.25	10.00	10.00	9.75	10.25	9.50	9.50	9.75	5.8

[a]A total of 192 pigs (six pigs/pen and four pens/treatment) with an average initial weight of 12.6 lb.
[b]SBM=soybean meal, ESBM=extruded soybean meal, Ecorn=extruded corn, and Esorghum=extruded sorghum.
[cd]Corn vs sorghum (P<.05 and P<.01, respectively).
[ef]Ground grain vs extruded grain (P< .01 and P<.001, respectively).
[gh]SBM vs ESBM (P<.05 and P<.01, respectively).
[i]Corn vs sorghum × ground grain vs extruded grain (P<.05).
[jkl]Corn vs sorghum × SBM vs ESBM (P<.06, P<.01, and P<.001, respectively).
[mn]Ground grain vs extruded grain × SBM vs ESBM (P<.06 and P<.01, respectively).
[o]Corn vs sorghum × ground grain vs extruded grain × SBM vs ESBM (P<.01).

INFLUENCE OF HIGH LEVELS OF B-VITAMINS ON STARTER PIG PERFORMANCE[1]

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

Summary

A total of 318 pigs was used in a 25-d growth trial to determine the influence of high levels of B-vitamins on starter pig performance. At weaning (16-d of age), pigs were blocked by weight to one of six dietary treatments based on B-vitamin level. The negative control diet contained the standard KSU B-vitamin additions. The next four diets contained vitamin B_{12}, riboflavin, pantothenic acid, or niacin at 10 × the level recommended by NRC (1988). The positive control diet contained all four vitamins at 10 × the levels suggested by NRC (1988). B-vitamin inclusion rate did not influence average daily gain or feed intake. High levels of riboflavin resulted in a slight improvement in feed efficiency compared to pigs fed the control diets. These results do not support including B-vitamins in the starter diet at levels higher than currently recommended by KSU.

(Key Words: Starter, Performance, B-vitamins.)

Introduction

Recent research at University of Minnesota has investigated injection and dietary supplementation of B-vitamins for starter pigs. Results of this research has indicated that injecting B-complex vitamins into pigs at weaning increased daily gain and feed intake in the starter phase. Additional trials have proven that dietary supplementation of B-vitamins at 10 × NRC (1988) levels will improve daily gain and feed intake of starter pigs. This research has provided an excellent base to demonstrate the effectiveness of B-vitamins at levels above those suggested by NRC (1988). However, because four B-vitamins (vitamin B_{12}, riboflavin, pantothenic acid, and niacin) were added to the diet at the same time in the previous trials, it is impossible to determine which vitamin(s) is important. Additionally, the control diet in those experiments was formulated with B-vitamins at 100 to 140% of NRC (1988) recommendations. These levels are much lower than those used in the feed industry and recommended by KSU. Therefore, the objective of this trial was to determine which B-vitamins are necessary to elicit the growth response and if that response will occur when the control diet contains normal industry levels of B-vitamins.

Procedures

A 25-d growth trial utilizing 318 weanling pigs (initially 12.2 lb and 16 d of age) was conducted to evaluate high levels of B-vitamins in starter diets. At weaning, pigs were blocked by weight and allotted to the six experimental treatments. Pigs were housed eight or nine per pen (six pens per treatment) in an environmentally controlled nursery with metal flooring and allowed ad libitum access to feed and water. Pigs and feeders were weighed on d 7, 14, and 25 after weaning to

[1]Appreciation is expressed to Lonza, Inc. for partial financial support and to Merrick's, Inc., for donating plasma protein for the trial. The authors wish to thank Steve Eichman and Eichman Farms, St. George, KS, for use of facilities and animals in this experiment.

determine average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G).

Experimental diets were split into two phases. During phase I (d 0 to 14 postweaning), high nutrient density diets containing 7.5% spray-dried porcine plasma, 1.75% spray-dried blood meal, and 20% dried whey were fed (Table 1). The phase I diet was formulated to 1.5% lysine, .9% calcium, and .8% phosphorus. Pigs were switched to the phase II diets on d 14 postweaning. Phase II diets contained 10% dried whey and 2.5% spray-dried blood meal and were formulated to contain 1.25% lysine, .9% calcium, and .8% phosphorus. Phase I diets were fed as 5/32 in. pellets. Phase II diets were fed in meal form. The negative control diet contained the standard KSU additions of vitamin B_{12} (30 mg/ton), riboflavin (7,500 mg/ton), pantothenic acid (26,000 mg/ton), and niacin (45,000 mg/ton). These levels are 1.9 to 3.3 × NRC (1988) requirements. Experimental diets were formed by replacing corn with premixes containing each B-vitamin. Final inclusion rates to achieve 10 × NRC (1988) levels for each treatment were: vitamin B_{12}, 158 mg/ton; riboflavin, 31,752 mg/ton; pantothenic acid, 90,720 mg/ton; niacin, 136,080 mg/ton. The positive control (All) contained all four B-vitamins at 10 × the level suggested by NRC (1988).

Results and Discussion

High levels of B-vitamins did not influence daily gain or feed intake during this experiment (Table 2). Additions of niacin improved F/G (P<.04) during phase I. However, this benefit was not present at the end of the experiment. Pigs fed the diet containing riboflavin at 10 × the level suggested by NRC (1988) had slightly improved F/G during phase I (P<.10), phase II (P<.12), and the overall trial (P<.07) compared to pigs fed the control diet. Adding high levels of riboflavin alone was superior to adding riboflavin in conjunction with the other four vitamins (All) during phase II (P<.04) and for the overall trial (P<.07). However, the extra cost of the vitamins offsets the small improvements in feed efficiency identified in this trial.

These results were dissapointing, considering the large improvements in performance previously identified by the University of Minnesota. However, there is a basic difference between the trial conducted at KSU and the earlier research. The control diet in this experiment contained much higher levels of B-vitamins than those used in the previous trials. Therefore, these results simply verify that the B-vitamin levels in the current KSU premix are sufficient to support maximal performance.

We have cooperated with the University of Minnesota to conduct an identical trial in their facilities. Their research supports our conclusion that the current KSU B-vitamin recommendations are adequate (Table 3). These levels are 1.9 to 3.3 × those suggested by NRC (1988). Because the previous research at the University of Minnesota has determined that levels suggested by NRC (1988) are deficient, further research is needed to determine the exact B-vitamin requirements.

Table 1. Composition of Diets[a]

Ingredient, %	Phase I	Phase II
Corn[b]	44.89	58.17
Soybean meal (48% CP)	16.95	21.86
Dried whey	20.00	10.00
Porcine plasma	7.50	
Spray-dried blood meal	1.75	2.50
Soybean oil	5.00	3.00
Monocalcium phosphate (21% P)	1.90	1.96
Limestone	.69	.83
Apralan	1.00	
Mecadox		1.00
Copper sulfate	.08	.08
L-lysine	.10	.15
DL-methionine	.10	.05
Vitamin premix[c]	.25	.25
Trace mineral premix[d]	.15	.15
Total	100.00	100.00
Calculated Analysis, %		
Crude protein	21.2	18.9
Lysine	1.50	1.25
Methionine	.38	.33

[a]Pigs were fed the phase I and II diets from d 0 to 14 and d 14 to 25, respectively.
[b]Each vitamin was added at the expense of corn to form the experimental diets.
[c]Each lb of premix contained: vitamin A, 2,000,000 IU; vitamin D_3, 200,000 IU; vitamin E, 8,000 IU; menadione, 800 mg; vitamin B_{12}, 6 mg; riboflavin, 1,500 mg; pantothenic acid, 5,200 mg; niacin, 9,000 mg; choline, 30,000 mg.
[d]Each lb of premix contained: zinc, 50 g; iron, 50 g; manganese, 12 g; copper, 5 g; iodine, 90 mg; selenium, 90 mg.

Table 2. Influence of High Levels of B-Vitamins on Starter Pig Performance[a,b]

Item	Control	B_{12}	Riboflavin	Pant. acid	Niacin	All	CV
D 0-14							
ADG, lb	.68	.68	.68	.68	.69	.69	6.8
ADFI, lb	.74	.73	.72	.74	.72	.73	6.6
F/G[c]	1.10	1.08	1.05	1.09	1.04	1.05	4.4
D 14 - 25							
ADG, lb	1.01	1.03	1.07	1.02	.99	1.03	8.4
ADFI, lb	1.60	1.65	1.63	1.65	1.60	1.66	5.5
F/G[d]	1.59	1.60	1.52	1.63	1.62	1.62	4.9
D 0 - 25							
ADG, lb	.83	.84	.86	.84	.83	.85	6.3
ADFI, lb	1.14	1.15	1.14	1.16	1.13	1.16	5.1
F/G[e]	1.37	1.37	1.32	1.39	1.36	1.37	3.4

[a]Each value is the mean of six pens containing eight to nine pigs per pen. Pigs were weaned at 16 days of age.
[b]Each B-vitamin was added to the diet individually or together (all) at 10 X NRC (1988) requirement to acheive the experimental diets.
[c]Contrasts: control vs all (P<.10); control vs riboflavin (P<.11); control vs niacin (P<.04).
[d]Contasts: control vs riboflavin (P<.12); all vs riboflavin (P<.04).
[e]Contrasts: control vs riboflavin (P<.07); all vs riboflavin (P<.07).

Table 3. Influence of High Levels of B-Vitamins on Starter Pig Performance[a,b]

Item	Control	B_{12}	Riboflavin	Pant. acid	Niacin	All	CV
D 0-14							
ADG, lb	.88	.89	.94	.86	.87	.88	8.9
ADFI, lb	1.04	1.05	1.08	1.01	1.07	1.02	7.5
F/G	1.18	1.18	1.15	1.18	1.24	1.17	4.7
D 14 - 28							
ADG, lb	1.07	1.08	1.06	1.03	1.08	.97	9.7
ADFI, lb	1.85	1.93	1.93	1.88	1.86	1.82	7.8
F/G	1.73	1.79	1.82	1.83	1.74	1.87	8.4
D 0 - 28							
ADG, lb	.98	.99	1.00	.94	.97	.92	7.4
ADFI, lb	1.44	1.49	1.50	1.44	1.46	1.42	7.1
F/G	1.48	1.51	1.50	1.53	1.51	1.54	4.1

[a]Each value is the mean of four pens containing 8 to 9 pigs per pen. Pigs were weaned at 25 days of age. This trial was conducted at the University of Minnesota.
[b]Each B-vitamin was added to the diet individually or together (all) at 10 X NRC requirement to acheive the experimental diets.

INFLUENCE OF FUMARIC ACID AND CALCIUM FORMATE ON STARTER PIG PERFORMANCE[1]

M. D. Tokach, J. L. Nelssen, R. D. Goodband, and L. J. Kats

Summary

A 25 d growth trial utilizing 198 pigs was conducted to determine the influence of fumaric acid and calcium formate on starter pig performance. At weaning (19 d of age and 11.9 lb), pigs were blocked by weight and allotted to one of three dietary treatments: a control diet without acid addition or diets containing 1.5% fumaric acid or 1.5% calcium formate. Adding calcium formate to the diet had no influence on average daily gain (ADG), average daily feed intake (ADFI), or feed efficiency (F/G). Pigs fed the diet containing fumaric acid had improved feed efficiency during the first 2 weeks postweaning compared to pigs fed the other two diets. These results do not support the addition of calcium formate to the starter diet. However, results warrant additional research to determine the efficacy of fumaric acid in high nutrient density starter diets.

(Key Words: Starter, Performance, Fumaric acid, Calcium formate.)

Introduction

Previous research has demonstrated that adding organic acids to corn-soybean meal starter diets improves pig performance. However, similar results have not been found when adding organic acids to diets containing high levels of milk products. The high nutrient density diet, which has become the standard diet for the early-weaned pig, traditionally contains high levels of milk products. Recent availability of spray-dried blood products has reduced the use of milk products in these diets. Therefore, the addition of acids to these low milk product, high nutrient density diets should be assessed. This trial was conducted to compare fumaric acid and calcium formate as acidifiers in diets for early-weaned pigs and to determine their influence on pig performance.

Procedures

A total of 198 pigs (initially 19 d and 11.9 lb) was used in this 25 d growth trial. Pigs were blocked by weight and allotted to one of three dietary treatments for a total of 11 pigs/pen and six pens/treatment. The three treatments were a control diet without acid or diets containing 1.5% fumaric acid or 1.5% calcium formate.

The trial was divided into two phases. During phase I (d 0 to 14 postweaning), high nutrient density diets containing 20% dried whey, 7.5% porcine plasma, and 1.5% spray-dried blood meal were fed (Table 1). Diets were formulated to contain 1.5% lysine, .8% phosphorus, and at least .9% calcium. During phase II (d 14 to 25 postweaning), diets contained 10% dried whey and 2.5% spray-dried blood meal and were formulated to 1.25% lysine, .8% phosphorus, and at least .9% calcium. Fumaric acid and calcium formate replaced corn in the phase I and II diets to achieve the three experimental diets.

[1]Appreciation is expressed to Mobay Corp., Shawnee Mission, KS, for partial financial support for this trial. The authors wish to thank Steve Eichman and Eichman Farms, St. George, KS, for use of facilities and animals in this experiment.

The limestone was removed from the diets containing calcium formate to maintain calcium at less than 1.1% of the diet. Phase I diets were fed as pellets, whereas phase II diets were fed in meal form.

Pigs were housed in an environmentally controlled nursery in 5 x 7 ft pens. They had ad libitum access to feed and water.

Pigs were weighed and feed disappearance was determined at the end of phase I (d 14) and at the conclusion of the 25 d trial. Average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G) were determined.

Results and Discussion

Including calcium formate in the phase I and II diet had no influence on ADG, ADFI, or F/G (Table 2). Fumaric acid improved ADG by 10.7% during phase I; however, this response was not statistical significant (P=.18). Adding fumaric acid to the diet improved (P<.07) feed efficiency by 7% during phase I. Pigs fed the diet containing fumaric acid had slightly lower feed intake during phase II (P<.09); however, this did not translate into differences in ADG or F/G. For the overall trial (d 0 to 25), adding fumaric acid to the diet had no influence on pig performance

The main theory behind the addition of acids to starter diets for the early-weaned pig is that the pig is unable secrete enough gastric acid to lower the pH of the stomach and small intestine. The lower pH is necessary to allow maximal activity of the enzymes needed to digest complex proteins and carbohydrates. Research from the University of Illinois has demonstrated that adding fumaric acid to a corn-soybean meal diet for the young pig will decrease pH in the stomach and small intestine, enhancing digestibility and performance. Under disease situations, decreasing the pH of the gut is especially important because bacterial growth is maximized at higher pH.

The reason for the relatively small response to acid inclusion in the diet in this experiment may have been the milk and blood product inclusion levels in the diet. As explained above, previous research indicated that adding acids to diets containing high levels (40%) of milk products did not influence pig performance. In this trial, the phase I and II diets contained only 20 and 10% milk products, respectively. However, because the diets also contained highly digestible spray-dried blood products, they may have been too digestible to detect any improvement from lowering the pH of the gastrointestinal contents.

Further research is needed to evaluate the effectiveness of calcium formate in less complex diets for the early-weaned pig. Additional research also is needed to determine the repeatability of the 5 to 7% improvement in feed efficiency seen in this trial when fumaric acid was added to the diet.

Table 1. Composition of Diets[a]

Ingredient, %	Phase I	Phase II
Corn[b]	44.59	58.92
Soybean meal (48% CP)	19.30	21.04
Dried whey	20.00	10.00
Porcine plasma	7.50	
Spray-dried blood meal	1.50	2.50
Soybean oil	3.00	3.00
Monocalcium phosphate (21% P)	1.83	1.98
Limestone	.69	.83
Apralan	1.00	
Mecadox		1.00
Copper sulfate	.08	.08
L-Lysine HCl		.15
DL-methionine	.06	.05
Vitamin premix	.25	.25
Trace mineral premix	.15	.15
Selenium premix	.05	.05
Total	100.00	100.00
Calculated Analysis, %		
Crude protein	22.5	18.9
Lysine	1.50	1.25
Methionine	.37	.35
Ca[c]	.90	.90
P	.80	.80

[a]Pigs were fed the phase I and II diets from d 0 to 14 and d 14 to 25, respectively.
[b]Calcium formate and fumaric acid (1.5%) and soybean meal (.13%) replaced corn (1.63%) to form the experimental diets. Limestone was replaced with corn in the calcium formate diet to account for the extra calcium.
[c]Phase I and II diets with calcium formate contained 1.04% calcium.

Table 2. Influence of Fumaric Acid and Calcium Formate on Starter Pig Performance[a]

Item	Control	Fumaric acid	Calcium formate	CV
D 0 to 14				
ADG, lb	.47	.52	.47	12.5
ADFI, lb	.58	.60	.58	8.3
F/G[b]	1.26	1.17	1.26	6.4
D 14 to 25				
ADG, lb	1.07	1.04	1.07	5.6
ADFI, lb[c]	1.65	1.55	1.61	5.0
F/G	1.54	1.49	1.53	9.6
D 0 to 25				
ADG, lb	.74	.76	.74	6.2
ADFI, lb	1.07	1.03	1.05	4.1
F/G	1.44	1.37	1.44	7.1

[a]Each value is the mean of six pens containing 11 pigs per pen. Pigs were weaned at 16 d of age and 11.9 lb.
[b]Contrast: control vs fumaric acid (P<.07); fumaric acid vs calcium formate (P<.07).
[c]Contrast: control vs fumaric acid (P<.09).

INFLUENCE OF HIGH LEVELS OF ZINC OXIDE IN STARTER DIETS ON PIG PERFORMANCE[1]

M. D. Tokach, L. M. Tokach[2], R. D. Goodband, J. L. Nelssen, S. C. Henry[2], and T. A. Marsteller[2]

Summary

Two trials were conducted to determine the influence of high levels of zinc oxide on starter pig performance. Two dietary treatments (110 or 3,110 ppm zinc) were used in each trial. In trial 1, 180 pigs (17 d of age and 10.9 lb) were blocked by weight and allotted to 20 pens for a total of eight or nine pigs/pen and 10 pens/treatment. In trial 2, 168 pigs (21 d of age and 12.8 lb) were blocked by weight and sex and allotted to six pens for a total of 28 pigs/pen and three pens/treatment. Experimental diets were fed for d 0 to 14 after weaning (Phase I). All pigs were fed a common diet containing 110 ppm zinc during phase II (d 14 to 25 in trial 1 and d 14 to 29 in trial 2). Adding 3,000 ppm zinc as zinc oxide to the starter diet did not influence starter pig performance in either trial.

(Key Words: Zinc, Starter, Performance.)

Introduction

Postweaning colibacillosis is a problem in many swine herds in the United States. Several veterinarians have reported that adding high levels of zinc oxide (3,000 ppm zinc) to the starter diet will decrease the incidence of postweaning scours and, thus, increase daily gain. A proposed mode of action is that zinc oxide binds excess iron in the intestine. Because iron enhances *E. coli* growth, the reduction in iron would decrease this growth. However, a possible concern is that zinc oxide may improve fecal quality by simply depressing feed intake. Therefore, two growth trials were conducted to determine the influence of high levels of zinc in the starter diet on pig performance.

Procedures

Two trials were conducted on commercial swine farms in Northeast Kansas. Two dietary treatments (110 or 3,110 ppm zinc) were used in each trial. The control diet in each trial contained the normal zinc level (110 ppm) recommended by KSU. Zinc oxide was considered to contain 78% zinc in dietary formulations and, thus, .385% zinc oxide (7.7 lb/ton) was added to the diet to obtain the high zinc treatment (3,110 ppm). Experimental diets were only fed from d 0 to 14 postweaning (Phase I). In each trial, all pigs were fed a common diet containing 110 ppm zinc during phase II (d 14 to 25 in trial 1 and d 14 to 29 in trial 2). Complexity of the experimental diets was different for the two trials as depicted in Table 1.

In trial 1, 180 pigs (17 $\pm$ 3 d of age and 10.9 lb) were blocked by weight and allotted to 20 pens for a total of 8 or 9 pigs/pen and 10 pens/treatment. Adjacent pens shared a common feeder. Therefore, there were 10 replications for ADG and five replications for ADFI and F/G.

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[1]The authors wish to thank Steve Eichman and Eichman Farms, St. George, KS, and Roy Henry and Henry's LTD., Longford, KS, for use of facilities and animals in these experiments.

[2]Abilene Animal Hospital, P.A., Abilene, KS 67410.

In trial 2, 168 pigs (21 ± 2 d of age and 12.8 lb) were blocked by weight and sex and allotted to six pens for a total of 28 pigs/pen and three pens/treatment.

In both trials, pigs were housed in environmentally controlled nurseries with metal flooring and allowed ad libitum access to feed and water. Pigs and feeders were weighed at the end of phase I and II to determine ADG, ADFI, and F/G.

Results and Discussion

Adding 3,000 ppm zinc as zinc oxide to the starter diet did not influence starter pig performance in either trial (Table 2). Although fecal scores were not given, adding zinc oxide to the starter diet visually changed the color of the feces from dark black to a light brown (tan) color. However, this change in stool color and consistency did not influence pig performance.

High levels of zinc oxide did not improve pig performance in these trials. However, the prevalence of scours in these herds may have been too low to detect a response. Because high levels of zinc oxide did not improve pig performance, herds without postweaning colibacillosis do not need high levels of zinc in starter diets. An alternative view is that zinc oxide did not decrease feed intake or growth performance indicating that the only cost of adding zinc to the diet is the actual cost of zinc oxide (approximately $10 for the 7.7 lb per ton addition). Thus, zinc oxide may be an attractive treatment option for herds with a history of postweaning colibacillosis.

Further research with zinc oxide is needed in herds with histories of postweaning colibacillosis. Trials are needed in these on-farm situations to ensure that the reported changes in stool consistency and color associated with the addition of zinc oxide to the diet translate into improved pig performance.

Table 1. Composition of Diets[a]

	Trial 1		Trial 2	
Ingredient, %	Phase I	Phase II	Phase I	Phase II
Corn[b]	39.17	58.17	57.13	66.23
Soybean meal (48% CP)	14.07	21.86	23.50	27.12
Dried whey	25.00	10.00	10.00	
Porcine plasma	10.00			
Spray-dried blood meal		2.50		
Menhaden fish meal			3.75	
Lactose	2.50			
Soybean oil	5.00	3.00	2.00	2.00
Dicalcium phosphate (18.5% P)	2.21			
Monocalcium phosphate (21% P)		1.96	1.45	2.09
Limestone	.33	.83	.54	.94
Antibiotic[c]	1.00	1.00	1.00	1.00
Copper sulfate	.08	.08	.08	.08
L-lysine	.15	.15	.15	.15
DL-methionine	.10	.05		
Vitamin premix	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15
Total	100.00	100.00	100.00	100.00
Calculated Analysis, %				
Crude protein	21.2	18.9	19.5	18.4
Lysine	1.50	1.25	1.25	1.10

[a]Pigs were fed the phase I diets from d 0 to 14 postweaning. Phase II diets were fed from d 14 to 25 and d 14 to 29 in trials 1 and 2, respectively.
[b]Zinc oxide (.385%) was added at the expense of corn during phase I to form the experimental diets.
[c]Antibiotics were apralan and mecadox during phase I and II of trial 1, respectively, and neoterramycin in trial 2.

Table 2. Influence of Zinc Oxide on Starter Pig Performance

	Trial 1[a]			Trial 2[b]		
Item	Control	Zinc oxide	CV	Control	Zinc oxide	CV
Phase I[c]						
ADG, lb	.54	.54	9.5	.71	.70	7.9
ADFI, lb	.65	.66	9.3	1.09	1.12	3.8
F/G	1.19	1.23	5.9	1.53	1.62	10.6
Phase II[d]						
ADG, lb	.91	.86	10.4	.92	.92	13.7
ADFI, lb	1.43	1.31	4.1	1.84	1.86	3.3
F/G	1.58	1.52	4.4	2.01	2.06	9.3
Overall						
ADG, lb	.69	.67	7.5	.82	.81	5.2
ADFI, lb	.96	.92	6.1	1.48	1.50	3.1
F/G	1.39	1.38	1.3	1.81	1.85	1.9

[a]Each value for ADG is the mean of 10 pens containing 8 or 9 pigs per pen. Each value for ADFI and F/G is the mean of 5 feeders servicing 2 pens each. Pigs were weaned at an average initial wt and age of 10.9 lb and 17 d, respectively.
[b]Each value is the mean of 3 pens containing 28 pigs per pen. Pigs were weaned at an average initial wt and age of 12.8 lb and 21 d, respectively.
[c]Phase I was d 0 to 14 postweaning.
[d]Phase II was d 14 to 25 postweaning in trial 1 and d 14 to 29 postweaning in trial 2.

COMPARISON OF ORAL IRON AND INJECTABLE IRON FOR THE PREVENTION OF IRON DEFICIENCY ANEMIA IN BABY PIGS

K. B. Beeman[1] and D. A. Schoneweis[1]

Summary

One of two oral iron compounds or an injectable iron (100 mg iron per treatment) were administered to pigs on d 1 and 15 post-farrowing, and they were compared with untreated littermates. There was no significant difference between the pigs receiving the oral iron and the negative controls in serum iron or total iron binding capacity. Pigs that received iron by injection had higher serum iron and packed cell volume and a lower total iron binding capacity compared with pigs given oral iron or untreated controls.

(Key Words: Piglet, Iron, Anemia.)

Introduction

In 1990, all injectable iron products approved in the United States were removed from the market pending upgrading of the manufacturer's equipment and manufacturing protocols. Many oral iron products were sold; however, their abilities to prevent anemia were variable. This experiment compared two oral iron products, an injectable iron, and effects of no supplemental iron in neonatal pigs.

Experimental Design

Five litters of crossbred piglets were used in the experiment. After the sow had finished farrowing, the pigs were processed and ear notched. Pigs 1, 4, and 7 (group 1) received 100 mg of an oral iron compound (F4C-70) on d 1 and 15. Pigs 2, 5, and 8 (group 2) received 100 mg of iron fumarate orally on d 1 and 15. Pigs 3, 6, and 9 (group 3) received 100 mg of iron dextran IM in the neck on d 1 and 15. Other pigs in the litter served as negative controls (group 4). The pigs were weighed on d 1 and at one, two, and three weeks of age. Pigs were bled at one, two, and three weeks of age for serum iron (SI), total iron binding capacity (TIBC) and packed cell volume (PCV) determinations.

Results and Discussion

Weight gains were similar for the groups (9.6 lb). Growth rate was probably not affected in this study, because typically at least 3 to 4 weeks are required to observe a depression in growth rate from anemia. There was no significant difference in the SI or TIBC levels of the pigs receiving the oral iron and the negative control pigs; however, the injectable iron produced significantly improved SI and TIBC values ($P<.01$; Table 1). Total iron binding capacity indicates the amount of iron the serum could bind, and the higher the number, the greater the likelihood that the pig is anemic. The PCV gives an estimation of the number of erythrocytes and amount of hemoglobin and is used to determine if an animal is anemic. The injectable iron produced a marked increase in the PCV. There was no significant difference in the PCV of pigs receiving oral iron and the negative controls. These results suggest that oral iron products are not as effective as injectable iron in preventing anemia in baby pigs.

[1] Department of Clinical Sciences, College of Veterinary Medicine

Table 1. Average Values for Serum Iron, Total Iron Binding Capacity, and Packed Cell Volume for Pigs (Age 22 Days)

	Iron source			
Item	Serum iron F4C-70	Oral iron fumerate	Injectable iron dextran	Control
Serum iron, µg/dL	31.1[a]	29.1[a]	161.8[b]	26.2[a]
Total iron binding capacity, µg/dL	613[a]	670[a]	382[b]	672[a]
Packed cell volume, %	22.1[a]	20.3[a]	36.0[b]	18.8[a]

[ab]Means on the same row with different superscripts differ (P<.05).

Mark Nelson, breeding barn manager, artifically inseminates a gilt.

THE EFFECT OF DIETARY THREONINE ON GROWING PIG GROWTH PERFORMANCE

K. G. Friesen, J. L. Nelssen, R. D. Goodband, B. T. Richert, J. L. Laurin, and T. L. Weeden

Summary

Sixty pigs (initially 68.57 lb BW) were used in a 28-d growth trial to determine the effect of increased dietary threonine on growth performance for the grower pig. The basal diet was formulated with corn and peanut meal to contain 1.00% dietary lysine and .40% dietary threonine. Sucrose was replaced by synthetic threonine to give dietary threonine levels of .50, .60, .70, and .80%. Two pigs were housed per pen for a total of six pens per treatment (12 pigs per treatment). Pig weights and feeder weights were recorded weekly to determine ADG, ADFI, and feed efficiency. On d 14 and 28 of the experiment, serum samples were collected to determine serum urea N concentrations. From d 0 to 14, ADG increased quadratically and feed efficiency improved linearly and quadratically as dietary threonine increased. Average daily feed intake was not affected by dietary treatment. From d 14 to 28, ADG, ADFI, and feed efficiency were not affected by increased dietary threonine. Cumulative (d 0 to 28) ADG and ADFI were not significantly influenced by dietary treatment. However, ADG improve by 17% when dietary threonine was increased from .40 to .50%. Feed efficiency improved linearly and quadratically when dietary threonine was increased and was optimized between .50 and .60% dietary threonine (approximately 10 to 12 g/d) from d 0 to 28. Serum urea N was decreased as dietary threonine increased. Pigs fed .60% dietary threonine had the lowest serum urea N concentrations compared to the other treatments. These data suggest that the grower pig requires dietary threonine at approximately .50 to .60% (10 to 11 g/d) to optimize growth performance.

Introduction

A great deal of attention has been focused on determining the lysine requirement for all weight ranges of pigs. This research is essential because lysine is normally the first limiting amino acid for protein synthesis in pigs. However, once the lysine requirement is established, the effects of excess or deficient amounts of the remaining essential amino acids must be considered. Research from both the Universities of Georgia and Kentucky has suggested that increased dietary threonine above NRC (1988) recommendations in high lysine nursery and grower pig diets results in improved growth performance. Thus, the objective of this experiment was to determine the effect increasing dietary threonine has on growth performance and serum urea N in growing pigs.

Procedures

Sixty pigs (initially 68.57 lb) were allotted to one of five dietary treatments based upon initial BW. Pigs were fed a sorghum-peanut meal (1.00% dietary lysine) diet containing either .40, .50, .60, .70, or .80% dietary threonine (Table 1) throughout the entire 28-d trial. Peanut meal was used as the primary protein source, because it is deficient in threonine. The sorghum and peanut meal concentrations remained constant in each experimental diet. Sucrose was replaced by synthetic threonine on a 1 to 1 basis to increase the dietary threonine above that of the basal diet. Each pen housed two pigs, with each dietary treatment having six pens. Pigs were housed in 4 ft × 4 ft total slated pens containing a single hole feeder and a nipple waterer to provide *ad libitum*

access to feed and water. Pig and feeder weights were recorded weekly to determine average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G) ratio. On d 14 and 28, serum samples were collected to determine serum urea nitrogen (N) concentrations.

Table 1. Basal Diet Composition[a]

Ingredient	Percentage
Grain sorghum	76.08
Peanut meal	15.32
Soy oil	3.00
Monocalcium phosphate (21% P)	1.67
Limestone	1.02
Vitamin premix	.25
Trace mineral premix	.15
Selenium premix	.05
Salt	.25
Sucrose[b]	.40
L-lysine HCL	.72
L-tryptophan	.02
DL-methionine	.07
Antibiotic[c]	1.00
Total	100.00

[a]Basal diets were formulated to 1.00% lysine, .40% threonine, .75% Ca, and .65% P.
[b]L-threonine replaced sucrose on a lb/lb basis to achieve the .50, .60, .70, and .80% dietary threonine experimental diets.
[c]Provided 50 g/ton carbodox.

Results and Discussion

Average daily gain increased quadratically (P<.05) and F/G improved (P<.05) both linearly and quadratically as dietary threonine increased from d 0 to 14. A plateau in ADG was detected at approximately .60% dietary threonine, whereas feed efficiency reached a plateau at approximately .50 to .60% dietary threonine. Average daily feed intake was not influenced by increased dietary threonine; thus, threonine intake increased as threonine concentration increased. The NRC (1988) requirements suggest that the threonine requirement for the 45 to 110 lb pig is approximately .48% (9.1 g/d). The threonine requirement was nearly met when .50% (8.96 g/d) dietary threonine was fed. However, a 3% improvement in ADG was detected when dietary threonine was increased to .60% (10.83 g/d). Feed efficiency was also improved by 3% when dietary threonine was increased from .50 to .60%, suggesting improved amino acid utilization.

From d 14 to 28, no treatment effects were detected for ADG, ADFI, and F/G when dietary threonine was increased. However, ADG was improved by 16% and F/G was improved by 10% when dietary threonine was increased from .40 to .50%. This represents an increase in threonine intake from 8.18 to 11.00 g/d. The data from this period (d 14 to 28) suggest that in the later stages of the grower phase dietary threonine intake is greater than typical recommendations. As feed intake increased with maturity, the threonine intake required to maximize growth performance was achieved at a lower dietary threonine concentration than in the early (d 0 to 14) grower phase.

Although cumulative (d 0 to 28) ADG and ADFI were not influenced by increased dietary threonine, F/G improved (P<.01) linearly and quadratically as dietary lysine increased. A 17% increase in ADG was detected when dietary threonine was increased from .40 to .50% (7.60 vs 9.98 g/d, respectively), and F/G was improved 15% by the same increase. A 3% improvement in feed efficiency was detected when dietary threonine was increased form .50 to .60%.

Serum urea N (d 14) decreased (P<.01) linearly and quadratically as dietary threonine increased from .40 to .80%. A similar response was detected on d 28; serum urea N decreased linearly (P<.01) and quadratically (P<.05) as dietary threonine increased. In both instances, serum urea N was minimized at .60% dietary lysine. These data suggest that amino acid utilization is optimized for growing pigs when approximately .60% threonine is included in a 1.00% lysine diet.

Currently, NRC (1988) recommendations suggest that threonine be included at .48% (9.1 g/d) in 45 to 110 lb pigs. The results from this experiment suggest that ADG and F/G are optimized between .50 and .60%. Thus, dietary threonine requirements for grower pigs may be greater than current NRC recommendations during the early grower phase. The quadratic response to increased dietary threonine indicates maximal feed efficiency at approximately .60% dietary threonine. This observation is further supported by the minimal serum urea N concentrations in pigs fed .60% dietary threonine. Diets containing .60% threonine correspond to a threonine intake of approximately 10.83 g/d. As the pig matures, the magnitude of response to dietary threonine is not as great. Feed efficiency is improved by 15% when dietary threonine is increased from .40 to .50%, but by only 3% when it is increased from .50 to .60%. Thus, threonine intake at approximately 11 g/d (.60% dietary threonine from d 0 to 14 and .50% dietary threonine from d 14 to 28) is required to optimize growth performance during the growing phase.

The typical corn-soybean meal diet is not deficient in threonine. However, the results of our experiment and research from the Universities of Kentucky and Georgia suggest that dietary threonine may need to be increased in growing pig diets. Further research is necessary to quantitate the amount of dietary threonine required relative to lysine to optimize growth performance.

Table 2. The Effect of Increased Dietary Threonine on Growth Performance and Serum Urea Nitrogen in 60 lb Growing Pigs[a]

	Dietary threonine, %					
Item	.40	.50	.60	.70	.80	CV
ADG, lb						
d 0 to 14[e]	1.29	1.60	1.65	1.66	1.51	15.31
d 14 to 28	1.58	1.89	1.91	1.49	1.93	40.13
d 0 to 28	1.44	1.74	1.78	1.57	1.72	21.33
ADFI, lb						
d 0 to 14	3.87	3.95	3.98	3.86	3.81	11.40
d 14 to 28	4.51	4.85	4.72	4.90	4.71	9.34
d 0 to 28	4.19	4.40	4.35	4.35	4.26	9.51
F/G						
d 0 to 14[cd]	3.00	2.47	2.41	2.33	2.52	9.58
d 14 to 28	2.85	2.57	2.00	3.29	2.44	37.40
d 0 to 28[bd]	2.91	2.53	2.00	2.77	2.48	5.28
Threonine intake, g/d						
d 0 to 14	7.02	8.96	10.83	12.26	13.83	--
d 14 to 28	8.18	11.00	12.85	15.56	17.09	--
d 0 to 28	7.60	9.98	11.84	13.81	15.46	--
Serum urea N, mg/dl						
d 14[bd]	21.07	11.94	11.70	13.21	11.56	18.39
d 28[be]	18.43	13.03	12.84	13.62	12.39	20.58

[a]Means calculated from 60 pigs (initially 68.57 lb BW); two pigs/pen and six pens/treatment.
[bc]Linear effect of dietary threonine (P<.01) and (P<.05), respectively.
[de]Quadratic effect of dietary threonine (P<.01) and (P<.05), respectively.

THE INTERRELATIONSHIP BETWEEN GENOTYPE, SEX, AND DIETARY LYSINE EFFECTS ON GROWTH PERFORMANCE AND PROTEIN ACCRETION IN FINISHING PIGS FED TO 230 AND 280 LB[1]

K. G. Friesen, J. L. Nelssen, J. A. Unruh, R. D. Goodband, M. D. Tokach, L. J. Kats, J. A. Hansen, and J. L. Laurin

Summary

One hundred and twenty pigs (initially 96 lb BW) were used to determine the interrelationship between genotype, sex, and dietary lysine effects on growth performance and carcass composition in a 2 × 2 × 2 factorial arrangement. Genetic comparisons were made between pigs characterized by either high or medium potential for lean tissue gain. Within genotype, barrows and gilts were separately fed either a .90 or a .70% lysine diet until the mean weight of pigs in each pen of three reached 230 lb. One pig per pen was then slaughtered to determine carcass characteristics and chemical composition. From 230 to 280 lb, dietary lysine was lowered to .75 or .55% for pigs fed .90 or .70% dietary lysine, respectively. When the pig mean weight met or exceeded 280 lb, both pigs were slaughtered to determine carcass characteristics and chemical composition. The right side of the carcass was then ground and chemically analyzed to determine protein and lipid accretion rates. No interactions were detected; therefore, main effect means will be discussed. At 230 lb, high lean gain pigs had increased ADG and gain to feed ratio compared to medium lean gain pigs. Barrows had increased ADG and ADFI, but exhibited a poorer feed to gain ratio than gilts. Pigs fed .90% lysine had improved ADG compared to pigs fed .70% lysine. High lean gain pigs had increased CP accretion and lipid accretion compared to medium lean gain pigs. Similarly, gilts had increased CP accretion and decreased lipid accretion compared to barrows. Cumulative ADG (96 to 280 lb) was greater for high lean gain pigs, barrows, and pigs in the .90/.75% lysine regimen. Average daily feed intake was increased in barrows compared to gilts. Gilts had greater CP accretion than barrows. Crude protein accretion was greater in high lean gain pigs compared to medium lean gain pigs, with high lean gain gilts having the greatest magnitude of response to increased dietary lysine. High lean gain pigs exhibited greater growth performance and CP accretion compared to medium lean pigs, with high lean gain gilts offering the largest potential for maximized lean tissue accretion and improved lean efficiency.

(Key Words: Pigs, Lysine, Sex, Carcass Composition, Genotypes)

Introduction

The production of lean pork has become a major priority to the swine industry over the past 5 yrs. Increased market premiums for lean carcasses and decreased profit margins for fat, less efficient hogs have driven the industry towards leaner, more efficient hogs. Production is targeted at raising hogs with increased lean gain and improved lean efficiency. Lean gain is the rate at which muscle tissue is deposited as a function of time, and lean efficiency is the amount (lb) of feed required to deposit 1 lb of muscle tissue. Although these measurements are similar to

[1]The authors wish to acknowledge Nutri-Quest and BioKyowa for partial financial and amino acid support for this project and Pig Improvement Co. Inc., Franklin, KY for partial financial support.

ADG and the F/G ratio, they allow a producer to access the rate and efficiency of lean tissue produced instead of total (muscle, fat, and bone) weight gain. Muscle tissue is the marketable product and should be the emphasis of production analysis in the quest for improved production efficiency. Research has suggested that lean gain can be influenced by genotype, gender, and dietary lysine. Selection for decreased backfat and improved feed efficiency has resulted in pigs with increased lean gain potential. Within genotype, barrows typically exhibit a 5 to 6% increase in ADG and ADFI but poorer feed efficiency compared to gilts. By selecting for increased lean gain and by using split-sex feeding methods, the potential exists for increased dietary lysine to optimize lean growth. Thus, the objective of this experiment was to determine the interrelationship between genotype, sex, and dietary lysine effects on growth performance and protein accretion in finishing pigs fed to 230 and 280 lb.

Procedures

Animals. One hundred and twenty pigs (initially 96 lb) were used in a 2 × 2 × 2 factorial arrangement. Genetic comparisons were made between pigs previously characterized as having either high or medium lean gain potential by the procedures developed at Purdue University. Briefly, initial composition was determined by the following equation:

Initial muscle = -3.5 + (.44 × initial wt).

Hot carcass weight and 10th rib fat and loin depths were recorded to determine final composition by use of simple linear regression. Lean deposition per day was determined by the difference between final and initial composition divided by the number of days between the initial and final composition determinations. For a pig to be classified as high lean gain, the lean growth rate must equal or exceed .75 lb/day of lean tissue per day. Medium lean gain pigs have a lean deposition rate ranging from .50 to .75 lb/day. Within genotype, barrows and gilts were fed separately two dietary lysine regimens. Three pigs were housed per pen (15 ft × 4 ft pens with solid concrete flooring) in a open-fronted facility with five replicate pens per treatment. Drip coolers were activated when temperatures exceeded 80°F, cycling on for three out of every 15 min. Each pen contained a single hole self-feeder and a nipple waterer to accommodate ad libitum feed and water intake. Pig weights and feed disappearance were recorded at 14 d intervals to determine ADG, ADFI, and gain to feed ratio, until d 56 of the trial. From this point until the termination of the experiment, data were collected weekly. When the mean weight of pigs in a pen equalled or exceeded 230 lb, one pig from each pen was randomly selected and slaughtered for carcass analysis. The remaining two pigs were grown to a pen mean weight of 280 lb and then slaughtered for carcass analysis.

Diets. Two dietary regimes (Table 1) were used in this experiment based upon the dietary lysine estimates proposed by the University of Kentucky for high and medium lean gain potential genotypes. Pigs were fed either a diet containing either.90 or .70% dietary lysine until a pen mean weight of 230 lb was achieved. At this point, dietary lysine was decreased to .75 and .55%, respectively. Dietary isoleucine, methionine + cystine, threonine, and tryptophan were maintained relative to lysine (Table 1) according to the ratio proposed by NRC (1988) for 110 to 240 lb finishing pigs. All other nutrient requirements met or exceeded NRC recommendations for 110 to 240 lb finishing pigs.

Results and Discussion

Growth Performance. Average daily gain was higher ($P<.01$) for pigs from the high lean gain genotype compared to pigs from the medium lean gain genotype when fed to 230 lb (Table 2). Within genotype, ADG was greater ($P<.05$) in barrows compared to gilts, with increased dietary lysine

(.90 vs .70%) improving (P<.01) ADG in both barrows and gilts. An interaction (P<.05) between genotype, sex, and dietary lysine existed during the period between 230 and 280 lb for ADG. Average daily gain was greatest in high lean gain barrows fed a diet containing .75% dietary lysine with medium lean gain gilts on the .55% dietary lysine diet having the poorest ADG (2.2 vs 1.6 lb, respectively). Cumulative ADG was higher (P<.01) for high lean gain pigs compared to medium lean gain pigs. Within genotype, ADG was increased (P<.05) in barrows compared to gilts and when dietary lysine was increased (P<.05). Genotype did not influence (P>.10) ADFI from 96 to 230 lb and from 230 to 280 lb, but ADFI was higher (P<.05) in high lean gain pigs compared to medium lean gain pigs for the entire growth period (96 to 230 lb). Average daily feed intake was greater (P<.05) for barrows from 96 to 230 lb and 230 to 280 lb compared to gilts. For the entire experiment, barrows consumed more (P<.01) feed than gilts regardless of genotype or dietary lysine. Gain to feed ratio (96 to 230 lb) was improved (P<.05) in the high lean gain pigs compared to pigs from the medium lean gain genotype. Lysine intake was higher (P<.01) for pigs fed increased dietary lysine and for barrows compared to gilts during all phases of the experiment.

Accretion Rates. A genotype by sex interaction (P<.05) was detected for moisture accretion in the 230 lb pigs. Moisture accretion increased at a greater magnitude in high lean gain barrows compared to high lean gain gilts than in medium lean gain barrows compared to gilts. Moisture, CP, and lipid accretion rates (Table 3) were increased (P<.01) in high lean gain pigs (334.15 vs 261.93 g/d, 118.17 vs 92.97 g/d and 272.26 vs 221.37 g/d, respectively) compared to medium lean gain pigs. Gilts had an increased (P<.01) CP accretion rate (114.26 vs 96.88 g/d, respectively) and a decreased (P<.01) lipid accretion rate (219.61 vs 274.02 g/d, respectively) compared to barrows. Feeding increased dietary lysine increased (P<.01) CP accretion rate regardless of genotype and gender (114.39 vs 96.75 g/d, respectively).

Moisture accretion was influenced (P<.01) by genotype, sex, and dietary lysine in the 280 lb pigs. Moisture accretion was maximized in high lean gain barrows fed increased dietary lysine compared to medium lean gain gilts fed low dietary lysine. Crude protein accretion (Table 3) was greater (P<.01) in high lean gain pigs compared to medium lean gain pigs (106.30 vs 89.65 g/d, respectively) and in gilts compared to barrows (106.53 vs 89.42 g/d, respectively). Conversely, lipid accretion was decreased (P<.05) in gilts compared to barrows (206.82 vs 264.20 g/d, respectively). Ash accretion rate was not influenced by treatment.

The results from this experiment indicate the differences between genotypes for growth performance and lean tissue accretion rate. The increased ADG in high lean gain pigs corresponded to increased CP accretion compared to medium lean gain pigs. Conversely, medium lean gain pigs had a poorer ADG and CP accretion rate than the high lean gain pigs even though feed intake was similar between the two genotypes. This can potentially be explained by poor feed efficiency from 96 to 230 lb and by an over- consumption of lysine/d (Table 3). Fat accretion was greater in high lean gain pigs, which can potentially be explained by the increased ADG compared to medium lean gain pigs. Within genotype, barrows had increased ADG and ADFI with poorer feed efficiency compared to gilts. This response is typical of the differences detected between gilts and barrows. Both barrows and gilts in either genotype responded to increased dietary lysine. This response can be explained by the high ADFI recorded in all pigs, resulting in an increased lysine intake. High lean gain gilts had the greatest magnitude of response to increased dietary lysine, suggesting that the high lean gain gilt may have a greater dietary lysine requirement compared to high lean gain barrows and medium lean gain barrows and gilts. Further research is required to

determine lysine needs to optimize growth performance and protein accretion. However, this research emphasizes the need to select a genotype with a high rate and efficiency of lean gain in modern swine production.

Table 1. Diet Composition[a]

	Lysine, %			
Item, %	.90	.70	.75	.55.
Corn	76.92	83.73	82.02	88.84
Soybean meal (48% CP)	20.79	13.83	15.57	8.62
Monocalcium phosphate (21%	1.09	1.23	1.19	1.33
Limestone	.73	.74	.74	.74
Salt	.15	.15	.15	.15
Vitamin premix	.15	.15	.15	.15
Trace mineral premix	.10	.10	.10	.10
Lysine-HCl	.07	.07	.07	.07
Total	100.00	100.00	100.00	100.00
Chemical Analysis, %				
Isoleucine	.76	.60	.59	.49
Lysine	.97	.73	.73	.59
Methionine	.26	.25	.24	.22
Threonine	.63	.52	.50	.44
Tryptophan	.20	.15	.18	.14

[a]Pigs (3 pigs/pen) were fed diets containing either .90% or .70% dietary lysine until a pen mean weight equaled 230 lb. At this point one pig was slaughtered and the remaining two were fed either a .75% or .55% dietary lysine.

Table 2. The Effect of Genotype, Sex, and Dietary Lysine on Growth Performance in Pigs Fed to 230 and 280 lb[a]

	High lean genotype				Medium lean genotype				
	Barrows		Gilts		Barrows		Gilts		
Item	.90%[b]	.70%	.90%	.70%	.90%	.70%	.90%	.70%	CV
ADG, lb									
96-230 lb[cfg]	2.17	2.05	2.00	1.91	2.01	1.80	1.89	1.65	9.29
230-280 lb[i]	2.21	1.83	1.99	2.14	2.06	2.10	2.04	1.57	16.86
96-280 lb[cfh]	2.17	2.01	1.99	1.94	2.02	1.84	1.90	1.74	8.14
ADFI, lb									
96-230 lb[f]	6.85	6.62	6.12	6.33	6.68	6.11	6.36	5.60	8.65
230-280 lb[f]	9.83	8.58	8.30	8.40	9.33	9.30	8.59	8.09	12.04
96-280 lb[de]	7.50	6.97	6.58	6.68	7.19	6.53	6.40	6.20	6.88
F/G									
96-230 lb[d]	3.16	3.23	3.06	3.31	3.32	3.39	3.37	3.39	8.47
230-280 lb	4.45	4.69	4.17	3.93	4.53	4.43	4.21	5.15	15.22
96-280 lb	3.46	3.47	3.31	3.44	3.56	3.55	3.37	3.56	6.62
Lysine intake,									
96-230 lb[eg]	27.97	21.01	24.97	20.09	27.27	19.68	25.96	17.78	8.71
230-280 lb[eg]	33.43	21.41	28.24	20.95	31.74	23.19	29.23	20.19	11.47
96-280 lb[eg]	31.17	21.22	26.88	20.58	29.83	20.90	27.10	19.47	8.33

[a]A total of 120 pigs, 3 pigs/pen from 96-230 lb and 2 pigs/pen from 230-280 lb, 5 pens/treatment.
[b]A .90% or .70% dietary lysine was fed until a pen average of 230 lb was achieved. At this point one pig/pen was removed for slaughter with the remaining 2 pigs receiving .75% or .55% dietary lysine.
[c,d]Genotype effect (P<.01) and (P<.05), respectively.
[e,f]Sex effect (P<.01) and (P<.05), respectively.
[g,h]Dietary lysine effect (P<.01) and (P<.05), respectively.
[i]Genotype × sex × lysine interaction (P<.05).

Table 3. The Effect of Genotype, Sex, and Dietary Lysine on Moisture, CP, Lipid, and Ash Accretion Rates in Finishing Pigs Fed to Either 230 or 280 lb[a]

	High lean genotype				Medium lean genotype				
	Barrows		Gilts		Barrows		Gilts		
Item, g	.90[b]	.70	.90	.70	.90	.70	.90	.70	CV
96-230 lb									
Moisture[di]	363.7	356.7	325.3	290.9	289.3	190.9	301.4	266.1	23.4
CP[ceg]	115.9	105.3	131.9	119.5	102.2	64.1	107.5	98.1	16.0
Lipid[de]	334.1	278.3	238.8	237.9	249.6	324.1	213.7	188.1	23.9
Ash[d]	19.1	18.1	23.3	16.2	11.2	11.0	17.3	15.0	35.5
96-280 lb									
Moisture[ceg]	698.6	666.3	643.4	623.9	608.6	577.4	608.4	561.2	9.8
CP[ce]	99.7	91.7	115.8	118.1	81.1	85.4	100.4	91.8	13.2
Lipid[f]	319.0	258.2	218.0	178.6	245.0	234.5	234.9	195.8	28.9
Ash	19.4	17.7	20.8	15.4	18.9	18.9	18.5	16.6	27.7

[a]A total of 120 pigs, 3 pigs/pen from 96-230 lb and 2 pigs/pen from 230-280 lb, 5 pens/treatment.
[b]A .90% or .70% dietary lysine was fed until a pen average of 230 lb was achieved. At this point one pig/pen was removed for slaughter with the remaining 2 pigs receiving .75% or .55% dietary lysine.
[c,d]Genotype effect (P<.01) and (P<.05) respectively.
[e,f]Sex effect (P<.01) and (P<.05) respectively.
[g,h]Dietary lysine effect (P<.01) and (P<.05) respectively.
[i]Genotype by sex interaction (P<.05).

THE INTERRELATIONSHIP BETWEEN GENOTYPE, SEX, AND DIETARY LYSINE EFFECTS ON CARCASS CHARACTERISTICS IN 230 AND 280 LB FINISHING PIGS[1]

K. G. Friesen, J. L. Nelssen, J. A. Unruh, R. D. Goodband, M. D. Tokach, T. L. Weeden, B. T. Richert, and L. J. Kats

Summary

One hundred and twenty pigs (initially 96 lb BW) were slaughtered either at 230 lb (40 pigs) or at 280 lb (80 pigs) to determine the interrelationship between genotype, sex, and dietary lysine effect on carcass characteristics in a 2 × 2 × 2 factorial arrangement. Genetic comparisons were made between pigs characterized by either high or medium potential for lean tissue gain. Barrows and gilts were separately fed either .90 or .70% dietary lysine within genotype. One pig per pen was slaughtered for carcass evaluation at a pen mean weight of 230 lb, with the remaining two pigs fed .75 or .55% dietary lysine until a pen mean weight of 280 lb was obtained. At this point, the remaining two pigs were slaughtered for carcass evaluation. High lean gain pigs slaughtered at 230 lb had a heavier chilled carcass weight and longer carcasses than medium lean gain pigs. Gilts had larger loineye area and less backfat compared to barrows. Increased dietary lysine did not influence carcass characteristics at 230 lb. At 280 lb, high lean gain pigs had increased hot carcass weight, chilled carcass weight, loineye area and carcass length compared to medium lean gain pigs. Gilts had an increased dressing percentage, loineye area, and carcass length in conjunction with decreased backfat thickness and kidney fat compared to barrows. Increased dietary lysine did not influence carcass characteristics in pigs slaughtered at 280 lb. These data indicate that carcass characteristics were not influenced by genotype at 230 lb. However, in the group fed to 280 lb, high lean gain pigs had superior carcasses compared to medium lean gain pigs. Carcass characteristics were optimized in gilts at either slaughter weight, suggesting that high lean gain gilts can be fed to heavier weights without sacrificing carcass merit.

(Key Words: Pigs, Genotype, Sex, Lysine, Backfat, Loineye Area.)

Introduction

As the swine industry moves closer to a value-based market, the demand for high lean carcasses is continually increasing. Current merit value buying programs offer a premium between 103.3 and 111.0% as a percentage of the base sale price for 230 to 245 lb pigs, when backfat is reduced below .6 in. This system offers the producer an opportunity to increase profit margins for the sale of superior carcasses. It also gives the producer an incentive to improve the finishing pigs marketed by using improved genotypes, implementing split-sex feeding, and altering nutritional programs to maximize the rate of lean gain and the efficiency at which lean tissue is deposited. Thus, the objective of this experiment was to determine the interrelationship between genotype, sex, and dietary lysine effects on carcass characteristics in finishing pigs fed to 230 and 280 lb.

[1]The authors wish to acknowledge Nutri-Quest and BioKyowa for financial and amino acid support and Pig Improvement Co. Inc., Franklin, KY for partial financial support.

Procedures

The experimental design and animal handling procedures are described in the preceding paper. Briefly, 120 pigs (initially 96 lb BW) were used in a 2 × 2 × 2 factorial arrangement. Pigs were predetermined as high or medium lean gain potential and barrows and gilts were fed separately within genotype. Either .90 or .70% dietary lysine was fed until the pen average weight of 230 lb was achieved. At this point, one pig/pen (five pigs/treatment) was slaughtered for carcass evaluation, and the remaining two pigs were fed .75% or .55% dietary lysine, respectively. Both remaining pigs were slaughtered at a pen mean weight of 280 lb for carcass evaluation.

Carcass Data Collection. Carcasses were weighed at slaughter and reweighed 24 hr postmortem to record hot and chilled carcass weights and determine dressing percentage. At slaughter, the heart, liver, kidneys, and kidney fat were removed and weighed. Backfat thickness was measured at the first rib, last rib, and last lumbar vertebrae. Measurements were taken from both the right and left sides, with the average backfat thickness calculated from the six measurements. Tenth rib fat thickness was measured 3/4 the length of the loin muscle from the midline. Loin muscle area at the 10th rib and carcass length were also recorded on the chilled carcasses.

Results and Discussion

Treatment effects were not detected for live or hot carcass weight when pigs were slaughtered at a mean weight of 230 lb (Table 4). Medium lean gain pigs had lighter (P<.05) chilled carcass weight 24 h postmortem compared to high lean gain pigs (165.2 vs 171.0 lb, respectively). High lean gain pigs also had longer carcasses (P<.01) than did medium lean gain pigs (31.89 vs 30.68 in, respectively). Average backfat thickness and tenth rib fat depth were less (P<.01) in gilts compared to barrows (1.04 vs 1.18 and .96 vs 1.24 in, respectively). Conversely, loineye area was larger (P<.01) in gilts than in barrows (5.30 vs 4.61 in^2, respectively). Kidney fat weight and dressing percent were not affected by treatment.

At 280 lb, live weight was similar among all eight experimental treatments (Table 2). However, hot and chilled carcass weights were heavier (P<.01) in high lean gain pigs compared to medium lean gain pigs (216.90 vs 211.82 lb and 212.98 vs 208.32 lb, respectively). Dressing percentage was lower (P<.05) in barrows compared to gilts. Gilts had less (P<.01) average backfat thickness (1.29 vs 1.42 in, respectively) and tenth rib fat depth (1.20 vs 1.47 in, respectively) compared to barrows. Loineye area was larger (P<.01) in high lean gain pigs compared to medium lean gain pigs (6.06 vs 5.50 in^2, respectively). Within genotype, gilts had larger (P<.01) loineye area compared to barrows (6.14 vs 5.48 in^2, respectively). High lean gain pigs had increased (P<.01) carcass length compared to medium lean gain pigs (33.45 vs 32.81 in, respectively). Gilts had (P<.05) longer carcasses compared to barrows regardless of genotype (33.39 vs 32.92 in, respectively). Barrows had more carcass kidney fat than gilts (6.01 vs 5.21 lb, respectively).

These data indicate that genotype did not have a large influence on carcass characteristics for 230 lb pigs. However, acceptable carcasses were obtained from both the medium and high lean gain genotypes. This can potentially be explained by the high ADFI and lysine intake/d for both genotypes reported in the previous paper. Although carcass characteristics were not influenced by genotype, the rate of lean tissue gain and the efficiency of lean tissue gain was improved dramatically (previous paper). This suggests that high lean gain pigs can produce acceptable carcasses similar to medium lean gain pigs at a faster rate and more efficiently, decreasing the days to market and the amount of feed required to reach a desired market weight. Within genotype, gilts had superior

carcasses compared to barrows. Gilts typically have a higher lean proportion compared to barrows because of increased feed efficiency. Decreased ADFI in gilts results in an increased proportioning of feed intake towards muscle accretion as opposed to fat deposition. The increase in muscle accretion, in turn, increases body maintenance requirements, which also decreases energy concentrations for fat deposition. Increased dietary lysine did not influence carcass characteristics, which can be explained by the high lysine intake/d for both dietary lysine regimes.

In the group fed to 280 lb, high lean gain pigs had increased loin eye area and decreased backfat thickness compared to medium lean gain pigs. These data imply that pigs selected for increased lean gain have an extended growth curve, allowing these pigs to be fed to heavier weights without drastically increasing backfat thickness compared to medium lean gain pigs. Gilts retained superiority compared to barrows, with carcasses from gilts having increased loin eye area and decreased backfat thickness compared to barrows. This improvement in carcass merit may be related to increased amino acid requirements because of decreased ADFI, resulting in a more efficient use of amino acids consumed. Increased dietary lysine did not influence carcass merit, because lysine intake was adequate regardless of dietary lysine regime.

Table 1. The Effect of Genotype, Sex, and Dietary Lysine on Carcass Characteristics in Pigs Fed to 230 lb[a]

	High lean genotype				Medium lean genotype				
	Barrows		Gilts		Barrows		Gilts		
Item	.90[b]	.70	.90	.70	.90	.70	.90	.70	CV
Live wt, lb	240.59	240.79	235.20	238.19	240.20	230.60	235.40	234.50	3.56
Hot carcass wt, lb	173.01	175.01	174.31	173.10	172.90	162.49	171.09	168.50	4.11
Chilled carcass wt, lb[c]	169.91	171.71	170.70	171.71	169.40	159.90	167.60	163.75	3.86
Dressing percentage, %	71.91	72.68	74.11	72.67	71.98	70.46	72.68	71.85	3.82
Backfat thickness, in[e]	1.18	1.09	.96	1.08	1.27	1.21	1.11	1.02	13.25
Tenth rib fat depth, in[e]	1.27	1.14	.86	1.11	1.34	1.21	.96	.89	19.37
Loin area, in^{2}[e]	4.64	4.87	5.50	5.29	4.63	4.31	5.19	5.18	11.19
Carcass length, in[c]	32.18	31.50	32.16	31.74	30.38	30.46	30.86	31.13	2.00
Kidney fat, lb	3.67	3.56	2.62	3.83	3.63	4.14	3.96	3.76	36.37

[a]Means calculated from 40 pigs at a pen mean weight of 230 lb, 1 pig/pen, 5 pigs/treatment.
[b]Dietary lysine content.
[c,d]Genotype effect (P<.01) and (P<.05) respectively.
[e,f]Sex effect (P<.01) and (P<.05) respectively.
[g,h]Dietary lysine effect (P<.01) and (P<.05), respectively.

Table 2. The Effect of Genotype, Sex, and Dietary Lysine on Carcass Characteristics in Pigs Fed to 280 lb[a]

	High lean genotype				Medium lean genotype				
	Barrows		Gilts		Barrows		Gilts		
Item	.75[b]	.55	.75	.55	.75	.55	.75	.55	CV
Live wt, lb	292.10	291.60	289.30	284.90	287.40	288.20	284.25	283.00	2.51
Hot carcass wt, lb[c]	217.40	215.05	218.81	216.30	214.30	211.00	211.46	210.52	2.44
Chilled carcass wt, lb[c]	213.71	211.31	214.63	212.30	210.69	207.50	207.55	207.17	2.47
Dressing percentage, %[f]	74.48	73.73	75.65	75.94	74.59	73.18	74.82	74.26	2.03
Backfat thickness, in[e]	1.45	1.34	1.22	1.28	1.53	1.35	1.35	1.32	9.75
Tenth rib fat depth, in[e]	1.57	1.35	1.13	1.26	1.57	1.39	1.24	1.21	16.17
Loineye area, in^{2} [ce]	5.52	5.91	6.57	6.25	5.23	5.27	5.93	5.69	8.11
Carcass length, in[cf]	32.89	33.28	33.87	33.77	32.71	32.81	33.06	32.66	1.50
Kidney fat, lb[f]	5.10	6.18	5.61	5.61	5.81	5.85	5.19	4.49	15.85

[a]Means calculated from 80 pigs at a pen mean weight of 280 lb, 2 pig/pen, 5 pigs/treatment.
[b]Dietary lysine content.
[c,d]Genotype effect (P<.01) and (P<.05) respectively.
[e,f]Sex effect (P<.01) and (P<.05) respectively.
[g,h]Dietary lysine effect (P<.01) and (P<.05), respectively.

THE INFLUENCE OF GENOTYPE, SEX, AND DIETARY LYSINE ON CARCASS QUALITY CHARACTERISTICS OF 230 AND 280 LB FINISHING PIGS[1]

S. R. Stuewe, J. A. Unruh, K. G. Friesen, J. L. Nelssen, R. D. Goodband, and M. D. Tokach

Summary

When pigs were fed to 230 lb, high-lean genotype loin eyes had less visual marbling and a higher saturation index (more vivid or intense color) than medium-lean genotype loin eyes. Loin eye chops from high-lean gilts had greater cooking losses and Warner-Bratzler shear values (mechanically tougher) than those from high-lean barrows and medium-lean barrows and gilts. When pigs were fed to 280 lb, medium-lean genotype loin eyes had a lighter color visually and indicated by Hunter L* values, more marbling, less firmness, more moisture exudate, and a higher chop thaw loss than high-lean loin eyes. Barrow loin eyes had more marbling and less thaw loss than gilt loin eyes. Loin eye chops from high-lean barrows had higher Warner-Bratzler shear values than high-lean gilts and medium-lean barrows and gilts. Dietary lysine levels had minimal effects on carcass quality for pigs fed to either 230 or 280 lb.

(Key Words: Pork Quality, Lysine, Sex, Genotypes.)

Introduction

The swine industry has experienced increased market premiums for lean carcasses and discounts for fat, less efficient hogs. Research has suggested that carcass composition can be influenced by genotype, gender, and dietary lysine. Selection for decreased backfat and improved feed efficiency has resulted in pigs with increased lean gain potential. However, selection pressure for increased leanness only may have negative effects on carcass quality. Therefore, the objective of this experiment was to determine the interrelationship between genotype, sex, and dietary lysine and effects on carcass quality characteristics in finishing pigs fed to 230 and 280 lb.

Procedures

Diets, growth performance, and carcass characteristics for the pigs used in this study are described in previous papers in this Report of Progress. One hundred sixteen pigs were used in a 2 × 2 × 2 factorial arrangement. Genetic comparisons were made between pigs previously characterized as having either high or medium lean gain potential. Within genotype, barrows and gilts were fed separately (three pigs per pen) two dietary lysine regimens. Pigs were fed either a diet containing .90 or .70% dietary lysine until the mean weight of pigs in a pen equaled or exceeded 230 lb. One pig from each pen was then randomly selected and slaughtered. The remaining two pigs were fed diets that were decreased from .90 and .70% to .75 and .55% dietary lysine, respectively. These pigs were then slaughtered when their mean weight reached or exceeded 280 lb.

[1]The authors wish to acknowledge Nutri-Quest and BioKyowa for partial financial and amino acid support for this project and Pig Improvement Co. Inc., Franklin, KY for partial financial support.

At 24 hr postmortem, carcass data were collected. During fabrication, the 10th rib loin eye cut surface was evaluated for quality characteristics. Visual color, marbling, and firmness were assessed using a scale of 1 to 5 with 1 = white, traces, or very soft and watery and 5 = dark red, abundant, or very firm and dry, respectively. At 15 min after ribbing, circular 5.5 cm diameter Whatman No. 2 filter papers were placed for approximately 1 second on posterior cut surfaces of loins laid horizontally on tables. The difference between dry and moist weights was recorded as the weight of moisture exudate. Hunter L*, a*, b* values were measured using a Minolta CR-200 Chromometer. Saturation index and hue angle were calculated using the equations of $(a^{*2} + b^{*2})^{1/2}$ and arc tangent (b*/a*), respectively. Hunter L*, a*, and b*, saturation index, and hue angle were used as objective measures of lightness, redness, yellowness, color vividness or intensity, and red to orange. Muscle pH was determined on approximately 2 g samples using a Fisher Accument model 620 pH meter. At approximately 28 hr postmortem, 3 in. of boneless loin eye muscle was frozen at –4°F for future analysis. One-in. chops were cut, weighed, and thawed at 35°F for 18 hr. Chops were then weighed and cooked to an internal temperature of 160°F, surfaces were blotted, and chops were reweighed. Six 1/2 in. cores were sheared through the center using an Universal Instron machine to determine Warner-Bratzler shear values or muscle tenderness.

Results and Discussion

For carcasses from pigs fed to 230 lb (Table 1), high-lean genotype loin eyes had (P<.05) less visual marbling, higher Hunter a* values (more red), higher Hunter b* values (more yellow), and higher saturation indices (more vivid or intense) than medium-lean genotype loin eyes. In a genotype × lysine interaction (P<.05), loin eyes from high-lean genotype pigs fed lower (.70%) lysine and medium-lean genotype fed higher lysine (.90%) had significantly (P<.05) higher pH's than loin eyes from medium-lean pigs fed higher lysine levels. However, all pH means were in the normal range of 5.4 to 5.5. In a genotype × sex interaction (P<.05), medium-lean barrows had (P<.05) loin eyes with greater hue angles (more orange on a red to orange scale) than loin eyes from high-lean gilts. Loin eyes from high-lean barrows and medium-lean gilts had intermediate hue angles. Loin eye chops from high-lean gilts had (P<.05) greater cooking losses, combined thaw and cooking losses, and Warner-Bratzler shear values (were tougher) than chops from high-lean barrows. Medium-lean gilts and barrows had loin chops with intermediate cooking losses, combined thaw and cooking losses, and Warner-Bratzler shear values.

For carcasses from pigs fed to 280 lb (Table 2), high-lean genotype loin eyes were visually more reddish pink in color and firmer, but had less marbling (P<.05). Also, high-lean genotype loin eyes had (P<.05) a higher pH, less moisture exudate, lower Hunter L* values (darker), and smaller hue angles (more red on a red to orange scale) than medium-lean genotype loin eyes. Barrow loin eyes had (P<.05) more marbling and less thaw loss than gilt loin eyes. In a genotype × sex interaction (P<.05), high-genotype barrow loin eyes had (P<.05) higher Warner-Bratzler shear values (were tougher) than high-lean gilt, medium-lean barrow, and medium-lean gilt loin eyes. For pigs fed to either 230 or 280 lb, high-lean genotype loin eyes had less visual marbling than medium-lean loin eyes.

At 230 lb, high-lean loin eyes, compared with medium-lean loin eyes, objectively had a more vivid or saturated color resulting from more red and more yellow measurements. This could be partially explained by less marbling and less dilution of lean color. Chops from high-lean gilts were mechanically tougher than chops from high-lean barrows and medium-lean barrows and gilts partially because of a higher cooking loss.

For pigs fed to 280 lb, medium-lean loin eyes were lighter both visually and objectively, were less firm, and had more moisture exudate thaw loss partially because of a lower pH and binding of water by protein. At 280 lb, barrow loin eyes had more marbling and less thaw loss than gilt loin eyes. However, high-lean barrow chops were tougher than high-lean gilt and medium-lean barrow and gilt chops.

Table 1. The Effects of Genotype, Sex, and Dietary Lysine on Carcass Quality Characteristics of Pigs Fed to 230 lb

	Genotype		Sex		Dietary lysine, %		
Item	High (H)	Medium (M)	Barrows (B)	Gilts (G)	.90	.70	CV
USDA grade	1.3[m]	1.7[n]	1.8[k]	1.2[l]	1.5	1.5	44.6
Percent muscle	52.6	52.5	50.9[k]	54.3[l]	52.5	52.7	4.4
Visual color[a]	2.9	2.7	2.8	2.8	2.8	2.8	18.4
Marbling[a]	2.2[m]	2.9[n]	2.7	2.4	2.4	2.8	28.2
Firmness[a]	3.5	3.6	3.7	3.4	3.5	3.6	31.0
Moisture exudate, mg[b]	152.6	129.3	125.3	156.6	142.5	139.4	58.5
Hunter L*[c]	53.1	53.9	54.0	53.0	53.4	53.6	7.6
Hunter a*[d]	10.7[k]	8.6[l]	9.3	10.1	9.4	9.9	18.0
Hunter b*[e]	7.7[m]	6.5[n]	7.0	7.2	7.0	7.2	24.9
Saturation index[f]	13.2[k]	10.8[l]	11.7	12.4	11.8	12.3	19.9
Hue angle[g]	35.2[o]	36.8[o]	36.9[o]	35.1[o]	36.5	35.6	8.4
pH at 24 hr	5.5[p]	5.4[p]	5.5	5.4	5.5[p]	5.4[p]	2.2
Thaw loss, %[h]	2.9	3.1	2.7	3.3	2.9	3.1	40.1
Cook loss, %[i]	24.5[q]	24.5[q]	23.5[q]	25.5[q]	24.8	24.2	19.3
Total loss, %[j]	26.7[r]	26.8[r]	25.6[r]	27.9[r]	27.0	26.5	17.5
Warner Bratzler Shear, lb	10.1[s]	8.8[s]	9.2[s]	9.7[s]	9.7	9.0	13.3

[a]Scores of 1 to 5: 2 = gray, slight, or soft and watery; 3 = light pink, small or intermediate; 4 = reddish pink, moderate or firm.
[b]Moisture absorbed when placing a Whatman No. 2 filter paper on the loin eye cut surface.
[c]Measure of dark to light: a larger L* value represents a lighter color.
[d]Measure of redness: a larger a* value represents a more red color.
[e]Measure of yellowness: a larger b* value represents a more yellow color.
[f]Measure of vividness or intensity of the color: a larger index represents a more vivid color.
[g]Measure of red to orange: a larger angle represents a more orange and less red color.
[h]100 × (frozen chop wt – thawed chop wt)/frozen chop wt.
[i]100 × (thawed chop wt – cooked chop wt)/thawed chop wt.
[j]100 × (thawed chop wt – cooked chop wt)/frozen chop wt.
[kl]Means within genotype, sex, or dietary lysine level with different superscripts differ (P<.01).
[mn]Means within genotype, sex, or dietary lysine level with different superscripts differ (P<.05).
[o]Genotype × sex interaction (P<.05) for Hue angle – MB (38.9) > HG (35.5), HB (35.0) and MG (34.8), P<.05.
[p]Genotype × lysine interaction (P<.05) for pH at 24 hr – H .70 (5.5) and M .90 (5.5) > M .70 (5.4), P<.05; H .90 (5.4) intermediate.
[q]Genotype × sex interaction for cook loss, % – HG (27.4) > HB (21.4), P<.05; MB (25.4) and MG (23.6) intermediate.
[r]Genotype × sex interaction for total loss, % – HG (29.5) > HB (23.9), P<.05; MB (27.3) and MG (26.4) intermediate.
[s]Genotype × sex interaction (P<.05) for Warner-Bratzler shear, lb – HG (10.6) > HB (9.5), MB (9.0), and MG (8.6), P<.05.

Table 2. The Effects of Genotype, Sex, and Dietary Lysine on Carcass Quality Characteristics of Pigs Fed to 280 lb

	Genotype		Sex		Dietary lysine, %		
Item	High (H)	Medium (M)	Barrows (B)	Gilts (G)	.90/.75	.70/.55	CV
USDA grade	2.0[m]	2.5[n]	2.5[k]	1.9[l]	2.3	2.1	26.8
Percent muscle	51.4	50.8	49.9[k]	52.3[l]	50.7	51.4	3.7
Visual color[a]	3.1[k]	2.7[l]	3.0	2.8	3.0	2.9	9.7
Marbling[a]	2.6[m]	2.9[n]	3.0[m]	2.6[n]	2.7	2.8	18.4
Firmness[a]	3.9[m]	3.5[n]	3.9	3.5	3.8	3.7	15.0
Moisture exudate, mg[b]	129.8[m]	161.0[n]	131.0	160.0	136.0	154.8	30.0
Hunter L*[c]	50.7[k]	54.0[l]	52.0	52.7	52.1	52.6	4.9
Hunter a*[d]	9.6	9.1	9.0	9.8	9.5	9.3	14.9
Hunter b*[e]	6.4	7.0	6.4	7.0	6.7	6.7	17.5
Saturation index[f]	11.6	11.5	11.0	12.1	11.7	11.5	15.0
Hue angle[g]	33.3[k]	37.1[l]	35.1	35.3	35.2	35.2	7.6
pH at 24 hr	5.5[m]	5.4[n]	5.5	5.5	5.4	5.5	1.9
Thaw loss[h]	2.3[k]	3.6[l]	2.6[k]	3.3[l]	2.7	3.1	24.8
Cook loss[i]	22.0	21.4	21.5	21.9	23.0	20.3	15.4
Total loss[j]	23.8	24.2	23.5	24.4	25.1	22.8	13.5
Warner Bratzler Shear, lb	10.3	8.8	9.9	9.2	9.7	9.5	13.5

[a]Scores of 1 to 5: 2 = gray, slight, or soft and watery; 3 = light pink, small or intermediate; 4 = reddish pink, moderate or firm.
[b]Moisture absorbed when placing a Whatman No. 2 filter paper on the loin eye cut surface.
[c]Measure of dark to light: a larger L* value represents a lighter color.
[d]Measure of redness: a larger a* value represents a more red color.
[e]Measure of yellowness: a larger b* value represents a more yellow color.
[f]Measure of vividness or intensity of the color: a larger index represents a more vivid color.
[g]Measure of red to orange: a larger angle represents a more orange and less red color.
[h]100 × (frozen chop wt – thawed chop wt)/frozen chop wt.
[i]100 × (thawed chop wt – cooked chop wt)/thawed chop wt.
[j]100 × (thawed chop wt – cooked chop wt)/frozen chop wt.
[kl]Means within genotype, sex, or dietary lysine level with different superscripts differ (P<.01).
[mn]Means within genotype, sex, or dietary lysine level with different superscripts differ (P<.05).
[o]Genotype × sex interaction (P<.05) for Warner Bratzler shear, lb – HB (11.0) > HG (9.5), MB (8.8), and MG (9.0), P<.05.

THE INFLUENCE OF GENOTYPE, SEX, AND DIETARY LYSINE ON SUBPRIMAL CUT DISTRIBUTION OF 230 AND 280 LB. FINISHING PIGS[1]

B. L. Dunn, J. A. Unruh, K. G. Friesen, J. L. Nelssen, R. D. Goodband, and M. D. Tokach

Summary

One hundred sixteen pigs were used to determine effects of the interrelationship among genotype, sex, and dietary lysine on subprimal cut distribution of pigs fed to 230 and 280 lb. In a 2 × 2 × 2 factorial arrangement, barrows and gilts, previously characterized as having either high or medium lean-gain potential, were fed one of two dietary lysine regimens. One pig per pen was slaughtered when the mean weight of pigs in a pen reached 230 lb and the remaining two pigs were fed until the mean weight reached 280 lb. When fed to either 230 or 280 lb, carcasses from high-lean genotype pigs or gilts had higher percentages of combined closely trimmed boneless ham, loin, and shoulder than medium-lean genotype or barrow carcasses, respectively. Dietary lysine level had minimal influences on subprimal cut distribution. The highest percentages of major lean subprimal cuts for pigs fed either to 230 or 280 lb were in high-lean genotype gilts.

(Key words: Pork, Lysine, Sex, Genotypes, Meat Yield.)

Introduction

Because of consumer demand, a major priority over the past 5 years in the swine industry has been the production of lean pork. Packers are driving the industry towards leaner, more efficient pigs with market premiums and giving discounts for fat, less efficient hogs. Research has indicated that lean gain can be influenced by genotype, gender, and dietary lysine. Improved genetic evaluation and selection have resulted in pigs with increased lean gain potential and feed efficiency but decreased backfat measurements.

By selecting for increased lean gain and using split sex feeding methods, the potential exists for increased dietary lysine to optimize lean growth and subprimal cutout. Thus, the objective of this experiment was to determine the interrelationship between genotype, sex, and dietary lysine and how these factors influence the distribution of subprimal cuts.

Procedures

Diets, growth performance, and carcass characteristics for the pigs used in this study are described in previous papers in this Report of Progress. One hundred sixteen pigs were used in a 2 × 2 × 2 factorial arrangement. Genetic comparisons were made between pigs previously characterized as having either high or medium lean-gain potential. Within genotype, barrows and gilts were fed separately two dietary lysine regimens in pens of three. Pigs were fed either a diet containing .90 or .70% dietary lysine until a mean weight of pigs in a pen equaled or exceeded 230 lb. One pig from each pen was then selected randomly and slaughtered. The remaining two pigs were fed diets that were decreased from .90 and .70% to .75 and

[1]The authors wish to acknowledge Nutri-Quest and BioKyowa for partial financial and amino acid support for this project and Pig Improvement Co. Inc., Franklin, KY for partial financial support.

.55% dietary lysine, respectively, and slaughtered when their mean weight reached 280 lb.

Twenty-four hours postmortem, carcass data were collected. Then carcasses were fabricated into closely trimmed, bone-in and boneless, subprimal cuts according to Institutional Meat Purchase Specifications (IMPS). All boneless cuts were trimmed to less than .25 in. of fat.

Results and Discussion

USDA grade, percent muscle, and subprimal cut yield percentages for pigs fed to 230 lb are given in Table 1. High-lean genotype pigs had (P<.05) carcasses with more desirable USDA grades; heavier chilled side wt; a higher percent of 402C boneless ham, whole loin, 410 loin, 413 boneless loin, 415 tenderloin, and combined boneless ham, loin, and shoulder; and a lower percent of 420 front foot than medium-lean genotypes. Gilts had more desirable USDA grades (P<.05); higher percent muscle; and a higher percent of whole ham, 402 ham, 402C boneless ham, 410 loin, 413 boneless loin, 415 tenderloin, and combined boneless ham, loin, and shoulder than barrows. Dietary lysine did not influence (P<.05) USDA grade, percent muscle, or subprimal cut percentages.

For pigs fed to 280 lb (Table 2), high-lean gain pigs produced carcasses (P<.05) with more desirable USDA grades; heavier chilled side weights; a higher percent of whole shoulder, 404 shoulder, 405A boneless picnic shoulder, 406 Boston butt, 406A Boston butt, whole loin, 410 loin, 413 boneless loin, 415 tenderloin, and combined boneless ham, loin, and shoulder; and a lower percent of whole belly, hind foot, and 420 front foot than medium-lean genotype pigs. High-lean genotype carcasses also tended to have a higher percent of 402C boneless ham (P=.06) and a lower percent of 416 spareribs (P=.08) and 408 belly (P=.09). Gilts at 280 lb produced carcasses with more desirable USDA grades; higher percent muscle; and a higher percent of whole ham, 402 ham, 402C boneless ham, 405 picnic shoulder, 410 loin, 415 tenderloin, and combined boneless ham, loin, and shoulder than carcasses from barrows. Gilt carcasses tended also to have a higher percent of 405A boneless picnic shoulder (P=.06) and 413 boneless loin (P=.09).

Lower dietary lysine carcasses had (P<.05) a higher percent 405A boneless picnic shoulder than higher dietary lysine carcasses. Sex × dietary lysine interactions (P<.05) occurred for last rib backfat and percent 404 shoulder, 406 Boston butt, 406A boneless Boston butt, and 416 spareribs. The higher lysine barrow carcasses had more backfat (P<.05) than lower lysine barrow, higher lysine gilt, or lower lysine gilt carcasses. Higher lysine gilt carcasses had (P<.05) a higher percent of 404 shoulder and 406A boneless Boston butt than higher lysine barrow carcasses and a higher percent of 406 Boston butt than lower lysine gilt carcasses and higher lysine barrow carcasses.

Even though last rib backfat, 10th rib fat depth, and calculated percent muscle were similar for high lean-gain and medium lean-gain carcasses from pigs fed to 230 and 280 lb, high lean-gain carcasses had 3.0 and 2.7% higher yields of boneless, closely-trimmed ham, loin, and shoulder than medium lean-gain carcasses, respectively.

Compared with barrows, gilt carcasses had less carcass fat measured as last rib backfat and 10th rib fat depth and larger loin eye areas, resulting in more desirable USDA grades and 3.4 and 2.4% higher calculated percent muscle for pigs fed to 230 and 280 lb, respectively. Furthermore, gilt carcasses had 2.4 and 2.1% more combined boneless ham, loin, and shoulder for pigs fed to 230 and 280 lb, respectively, than barrow carcasses. Dietary lysine levels had minimal effects on subprimal cut distribution. The highest yields of major lean subprimal cuts for pigs fed to 230 or 280 lb were in high-lean genotype gilts. Therefore, the packer's

desire for heavier weight, high cutability hogs can be achieved by feeding high-lean genotype gilts to 280 lb.

Table 1. The Effects of Genotype, Sex, and Dietary Lysine on Subprimal Cut Distribution for Pigs Fed to 230 lb[a]

	Genotype		Sex		Dietary lysine, %		
Carcass traits	High (H)	Medium (M)	Barrow (B)	Gilt (G)	.90	.70	CV
Last rib backfat, in	.90	.94	1.00[f]	.84[g]	.94	.89	15.2
Muscle score[b]	2.3[h]	2.1[i]	2.2	2.2	2.2	2.1	17.7
USDA grade[c]	1.3[h]	1.7[i]	1.8[f]	1.2[g]	1.5	1.5	44.6
10th rib fat depth, in	1.10	1.08	1.24[f]	.94[g]	1.11	1.07	19.4
Loin eye area, in^2	5.2	4.9	4.7[f]	5.4[g]	5.1	5.0	10.7
Percent muscle[d]	52.6	52.5	50.9[f]	54.3[g]	52.5	52.7	4.4
Chilled side wt, lb	85.8[f]	82.7[g]	84.1	84.4	85.2	83.3	4.0
Ham (whole), %	23.7	23.7	23.4[h]	24.1[i]	23.9	23.6	4.4
402 Ham, %	22.0	21.8	21.4[h]	22.4[i]	22.1	21.7	5.4
402C Ham, boneless, %	17.6[h]	16.4[j]	16.4[f]	17.6[g]	17.2	16.9	8.4
Shoulder (whole), %	21.0	21.5	21.2	21.3	21.0	21.5	5.7
421 Neck bone, %	1.6[j]	1.5[j]	1.5[j]	1.6[j]	1.6	1.6	17.3
404 Shoulder, %	17.6	17.8	17.5	17.8	17.5	17.8	5.2
405 Picnic shoulder, %	9.2	9.5	9.4	9.3	9.3	9.4	6.6
405A Picnic shoulder, boneless, %	6.9	6.8	6.8	6.8	6.8	6.9	8.5
406 Boston butt, %	8.4	8.0	8.2	8.2	8.1	8.3	10.7
406A Boston butt, boneless, %	7.7	7.4	7.4	7.7	7.5	7.6	10.0
Loin (whole), %	29.2[f]	27.8[g]	28.6	28.4	28.5	28.5	4.6
410 Loin, %	22.1[f]	20.2[g]	20.3[f]	22.0[g]	21.1	21.2	4.6
413 Loin, boneless, %	13.9[f]	12.6[g]	12.9[h]	13.6[i]	13.3	13.2	7.4
415 Tenderloin, %	1.3[f]	1.1[g]	1.1[f]	1.2[g]	1.2	1.1	13.0
416 Spareribs, %	3.7	3.6	3.6	3.7	3.6	3.8	9.2
Belly (whole), %	15.6	16.0	16.0	15.6	15.8	15.8	8.0
408 Belly, %	13.4	13.8	13.6	13.6	13.6	13.6	7.6
Jowl, %	3.0	3.0	3.2	2.8	3.0	3.0	20.5
Hind foot, %	1.8[k]	2.0[k]	1.9[k]	1.9[k]	1.9	1.9	11.6
420 Front foot, %	1.2[h]	1.3[i]	1.2	1.2	1.2	1.3	9.4
Boneless ham, loin and shoulder, %[e]	47.3[f]	44.3[g]	44.6[h]	47.0[i]	45.9	45.7	6.6

[a]Percentage of chilled side wt.
[b]Muscle score: 1=thin, 2=average, and 3=thick.
[c]USDA grade=(4 × last rib backfat, in) – (1 × muscle score).
[d]Percent muscle=100 × [10.5 + (0.5 × hot carcass weight, lb) + (2.0 × loin eye area, in^2) – (14.9 × 10th rib fat depth, in)]/ hot carcass weight, lb
[e]100 × (402C ham + 405A picnic shoulder + 406A Boston butt + 413 Loin + Tenderloin)/chilled side wt.
[fg]Means within genotype, sex, or dietary lysine level differ (P<.01).
[hi]Means within genotype, sex, or dietary lysine level differ (P<.05).
[j]Genotype × sex interaction (P<.05) for 421 neck bones, % - MG (1.7) > MB (1.4), P<.05; HB (1.6) and HG (1.5) intermediate.
[k]Genotype × sex interaction (P<.05) for hind foot, % - MG (2.1) > HB (1.9) and HG (1.7), P<.05; MB (1.9) intermediate.

Table 2. The Effects of Genotype, Sex, and Dietary Lysine on Subprimal Cut Distribution for Pigs Fed to 280 lb[a]

	Genotype		Sex		Dietary lysine, %		
Carcass traits	High (H)	Medium (M)	Barrow (B)	Gilt (G)	.90/75	.70/.55	CV
Last rib backfat, in	1.06	1.13	1.16[j]	1.03[j]	1.12[j]	1.07[j]	11.5
Muscle score	2.3[f]	2.0[g]	2.1	2.3	2.2	2.2	13.9
USDA	2.0[h]	2.5[i]	2.5[f]	1.9[g]	2.3	2.1	24.2
10th rib fat depth, in	1.32	1.34	1.46[f]	1.20[g]	1.37	1.29	16.5
Loin eye area, in^2	6.1[f]	5.5[g]	5.5[f]	6.1[g]	5.8	5.8	8.1
Percent muscle	51.4	50.8	49.9[f]	52.3[g]	50.7	51.4	3.7
Chilled side wt, lb	106.3[h]	103.8[i]	105.2	104.9	105.7	104.4	2.6
Ham (whole), %	23.5	23.6	23.3[h]	23.8[i]	23.4	23.6	3.0
402 Ham, %	21.7	21.6	21.2[f]	22.1[g]	21.4	21.9	3.9
402C Ham, boneless, %	16.7	16.0	15.9[f]	16.8[g]	16.2	16.5	5.7
Shoulder (whole), %	21.6[h]	21.0[i]	21.2	21.4	21.3	21.3	3.2
421 Neck bone, %	1.5	1.5	1.5	1.5	1.5	1.5	.7
404 Shoulder, %	18.1[h]	17.5[i]	17.6[k]	18.0[k]	17.7[k]	17.8[k]	3.9
405 Picnic shoulder, %	9.5	9.3	9.3[h]	9.6[i]	9.3	9.5	4.1
405A Picnic shoulder, boneless, %	7.1[h]	6.8[i]	6.8	7.1	6.8[h]	7.1[i]	5.3
406 Boston butt, %	7.9[f]	7.5[g]	7.6[l]	7.8[l]	7.7[l]	7.8[l]	5.3
406A Boston butt, boneless, %	7.5[f]	7.1[g]	7.2[m]	7.3[m]	7.2[m]	7.3[m]	5.5
Loin (whole), %	28.8[h]	28.0[i]	28.7	28.1	28.5	28.3	4.2
410 Loin, %	20.7[f]	19.4[g]	19.5[h]	20.6[i]	19.9	20.2	6.4
413 Loin, boneless, %	12.7[f]	11.5[g]	11.8	12.4	12.0	12.2	7.6
415 Tenderloin, %	1.1[f]	1.0[g]	1.0[f]	1.1[g]	1.1	1.1	8.3
416 Spareribs, %	3.7	3.9	3.8[n]	3.8[n]	3.7[n]	3.9[n]	7.4
Belly (whole), %	16.3[h]	17.0[i]	16.7	16.6	16.6	16.7	6.1
408 Belly, %	14.2	14.7	14.6	14.4	14.4	14.5	5.3
Jowl, %	2.7	2.7	2.6	2.7	2.7	2.7	14.8
Hind foot, %	1.7[g]	1.9[h]	1.8	1.8	1.8	1.8	7.2
420 Front foot, %	1.1[g]	1.2[h]	1.2	1.1	1.2	1.2	5.9
Boneless ham, loin and shoulder, %[e]	45.1[g]	42.4[h]	42.7[g]	44.8[h]	43.3	44.2	5.0

[abcde]See Table 1 for explanation of superscripts.

[fg]Means within genotype, sex, or dietary lysine level differ (P<.01).

[hi]Means within genotype, sex, or dietary lysine level differ (P<.05).

[j]Sex × dietary lysine interaction (P<.05) for last rib backfat, in - B.90 (1.2) > B.70 (1.1), G.90 (1.0) and G.70 (1.1), P<.05.

[k]Sex × dietary lysine interaction (P<.05) for 404 shoulder, % - G.90 (18.2) > B.90 (17.3), P<.05; B.70 (17.9) and G.70 (17.8) intermediate.

[l]Sex × dietary lysine interaction (P<.05) for 406 Boston butt, % - G.90 (8.5) > G.7 (8.0) and B.90 (7.8), P<.05; B.70 (8.2) intermediate.

[m]Sex × dietary lysine interaction (P<.05) for 406A boneless Boston butt, % - G.90 (7.9) > B.90 (7.4), P<.05; B.70 (7.7) and G.70 (7.5) intermediate.

[n]Sex × dietary lysine interaction (P<.05) for 416 spareribs - B.70 (3.9) > B.90 (3.6), P<.05; G.90 (3.9) and G.70 (3.8) intermediate.

KSU LEAN VALUE MARKETING PROGRAM[1]

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

Summary

The KSU Lean Value Marketing Program was developed to assist producers in understanding the quality of their market hogs by marketing on a wholesale cut basis. The program also allowed analysis of the current marketing practices of the producer in relation to sort loss. Producers lost an average of $1.08 (0 to $4.95) per head from sort loss by not marketing pigs in the proper weight range. Wholesale cuts for the 34 farms indicated that percent loins, hams, and spareribs represented the greatest portion of carcass value, whereas percent pork fat and bellies most accurately predicted the farms with low value carcasses. Backfat measurements and wholesale cut marketing indicated a large variation in genetic quality of pigs on swine farms in Kansas. The KSU Lean Value Program provides producers with important insights concerning their marketing practices and the genetic quality of pigs that they are currently producing.

(Key Words: Marketing, G-F.)

Introduction

Consumer demand for lean, trimmed pork has increased during the last 10 years. Packers are realizing the extra value of lean hogs that eliminate the need for excess fat trimming. At the same time, the swine producer understands that producing hogs with excess fat is inefficient and expensive.

These facts have led to changes in terminology of performance and profitability. New terminology includes lean gain, sort loss, carcass lean, carcass merit added value, sort discount, and merit yield.

Producers must also ask the question: "Do I have the genetic base to compete in a lean value system in the future?" To assist in answering this question, the KSU Lean Value Marketing program was developed. The objective of this program was to help Kansas producers understand the quality of the pigs on their farms when marketed on a wholesale cut basis. Carcass data for this program were supplied by Reeves Packing Company, Ada, Oklahoma.

Procedures

To obtain market weight gilts for this survey, four major areas of swine production in the state of Kansas were targeted: 1) Washington County, 2) Nemaha County, 3) Douglas County, and 4) Butler County. After scheduling a slaughter date approximately 3 weeks in advance with Reeves Packing Company, a letter inviting producers to participate in the KSU Lean Value Marketing program

[1]Appreciation is expressed to Rick Fahle, Plant Manager, and personnel at Reeves Packing Co., Ada, OK, for assistance in conducting this project. We also thank David Key, Joe Pistora, Kevin Steward, Paul Sterbenz and others for assisting with this project and the producers who furnished gilts for this study.

[2]Extension Agricultural Agent, Douglas County.

was sent to approximately 35 producers in each of the four areas mentioned above.

The following criteria were used as guidelines for selecting producers: 1) they had to be able to consign 25 gilts on a first come, first served basis; 2) they had to know the genetic background of the gilts; and 3) they had to be able to pay a prorated share of the freight from the farm to Reeves Packing Company in Ada, Oklahoma. Producers were asked to supply gilts weighing between 230 and 250 lb, although the acceptable live weight range at Reeves Packing was 220 to 260 lb.

Prior to loading the gilts on the trucks, each producer group was tagged with a different color ear tag. Upon arriving at Reeves Packing Company, the gilts were grouped by tag color, weighed, and penned. All gilts arrived between 2:30 am and 5:30 am on the day of slaughter.

Reeves Packing Company is a small, one line operation with a capacity of from 250 to 300 hogs per day. The slaughter line starts at about 8:00 am and is done by approximately 2:30 pm, with a 1 hour shutdown at noon.

After being scalded and split, carcasses were weighed individually as they left the kill floor headed for the cooler. Once the carcasses were in the cooler, KSU personnel measured backfat at the first rib, tenth rib, last rib, and the last lumbar vertebrae. Backfat measurements were taken at the midline on hot carcasses. Thus, they are slightly higher than would be measured on cold carcasses or off the midline. For the first two truck loads, a random sample of carcass lengths were taken. With additional help available, all carcass lengths were recorded for the last two truckloads. In addition, a partial herd health check was available for the last three truckloads of gilts.

The carcasses were spray-chilled overnight and cut into wholesale cuts the following morning. All individual wholesale carcass cuts of a producer were weighed and recorded as total weight to calculate the percent of the carcass.

The different wholesale cuts that were weighed included: hams, loins, butts, picnics, spareribs, bellies, trim 80%, trim 50%, jowls, pork fat, neckbones, feet, scrap/bones and cooler shrink/cutting loss. Trim 80% includes all trim that can be tested by the USDA to be 72% chemically lean. Trim 50% includes all trim that can be tested by the USDA to be 42% chemically lean. Pork fat is fat with no lean included. Cooler shrink/cutting loss is the carcass weight, minus total lb weighed during cutout. Loins were the only closely trimmed wholesale cut. The weight of the other main cuts (ham, butts, picnics, spareribs, and bellies) included fat and lean. The plant manager, Rick Fahle, weighed all of the wholesale cuts for the test groups involved in this study.

The carcass value is based on the weekly USDA Blue Sheet for individual prices of the various cuts. Because the gilts were marketed in June, July, and September of 1992, June 1992 prices were used to standardize all loads to compare over time. Grade was calculated as the premium for the actual value of the wholesale cuts above a plant standard. The plant standard was calculated as the average of the value of a grade 1 and 2 market hogs. The sort loss discount is the value lost because not all carcass weights were in the standard carcass weight range of 160 to 189 lb. As an example, if all carcasses weighed between 160 and 189 lb, the sort loss discount would be zero. The yield was compared against the plant standard for Reeves Packing Company. The difference between the standard (73%) and actual dressing percent determined the yield premium.

Results and Discussion

Sort Loss. Sort loss is the penalty for carcasses that are outside of the optimum carcass weight range when selling hogs on a carcass merit program. Each packing company has its own specific carcass weight range. The amount of the loss is based solely on the weight of the carcass. Yield, live weight, grade, backfat, or lean meat percentage has no bearing on the amount deducted for sort loss. This is based entirely on carcass weight.

The ideal carcass weight range at Reeves Packing was 160 to 180 lb. This translates to approximately 215 to 255 lb on a live weight basis. As explained above, all producers were asked to submit gilts weighing 230 to 250 lb. Sort loss for the farms in this program ranged from $0.00 to $4.95 per head. Figure 1 shows that five of the 34 groups had no sort loss deducted, whereas one group had a deduction of $4.95 per head. The average sort loss deduction for all groups was $1.08.

The sort loss discount is much greater for lightweight carcasses as compared to overweight carcasses. It is much better to sell hogs that are too heavy than too light. The reason is that it takes just as much labor and time to dress a lightweight pig as it does a heavier pig. In other words, the plant is more efficient with heavy hogs than it is with lightweight hogs.

How can one minimize the sort loss discount? As a producer, you need to know what your market hogs weigh and what the ideal carcass weight is for your packing company. By weighing your pigs individually, sort loss can be greatly reduced. As an example, if you run a 100 sow operation and sell 1,800 market hogs per year and have an average sort loss deduction of $1.08 per head, $1,944 in potential income is lost. For the producer with the $4.95 per head sort loss deduction, the potential income loss on 1800 head is $8,910. An average of 1 hour of extra labor per week to weigh pigs and reduce sort loss to zero would result in a return of $171.34 per hour ($4.95 deduction per head). At an average of $1.08 deduction per head, the return per hour is $37.38.

Sort loss has an enormous impact on the profitability from carcass merit buying programs. In order to receive the least sort loss deductions, hogs must be weighed individually.

Yield. Yield is a term used to explain the pounds of carcass left after the slaughtering process compared to live weight delivered to the packer. Yield is simply hot carcass weight divided by live weight. Another term for yield is dressing percent. The largest components of the difference in yields of hogs from different producers are gut fill and trim loss.

The yields in this study ranged from a low of 73.86% to a high of 76.29%. The average yield was 74.97%. Generally, leaner pigs have slightly lower yields than pigs carrying extra fat. This inverse relationship between yield and percent lean results in producers with fatter pigs receiving a yield premium. Many packer buying programs include a yield premium or discount. The optimal situation would be to buy pigs on a carcass weight basis. This would eliminate the premium or discount for gut fill. However, producers don't understand carcass prices as well as live prices. Thus, packers use yield premiums and discounts to back-calculate a carcass price to the live basis.

Grade. Grade premium is the extra value a producer receives for a superior lean hog as compared to a carcass with average leanness (plant standard). The premium is determined by subtracting the carcass merit base value from the actual carcass value. Reeves Packing determines carcass premium by weighing wholesale cuts and comparing the actual dollar value of these cuts to a standard USDA value. All carcasses in this survey were standardized to a 240 lb pig with a yield of 75%.

Figure 3 shows the range of grade values on a per head basis. The average grade value per head is $3.39. This added value is the reward for a producer raising a superior product. As an example, the 34 producers in this program represent approximately 135,000 hogs marketed per year. The $3.39 per head grade premium results in a total income of $459,000 for these producers.

Backfat and Wholesale Cuts. The actual backfat and carcass values for the 34 farms are shown in Table 1. Genotypes listed in the table are simply for information and do not imply an endorsement or ranking of genetics. The program was not designed to compare genotypes. Herds in the program were ranked by carcass value only, with no regard given to average daily gain, feed efficiency, sow productivity, or disease status.

Backfat measured at the tenth rib varied from .92 to 1.43 in. in the gilts in this study. As evidenced by the comparison between carcass value and backfat, that was not the only factor influencing carcass value. For example, farms 1, 5, and 9 had the same tenth rib backfat of .92 in. However, they ranked 1, 5, and 9 in actual carcass value. Therefore, carcass programs based entirely on backfat measurement do not accurately reward lean, heavy muscled pigs.

Standard deviation (SD) for the backfat for each farm indicates the variation in backfat measurements within the group of gilts from a particular farm. A lower SD indicates a more uniform load of gilts. For each producer, 95% of their gilts will have backfat measurements within two SD of the mean. For example, farm 20 had a standard deviation of .08, indicating that 95% of the gilts from this farm should have tenth rib backfat measurements between .93 and 1.25 in. ($1.08 \pm (2 \times .08)$). Conversely, the backfat range for farm 21 would be .67 to 1.75 in. ($1.21 \pm (2 \times .27)$). Smaller standard deviations are desirable, because they indicate a more uniform group of gilts. Uniformity is very important in determining marketing strategies.

The carcass values for the 34 farms indicates a difference of $6.16 between the farms with the highest and lowest carcass values. For a producer with 100 sows that markets 2,000 market hogs per year, this represents a difference in income of $12,320.

The ranges in the percents and dollar values of the wholesale cuts are shown in Table 2 and 3, respectively. Also depicted are the values for the farms with the highest and lowest carcass values. Hams and loins represent slightly more than 40% of the carcass weight. However, because they are the high priced cuts, they represent greater than 60% of the value of the carcass. Conversely, bellies represent approximately 14% of carcass weight, but only 7% of the carcass value.

The rankings of the best and worst loads demonstrate that the hams, loins, and spareribs are the most important cuts in determining improved carcass value on a wholesale cut basis. Decreased carcass value is represented by high levels of pork fat and bellies.

Marketing pigs on a wholesale cut basis provided the producers in this program with insight concerning their marketing practices and the genetic quality of the pigs that they are currently producing.

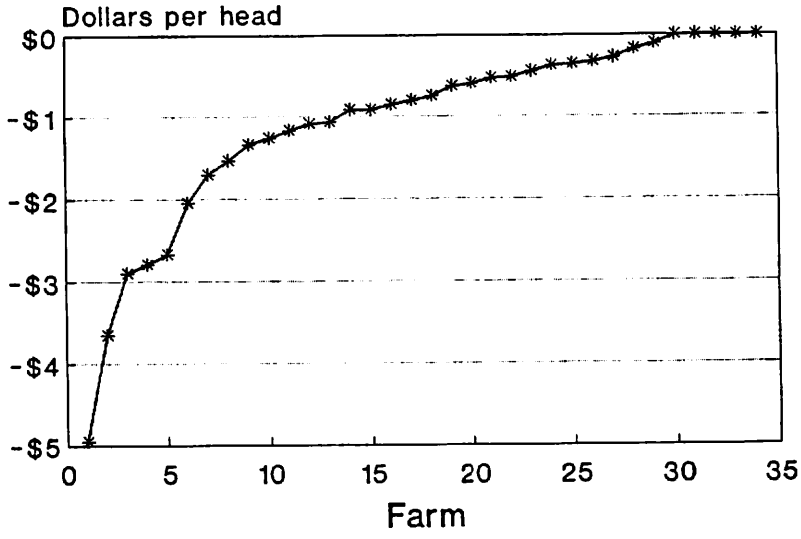

Figure 1. Sort Loss for Kansas Farms

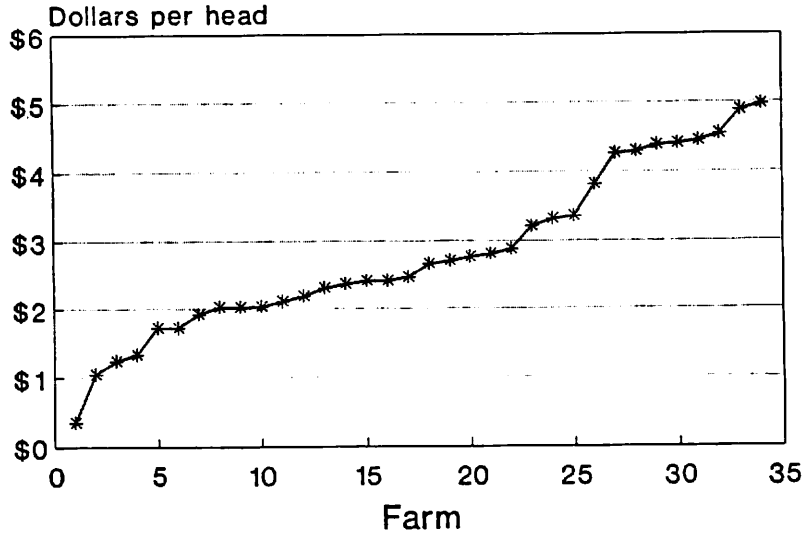

Figure 2. Yield Advantage for Kansas Farms

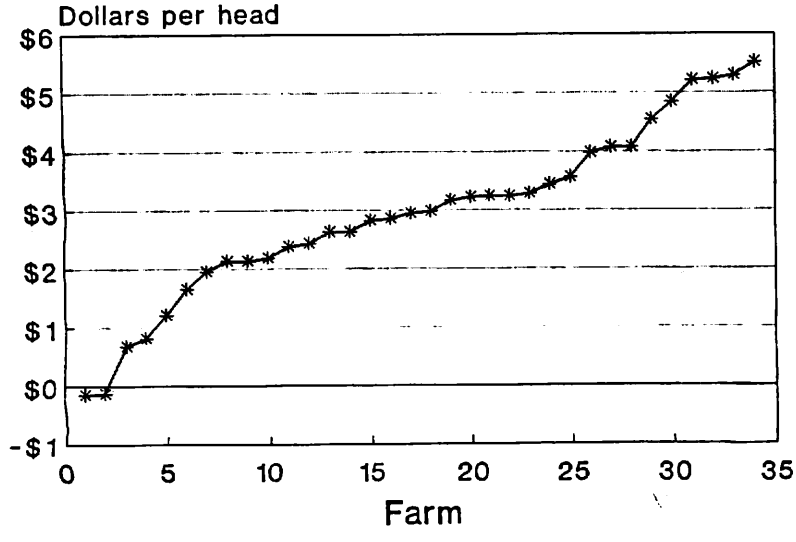

Figure 3. Grade Advantage for Kansas Farms

Table 1. Individual Farm Results from KSU Lean Value Marketing Program

Farm	Carcass Value, $[a]	10th Rib Backfat,in	SD[b]	Average Backfat, in.[c]	Ham Value, $	Loin Value, $	Herd Genetics[d]
1	128.51	.92	.14	1.12	27.98	54.37	PIC
2	128.15	.98	.22	1.12	29.20	52.16	PIC
3	128.15	1.09	.20	1.25	28.30	53.31	TERM
4	128.02	1.05	.12	1.29	27.97	54.60	TERM
5	127.86	.92	.17	1.13	28.72	53.48	PIC
6	127.80	.96	.13	1.18	27.93	54.52	TERM
7	126.80	1.03	.15	1.24	26.81	54.00	TERM
8	126.78	1.09	.18	1.28	28.07	53.73	TERM
9	126.64	.92	.18	1.15	28.44	52.56	PIC
10	126.61	1.18	.17	1.31	27.12	53.83	DK
11	126.43	1.08	.15	1.24	27.35	53.78	ROTA
12	126.34	1.23	.17	1.37	27.05	54.25	TERM
13	126.29	1.17	.17	1.36	27.63	53.26	PIC
14	126.27	1.04	.20	1.20	28.90	51.82	TERM
15	126.13	1.10	.13	1.29	27.70	52.21	LIESKE
16	126.06	1.12	.13	1.31	27.56	53.23	FH
17	125.77	1.08	.13	1.22	27.96	52.69	TERM
18	125.76	1.18	.17	1.33	27.77	51.87	DK
19	125.69	1.01	.15	1.21	28.34	51.32	ROTA
20	125.69	1.09	.08	1.32	27.18	52.61	TERM
21	125.48	1.21	.27	1.38	27.51	51.20	ROTA
22	125.33	1.18	.11	1.48	27.35	52.01	TERM
23	125.33	1.18	.18	1.36	28.36	50.95	TERM
24	125.26	1.04	.17	1.29	27.46	52.56	LIESKE
25	125.07	1.18	.10	1.32	27.35	52.64	TERM
26	125.07	1.23	.16	1.44	27.38	51.44	FH
27	124.69	1.15	.16	1.33	27.16	50.85	FH
28	124.53	1.08	.11	1.34	27.76	50.75	FH
29	124.26	1.18	.19	1.42	27.17	51.49	ROTA
30	124.10	1.12	.17	1.28	28.21	49.78	TERM
31	123.68	1.14	.20	1.33	27.87	49.90	ROTA
32	122.39	1.27	.15	1.47	27.03	50.28	FH
33	122.46	1.21	.14	1.39	27.85	48.74	ROTA
34	122.35	1.43	.17	1.53	26.55	50.50	ROTA
Averages:	125.79	1.10	.16	1.30	27.74	52.26	

[a]Carcass value is standardized to a 240 lb hog with a 75% yield. Wholesale cut values were determined by multiplying cut weights by the USDA Blue Sheet standard value for each cut for June 22, 1992.
[b]The standard deviation shows the amount of variance in 10th rib backfat within a producer group.
[c]Average of measurements at first rib, last rib and last lumbar vertebrae. Measurements were taken at the midline on hot carcasses.
[d]Genotype is listed as the sire of the gilts. Groups with sires originating from more than one source are listed as terminal (TERM) or rotational (ROTA) breeding systems. Breeding stock companies listed are Dekalb (DK), Farmers Hybrid (FH), Lieske (LIESKE), or Pig Improvement Company (PIC).

Table 2. Range of Wholesale Cuts from Gilts on Kansas Swine Farms

Wholesale Cut, %	Range			Best Load[a]	Worst Load
	Highest	Average	Lowest		
Ham	23.34	22.17	21.22	22.37 (10)[b]	21.22 (34)
Loin	21.98	21.04	19.62	21.89 (3)	20.33 (30)
Butt	7.81	7.34	6.79	7.49 (8)	7.43 (12)
Picnic	9.05	8.55	7.89	8.53 (20)	8.60 (16)
4 Primal cuts	62.18	59.10	55.52	60.28 (8)	57.58 (29)
Spareribs	4.86	4.47	3.90	4.73 (2)	3.90 (34)
Bellies	15.04	13.84	12.86	13.24 (29)	15.04 (1)
Trim 80%[c]	2.42	1.63	0.96	1.52 (25)	1.00 (32)
Trim 50%[d]	4.83	4.32	3.56	4.27 (18)	4.83 (1)
Jowls	2.27	1.90	1.24	2.07 (13)	2.01 (15)
Pork fat	8.81	7.43	6.27	6.95 (28)	8.81 (1)
Neckbones	1.61	1.46	1.34	1.49 (14)	1.42 (24)
Feet	1.61	1.27	0.97	1.32 (10)	1.08 (31)
Scrap/bones	4.74	4.22	3.76	4.01 (25)	4.07 (22)

[a]Loads were ranked by grade premium per hundred weight.
[b]Rank of the best and worst load for each wholesale cut is listed in parenthesis.
[c]All trim that can be tested by the USDA to be 72% chemically lean.
[d]All trim that can be tested by the USDA to be 42% chemically lean.

Table 3. Range of the Value of Wholesale Cuts from Gilts on Kansas Farms[a]

Wholesale Cut Value, $	Range			Best Load[b]	Worst Load
	Highest	Average	Lowest		
Ham	29.20	27.74	26.55	27.98 (10)[c]	26.55 (34)
Loin	54.60	52.26	48.74	54.37 (3)	50.50 (30)
Butt	14.90	14.01	12.96	14.29 (8)	14.18 (12)
Picnic	6.52	6.16	5.68	6.14 (20)	6.19 (16)
4 Primal cuts	103.18	100.16	95.95	102.79 (3)	97.41 (32)
Spareribs	11.37	10.46	9.13	11.07 (2)	9.13 (34)
Bellies	9.20	8.47	7.87	8.10 (29)	9.20 (1)
Trim 80%[d]	2.49	1.68	.99	1.57 (25)	1.03 (32)
Trim 50%[e]	2.17	1.94	1.60	1.92 (18)	2.17 (1)
Jowls	1.02	.86	.56	.93 (13)	.90 (15)
Pork fat	2.02	1.70	1.44	1.60 (28)	2.02 (1)
Neckbones	.32	.29	.27	.30 (5)	.28 (23)
Feet	.29	.23	.17	.24 (6)	.19 (31)

[a]Gilts were standardized to a common carcass weight of 180 lb (240 lb pig × 75% dressing percent).
[b]Loads were ranked by grade premium per hundredweight.
[c]Rank of the best and worst load of each wholesale cut is listed in parenthesis.
[d]All trim that can be tested by the USDA to be 72% chemically lean.
[e]All trim that can be tested by the USDA to be 42% chemically lean.

THE EFFECT OF L-CARNITINE ADDITIONS ON PERFORMANCE AND CARCASS CHARACTERISTICS OF GROWING-FINISHING SWINE[1]

K. Q. Owen, T. L. Weeden, J. L. Nelssen, and R. D. Goodband

Summary

An experiment was conducted to evaluate the efficacy of dietary carnitine on growth performance and carcass characteristics of growing-finishing swine. The trial was designed to investigate the response of pigs fed carnitine from weaning to market vs control pigs receiving no carnitine. In addition, the performance of these pigs was compared to that of pigs fed carnitine only during the starter or finishing phases. The trial was broken down into the following four phases: 1) phase I (0 to 14 d post weaning) 2) phase II (14 to 35 d post weaning) 3) grower (d 35 to 135 lb), and 4) finisher (135 to 230 lb). One hundred and twenty-eight pigs averaging 11.40 lb were used in the first two phases to investigate the effects of added carnitine on the performance of the early weaned pig. This also assisted in finding the proper carnitine administration period to elicit optimum growth performance and carcass characteristics in growing-finishing pigs. During phases I and II, one half of the pigs received a high nutrient density diet (HNDD) containing 1000 and 500 ppm, respectively, of carnitine; the other half received a HNDD with no added carnitine. These HNDD were formulated to contain 1.45% and 1.25% lysine, respectively. Pigs were allotted to pens on the basis of weight and sex, with each pen being randomly assigned to treatment. There was a total of 32 pens each containing four barrows or four gilts per pen. During phase I, pigs consuming the diet with carnitine were more efficient and had slightly higher daily gains. Nevertheless, during phase II, pigs receiving no carnitine had higher daily gains. Over the first 35 d of the trial, pigs offered no carnitine had higher daily gains and daily feed consumptions but were slightly less efficient. After the first two phases, pigs were reallotted within treatments on the basis of weight resulting in one of the following carnitine treatments: 1) feeding carnitine from weaning to market (15 to 230 lbs); (C/C) 2) carnitine during phases I and II only (C/N), 3) carnitine during growing-finishing only (N/C), and 4) no added carnitine (N/N). A total of 95 pigs (three pigs/pen) were used to provide eight replicates/treatment (four replicates/sex). Grower diets contained .85% lysine, and as pigs approached 135 lb, the lysine content was reduced to .75%. Carnitine was supplemented in the growing-finishing diets (N/C and C/C) at 25 ppm. During the growing-finishing phase, there were no difference in performance among treatments. However, a significant increase occurred in longissimus muscle area of pigs receiving carnitine only during the growing-finishing phase as compared to pigs fed no additions of carnitine throughout the trial. This suggests that carnitine supplementation during the growing-finishing phase increases loineye area, but has no effect on growth performance.

(Key Words: L-Carnitine, Growth, Carcass, Starter , G-F.)

[1]Appreciation is expressed to Lonza, Inc., Fairlawn, NJ for partial financial support.

Introduction

Resent research at the University of Georgia has shown that supplementing finishing diets with L-carnitine results in a small reduction in backfat thickness. A similar effect was observed at the Coastal Plains Research Center; however, these results were based on ultrasonic readings with no actual carcass measurements recorded. Resent research at KSU has shown that feeding high levels of carnitine in phase I nursery diets reduced fat accretion through the nursery phase. Limited research has been conducted addressing the effect L-carnitine elicits on carcass composition; however, no data have been collected to determine the subsequent effects of carnitine on performance and carcass characteristics. Therefore, this research was conducted to determine the appropriate dietary carnitine administration period to elicit optimum response of growth performance and carcass composition characteristics of growing-finishing swine.

Procedures

One hundred and twenty eight crossbred pigs, weaned at 21 d of age, and averaging 11.40 lb, were used in a 35 d growth trial. Pigs were allotted to two dietary treatments based upon weight, sex, and ancestory. One-half of the pigs received phase I (d 0-14 postweaning) diets containing 1000 ppm L-carnitine, whereas the other half received no added carnitine. The carnitine level in phase II (d 14 to 35 postweaning) diets was reduced to 500 ppm. There were four pigs per pen with 16 replicate pens per dietary treatment. Pigs were housed in an environmentally controlled nursery in 4 5 ft pens with woven wire flooring. Feed and water were offered on an ad libitum basis.

After the 35-d growth trial, 95 pigs (48 males, 47 females) were reallotted by weight and sex within phases I and II treatment groups. One-half of the pigs receiving carnitine supplementation during phases I and II were kept on diets containing 25 ppm carnitine, whereas the remaining pigs were placed on a basal grower diet without added carnitine. This procedure was also employed with pigs receiving no carnitine supplementation during phases I and II, resulting in four treatments represented in Table 1. The four dietary treatments were randomly assigned within blocks, providing eight replicate pens per treatment (four replicates/sex). Pigs were housed in a fully enclosed, environmentally regulated building with a totally slatted floor. Pig and feed weights were recorded every two weeks.

A total of four basal diets was used during the experiment. All diets (Table 2) were standard corn-soybean meal diets that met or exceeded recommended nutrient requirements. Phase I and II diets were formulated to contain 1.45 and 1.25% lysine, respectively. The grower diet contained .85% lysine, and as pigs approached 135 lb, the lysine content of the diet was reduced to .75%.

As the average pen weight reached 230 lb, 10 pigs/treatment (five pigs/sex) were slaughtered for determination of carcass characteristics.

Results and Discussion

Addition of L-carnitine to the starter diet did not significantly influence (P>.10) starter pig performance. However, pigs fed carnitine from d 0 to 14 were 8% more efficient and had 3% higher average daily gains (Table 3). Nevertheless, during phase II (d 14 to 35) and over the 35 d trial, pigs offered diets with no carnitine had 8 and 5% higher average daily gains and consumed 7 and 6% more feed per day, respectively. However, d 0 to 35 data revealed that pigs consuming carnitine were 3% more efficient.

During the grower phase (d 35 to 135 lb), there were no differences (P>.10) in performance among any treatment combinations. Similar responses were noted during the finishing phase (135 to 230 lb), but pigs on the N/N treatment had a tendency to consume

more feed per day. Performance from d 35 to 230 lb showed no response to the additions of carnitine during the growing-finishing phase. Feeding high to moderate levels of carnitine in the nursery or low levels in the growing-finishing phase has no subsequent effects on growth performance during the growing-finishing period or over the entire trial.

When pigs were slaughtered at a mean weight of 230 lb, there were no differences in dressing percentages. Average backfat thickness was increased (P=.09, P=.07) in pigs receiving carnitine during the nursery phase (C/N), compared to pigs having no (N/N) or continuous (C/C) carnitine supplementation throughout the trial , respectively. The longissimus muscle area was larger (P=.03) for pigs receiving carnitine additions during the growing-finishing phase (N/C) compared to pigs offered no carnitine (N/N). Also, there was a tendency for pigs receiving added carnitine at some point during the trial to have larger longissimus muscle area than pigs offered no carnitine (N/N). Pigs fed carnitine in the nursery or growing-finishing phase (N/C, C/N and C/C) had larger livers (P=.09) and smaller hearts (P=.05) than pigs that did not receive carnitine (N/N). Marbling score were inversely related to longissimus muscle area and percent crude protein in the carcass, because marbling scores were highest in pigs that did not receive L-carnitine (N/N). Analysis of carcass samples for fat has not been completed. However, because pigs receiving carnitine only in the growing-finishing phase (N/C) had higher crude protein values (P=.13) and larger loineye areas as compared to pigs receiving no carnitine (N/N), we expect the lipid accretion rates of these pigs on this treatment (N/C) to be lower. The decrease (P=.05) in marbling observed for pigs offered carnitine in the growing-finishing phase (N/C) compared to pigs receiving no carnitine (N/N) supports this assertion.

These data suggest that carnitine may play a larger role in carcass composition than in growth performance. This study shows the need for additional information addressing the action of carnitine as a metabolic modifier. Additionally, more information is needed to determine the optimal feeding level of L-carnitine during the nursery and growing-finishing phases.

Table 1. Carnitine Level (ppm) in Dietary Treatments

Item	Control[a] 15-230 lb	Carnitine[b] 15-50 lb	Carnitine[c] 50-230 lb	Carnitine[d] 15-230 lb
d 0 to 14	0	1,000	0	1,000
d 14 to 35	0	500	0	500
d 35 to 135 lbs	0	0	25	25
135 lbs to 230 lbs	0	0	25	25

[a]No carnitine supplementation throughout trial.
[b]Carnitine supplementation only in phases I and II.
[c]Carnitine supplementation only in growing-finishing phase.
[d]Carnitine supplementation throughout trial.

Table 2. Diet Composition

Ingredient, %	Phase I	Phase II	Grower	Finisher
Corn	33.66	47.00	79.55	79.55
Soybean meal, (44% CP)	18.20	33.10		
Soybean meal, (48.5% CP)			17.66	17.66
Dried skim milk	20.00			
Dried whey	20.00	10.00		
Monocalcium phosphate	1.23	1.85	1.68	1.02
Limestone	.44	.80	.95	.91
Salt	.10	.30	.30	.30
Vitamin premix	.25	.25	.25	.25
Soybean oil	5.00	5.00		
Trace mineral premix	.10	.10	.10	.10
Selenium premix	.05	.05	.05	.05
Copper sulfate	.05	.05	.05	.05
L-Lysine HCl	.22	.10		
DL-Methionine	.10			
Antibiotic[a]	.50	.10	.10	.10
Total	100.0	100.0	100.0	100.0
Calculated Analysis,%				
Protein	20.20	18.96	16.48	15.15
Lysine	1.45	1.25	.85	.75
Ca	.92	.90	.80	.65
P	.82	.80	.70	.55

[a]Anitibiotic was CSP 250: (Sulfathiazole) in phase I, Mecadox: (Carbadox) in phase II and CTC: (Chlortetracycline) in growing-finishing phase.

Table 3. Influence of L-Carnitine on Growth Performance of Nursery Pigs[ab]

Item	Control[c]	Carnitine[d]	CV
d 0 - 14			
ADG, lb	.64	.65	20.3
ADFI, lb	.61	.60	18.1
F/G	1.13	1.04	23.5
d 14 - 35			
ADG, lb	1.03	.95	15.1
ADFI, lb	1.54	1.44	14.1
F/G	1.69	1.71	16.5
d 0 - 35			
ADG, lb	.87	.83	13.9
ADFI, lb	1.17	1.10	13.2
F/G	1.46	1.42	13.7
Initial wt, lb	11.40	11.40	19.9
35 d wt, lb	42.06	40.60	12.4

[a]A total of 128 pigs, 4 pigs/pen, 16 pens/treatment.
[b]No treatments effect (P>.10).
[c]No carnitine supplementation throughout phases I and II.
[d]Carnitine supplementation throughout phases I and II.

Table 4. Influence of L-Carnitine on Growth Performance of Growing-Finishing Pigs[ab]

Item	Control[c] 15-230 lb	Carnitine[d] 50-230 lb	Carnitine[e] 15-50 lb	Carnitine[f] 15-230 lb	CV
d 35 to 135 lb					
ADG, lb	1.76	1.75	1.74	1.75	5.1
ADFI, lb	4.87	4.83	4.86	4.80	5.6
F/G	2.77	2.75	2.80	2.75	5.1
d 135 to 230 lb					
ADG, lb	1.78	1.76	1.72	1.76	8.1
ADFI, lb	6.62	6.48	6.33	6.57	10.4
F/G	3.72	3.69	3.67	3.74	5.3
d 35 to 230 lb					
ADG, lb	1.77	1.75	1.72	1.75	16.0
ADFI, lb	5.70	5.62	5.66	5.58	17.8
F/G	3.22	3.21	3.25	3.24	11.9

[a]A total of ninety-five pigs, 3 pigs/pen, 8 pens/treatment.
[b]No treatment effect (P>.10).
[c]No carnitine supplementation throughout trial.
[d]Carnitine supplementation only in growing-finishing phase.
[e]Carnitine supplementation only in phases I and II.
[f]Carnitine supplementation throughout trial.

Table 5. The Influence of L-Carnitine on Carcass Measurements[a]

Item	Control[b] 15-230 lb	Carnitine[c] 50-230 lb	Carnitine[d] 15-50 lb	Carnitine[e] 15-230 lb	CV
Dressing percent	71.08	71.50	71.39	70.8	22.4
Carcass length, in	31.40	31.16	31.45	31.20	2.6
Backfat thickness, in.[fg]	1.27	1.29	1.32	1.24	7.7
LEA, in.[2h]	5.14	5.66	5.32	5.36	9.5
Kidney fat, g	1,826	1,748	1,919	1,895	9.9
Kidney, g	340	306	322	304	15.9
Heart, g[ij]	317	317	300	296	8.6
Liver wt, g[ij]	1,331	1,402	1,400	1,477	9.4
Marbling[hj]	3.40	2.80	3.00	3.05	14.6
Color	2.60	2.60	2.70	2.50	21.1
Firmness	2.05	2.25	2.20	2.50	24.4
Crude protein, %[k]	15.25	16.00	15.45	15.73	6.6

[a]A total of 40 pigs, 10 pigs/treatment, 5 pigs/sex.
[b]No carnitine supplementation throughout trial.
[c]Carnitine supplementation only in growing-finishing phase.
[d]Carnitine supplementation only in phases I and II.
[e]Carnitine supplementation throughout trial.
[f]Carnitine (15-50 lb) vs Carnitine (15-230 lb) (P=.07).
[g]Control vs Carnitine (15-50 lb) (P=.09).
[h]Control vs Carnitine (50-230 lb) (P<.05).
[i]Control vs Carnitine (15-230 lb) (P<.05).
[j]Control vs Carnitine (15-50, 50-230, 15-230) (P<.09).
[k]Control vs Carnitine (50-230) (P=.13).

DOES DIET FORM (PELLETED VS MEAL) AFFECT OPTIMUM PARTICLE SIZE OF CORN FOR FINISHING PIGS?

K. J. Wondra, J. D. Hancock, K. C. Behnke[1], G. A. Kennedy[2], and R. H. Hines

Summary

One hundred and sixty pigs, with an average initial wt of 121 lb, were used in an experiment to determine the effects of diet form and particle size on growth performance and nutrient digestibility. The pigs were fed corn-soybean meal-based diets with the corn milled to particle sizes of 1,000, 800, 600, or 400 µm. The diets were fed in meal and pellet forms. In general, reducing particle size increased electrical energy required for milling and decreased production rate. Milling to 400 µm, as opposed to 600 µm, required twice as much electrical energy and reduced production rate by 50%. Reducing particle size of the corn from 1,000 to 400 µm resulted in a 4% increase in DE of the diets and 6% decrease in ADFI. The net result was similar DE intakes, with 22% less daily fecal excretion of DM, 25% less daily fecal excretion of N, and 7% greater efficiency of gain when particle size was reduced from 1,000 to 400 µm. Pelleting the diets resulted in 3% greater ADG and 6% greater efficiency of gain. Also, pelleting increased digestibilities of DM, N, and GE by 5 to 7%. Stomach keratinization and lesions increased with reduced particle size and pelleting, but performance was not affected. In conclusion, particle size reduction and pelleting improved efficiency of gain and decreased daily excretion of DM and N in the feces, with some increase in ADG because of pelleting.

(Key Words: Process, Particle Size, Pellet, Performance, Stomach Ulcer, G-F.)

Introduction

Particle size reduction is a process fundamental to preparation of ingredients for swine and is usually accomplished by grinding in a hammermill or roller mill. Grinding improves mixing and handling characteristics of ingredients (e.g., increased uniformity of blended diets and decreased segregation of ingredients) and efficiency of growth via increased nutrient digestibility. However, bridging can be a problem for diets with cereal grain particle size < 800 µm, thus requiring more attention to management, repairs, and design (especially agitators) of feeders.

Pelleting is a process used to prevent segregation and improve handling characteristics of mixed diets and would eliminate bridging problems in diets with small particle sizes. Pelleting improves efficiency of gain, but the response is thought to result from decreased feed wastage rather than improved nutrient digestibility. Thus, grinding and pelleting improve growth performance by different mechanisms, with the possibility that their benefits may be additive. The experiment reported herein was designed to determine the effects of pelleting diets with mean particle sizes ranging from 1,000 to 400 µm. Attention was given not only to potential positive effects on growth performance, but also to any negative effects from increased processing inputs or stomach lesions caused by fine grinding and(or) pelleting.

[1]Department of Grain Science and Industry.
[2]Department of Veterinary Diagnosis.

Procedures

A total of 160 finishing pigs (two groups of 80 pigs), with an avg initial wt of 121 lb, were blocked by weight and allotted to eight dietary treatments based on sex and ancestry. There were two pigs per pen and 10 pens per treatment. In the first group, 80 barrows were used (two per pen) and in the second group, 40 barrows and 40 gilts were used (one barrow and one gilt per pen). The pigs were housed in a totally enclosed, environmentally regulated building with a slatted floor. Each pen (5 ft × 5 ft) had a one-hole self-feeder and nipple waterer. The basal diet (Table 1) had corn ground to four particle sizes (1,000, 800, 600, or 400 µm) and was fed as meal and pellets. This resulted in a 4 × 2 factorial arrangement of treatments. The corn for the two groups of pigs had 12.5 and 13.0% moisture, respectively. To achieve desired particle sizes of 1,000, 800, 600, and 400µm, hammermill screens with openings of 3/8, 3/16, 1/8, and 1/16 in. were used in Rep. 1, and 1/2, 3/8, 3/16, and 1/16 in. were used in Rep. 2, respectively. A constant motor load during milling was maintained so production rate and electrical energy consumption could be measured. Pellet durability was recorded for the pelleted diets.

Five weeks after initiation of the experiment, chromic oxide was added to the diets (.20%) as an indigestible marker. After a 5–d adjustment period, fecal samples were collected from each pig and pooled within pen. The fecal and diet samples were dried; ground; and analyzed for Cr, DM, gross energy, and N concentrations so that apparent digestibilities of DM, energy, and N could be calculated. The pigs were slaughtered when each weight block reached an average of 250 lb. Hot carcass weight and last rib fat thickness were recorded, and stomachs were collected for evaluation of changes in morphology. Hot carcass wt was used as a covariate in analyses of last rib fat thickness.

Table 1. Composition of Basal Diet[a]

Ingredient	%
Corn	82.53
Soybean meal (48% CP)	14.37
Monocalcium phosphate	1.08
Limestone	1.02
Salt	.30
Vitamins and minerals[b]	.60
Antibiotic[c]	.10
Total	100.00

[a]The basal diet was formulated to .65% lysine, .65% Ca, .55% P, and 1.56 Mcal DE/lb.
[b]KSU vitamin mix (.25%), KSU mineral mix (.10%), and KSU selenium mix (.05%), with .20% chromic oxide added as an indigestible marker.
[c]Antibiotic supplied 100 g/ton chlortetracycline.

Results and Discussion

Measurements of milling characteristics are given in Table 2. Energy required for milling to 1,000, 800, and 600 µm increases slightly as particle size was reduced. However, milling to 400 µm required more than twice as much energy as milling to 600 µm (7.35 and 3.46 kWh/t, respectively). Likewise, production rate decreased sharply (2.85 vs 1.43 t/h) as particle size was reduced from 600 to 400 µm. Energy required for pelleting was similar for diets with the different particle sizes, but pellet durability increases from 78.8 to 86.4% as particle size of the corn was decreased from 1,000 to 400 µm.

Average daily gain was not affected by particle size of the diets ($P>.30$). However, feed intake was reduced with fine grinding ($P<.01$), so that efficiency of gain was increased by 7% (linear, $P<.001$) as particle size was reduced from 1,000 to 400 µm. The improvements in efficiency of gain associated with particle size reduction correlated well with the improvements of 3, 5, and 4% for digestibilities of DM, N, and GE as corn particle size was reduced from 1,000 to 400 µm. Thus, total feed intake was decreased by fine grinding, but the nutritional value of that

feed was increased, and improved efficiency of gain resulted.

A somewhat surprising response was that apparent feed intake was not reduced with pelleting. Historically, improved F/G with pelleted diets has been attributed to decreased feed wastage, giving decreased apparent feed intakes. In the present experiment, much attention was given to proper feeder adjustments to minimize wastage of meal and(or) pelleted diets. Given the similar feed intakes and greater nutrient digestibilities for pelleted diets (i.e., 5, 7, and 7% increases for digestibilities of DM, N, and GE), improvements in rate and efficiency of gain must be attributed to improved nutritional value of the pelleted diets and not to reduced feed wastage.

Another important issue facing swine producers is manure disposal. Thus, the effects of reducing particle size and pelleting on fecal excretion of DM and N was calculated. Reducing particle size of corn from 1,000 to 400 µm reduced daily excretions of DM and N by 22 and 25%, respectively. Pelleting reduced daily excretions of DM and N by 24 and 22%, respectively. These reductions in daily excretion of DM and N represent advantages to fine grinding and pelleting that should not be overlooked.

In contrast to the positive effects of fine grinding and pelleting on performance, negative effects of increased keratinization (an indication of irritation) and lesions (actual erosion of tissue) in the esophageal region of the stomach were detected. Both criteria increased linearly as particle size was reduced from 1,000 to 400 µm ($P<.001$). However, the significance of these increases is questionable, because there were no changes in growth performance or health of the animals. This does not exclude the possibility that finely ground corn may aggravate a genetic predisposition to stomach lesions, but it certainly does question the validity of assuming that finely ground diets (e.g., 600 to 400 µm) will cause severe stomach lesions in all populations of pigs.

In conclusion, particle size reduction and pelleting are processing methods that can improve growth performance and reduce manure disposal problems. Considering milling costs, growth performance, nutrient digestibility, and stomach morphology, a particle size of 600 to 500 µm is recommended for both meal and pelleted diets.

Table 2. Characteristics of Corn and Diets

	Particle size treatment, µm			
Item	1,000	800	600	400
Grain mean particle size, µm	1,020	778	650	450
Variation in particle size of grain (Sgw)	2.50	2.23	1.97	1.72
Diet mean particle size, µm	1,017	886	705	517
Variation in particle size of diet (Sgw)	2.55	2.22	2.05	1.78
Milling energy, kWh/t	2.42	2.78	3.46	7.35
Milling production rate, t/h[a]	3.00	3.00	2.85	1.43
Pellet durability, %	78.8	79.4	82.4	86.4

[a]Milling production rate of the 1,000 µm treatment was limited by capacity of the exit augers (i.e., 3 t/h).

Table 3. Effects of Particle Size and Diet Form on Performance of Finishing Pigs[a]

	Meal				Pellet				
Item	1,000	800	600	400	1,000	800	600	400	CV
ADG, lb/d[b]	2.11	2.07	2.09	2.17	2.18	2.21	2.24	2.16	6.8
ADFI, lb/d[e]	7.16	7.07	7.19	6.97	7.25	7.01	7.06	6.58	5.4
F/G[cf]	3.39	3.42	3.44	3.21	3.33	3.17	3.15	3.05	5.9
Last rib BF, in.	1.2	1.2	1.3	1.2	1.2	1.2	1.2	1.2	10.8
Dressing percentage	73.09	73.59	73.08	73.97	73.58	73.26	74.05	73.96	1.0
Apparent digestibility, %									
DM[cd]	80.77	81.78	79.57	83.87	84.85	84.77	85.57	87.04	2.6
N[cd]	73.27	74.31	73.10	77.18	78.39	78.28	79.21	82.69	4.5
GE[ceg]	80.00	80.28	78.55	83.95	85.07	85.36	86.13	87.96	2.7
Intake of digestible nutrients, lb/d									
DM[h]	5.68	5.69	5.86	5.68	6.13	5.80	5.68	5.59	4.9
N	.121	.122	.128	.123	.133	.126	.124	.125	6.0
DE[h]	11.21	11.14	11.55	11.32	12.26	11.63	11.41	11.25	4.9
Fecal excretion, lb/d									
DM[ce]	1.36	1.27	1.41	1.09	1.09	1.04	.96	.83	15.4
N[ce]	.044	.042	.043	.036	.037	.035	.032	.025	16.8
Stomach keratinization[f]	.95	1.68	1.25	2.13	.95	1.88	1.95	1.96	18.6
Stomach lesions[f]	.10	.15	.45	.80	.20	.68	.40	.85	25.3

[a]160 pigs (2 pigs/pen and 10 pens/trt) with an avg initial wt of 125 lb and an avg final wt of 253 lb.
[bc]Pellet vs meal (P<.01 and P<.001, respectively).
[def]Linear effect of particle size reduction (P<.05, P<.01, and P<.001, respectively).
[g]Quadratic effect of particle size reduction (P<.05).
[h]Pellet vs meal × particle size linear (P<.05).

EFFECTS OF MILL TYPE (HAMMER VS ROLLER) AND PARTICLE SIZE UNIFORMITY ON GROWTH PERFORMANCE, NUTRIENT DIGESTIBILITY, AND STOMACH MORPHOLOGY IN FINISHING PIGS

K. J. Wondra, J. D. Hancock, K. C. Behnke[1], C. H. Fahrenholz[1], C. R. Stark[1], and R. H. Hines

Summary

Two experiments were conducted to determine the effects of mill type and particle size uniformity on finishing pigs. In Exp. 1, 120 pigs, with an average initial weight of 105 lb, were fed corn-soybean meal-based diets for 57 d. The corn was milled so that all diets had an average mean particle size of 800 µm (± 20), yet differed in particle size uniformity (Sgw). To obtain the most uniform treatment (1.9 Sgw), corn was milled through a roller mill. The intermediate treatment (2.3 Sgw) was obtained by milling corn through a hammermill. The least uniform treatment (2.7 Sgw) was obtained by blending coarsely and finely ground corn. Growth performance of pigs was not affected by Sgw of the diet. However, digestibilities of DM, N, and GE increased as Sgw was reduced. In Exp. 2, 128 pigs, with an average initial weight of 150 lb, were fed diets with corn milled to 450 µm (± 7) in a hammermill or a roller mill. The hammermilled corn had an Sgw of 1.8 and the roller-milled corn had an Sgw of 2.0. The diets were fed in meal or pelleted form. There were no interactions among mill type and diet form. Digestibilities of DM and N were greater for the hammermilled treatments, but no growth performance differences were due to mill type. Pelleting increased ADG 9% and improved efficiency of gain by 5%. Pelleting also increased the severity of stomach lesions. In conclusion, at 800 and 450 µm, mill type did not affect growth performance. However, nutrient digestibilities were improved by decreasing variability in particle size, a response that merits further investigation.

(Key Words: Particle Size, Pelleting, Roller Mill, Performance, Stomach Ulcers, G-F.)

Introduction

Much attention has been given to the positive effects of reducing mean particle size of diets for broiler chicks and nursery pigs (1991 KSU Swine Day Report, page 56) and finishing pigs and lactating sows (Wondra et al., p. 6 and 122). From these and other reports, few would argue that reducing mean particle size of cereal grains from ≥ 900 µm to ≤ 600 µm results in marked improvements in nutrient digestibility and efficiency of growth. However, these experiments resulted from investigation of the effects of mean particle size and say nothing about the effects of variation of particle size within that mean. Must all of the particles in a diet be the same size to give maximum nutrient digestibility and growth performance? Does a diet with many particles at ≥ 1,000 and ≤ 600 µm give an average effect similar to a diet with all of its particles near 800 µm? These questions are particularly important when deciding whether to buy a hammermill or roller mill, because roller mills usually give greater particle size uniformity. The experiments reported herein were designed to determine the effects of particle size uniformity and milling with a hammermill vs roller mill on growth performance, nutrient digestibility, and stomach morphology in finishing pigs.

[1]Department of Grain Science and Industry.

Procedures

In Exp. 1, 120 finishing pigs, with an average initial wt of 105 lb, were blocked by weight and allotted to treatment based on sex and ancestry. There were eight pigs per pen and five pens per treatment. The pigs were housed in a modified open-front building, with 50% solid concrete and 50% concrete slat flooring. Each pen (6 ft × 16 ft) had a three-hole self-feeder and nipple waterer to allow ad libitum consumption of feed and water.

For the grain treatments, a single lot of corn was purchased from the 1990 harvest. Corn was ground through a well maintained hammermill, equipped with a 1/4 in. screen, to yield an intermediate degree of particle size uniformity (denoted as Sgw). Average particle size was 862 µm with an Sgw of 2.3. For the minimum Sgw, a well maintained roller mill was used to grind the corn, with an actual average particle size of 840 µm and Sgw of 2.0. For the high Sgw treatment, finely ground (ground through a 1/16 in. screen, avg particle size of 400 µm and Sgw of 1.8) and coarsely rolled (avg particle size of 2,200 µm and Sgw of 2.0) corn were blended, yielding a mixture with analyzed avg particle size of 868 µm and Sgw of 2.7.

The grain treatments were incorporated into a corn-soybean meal-based diet (Table 1). The pigs were fed for 57 d and scanned ultrasonically for fat thickness at the last rib; then all barrows were slaughtered. Samples of digesta were collected from the rectum for determination of DM and N digestibility (using the indirect ratio method with .20% chromic oxide as an indigestible marker), and the stomachs were harvested. The esophageal regions of the stomachs were scored on a scale of normal (0) to severe (3) for keratinization and erosions. The scores were transformed (square root transformation) before statistical analyses. Response criteria were ADG; ADFI; F/G; last rib fat depth; stomach keratinization; stomach lesions; and apparent digestibilities of DM, N, and GE.

In Experiment 2, 128 finishing pigs, with an average initial wt of 150 lb, were blocked by weight and allotted to four dietary treatments based on sex and ancestry. There were eight pigs per pen and four pens per treatment. Housing and management were the same as in Exp. 1.

Table 1. Composition of Basal Diet[a]

Ingredient	%
Corn	82.73
Soybean meal (48% CP)	14.37
Monocalcium phosphate	1.08
Limestone	1.02
Salt	.30
Vitamins and minerals[b]	.40
Antibiotic[c]	.10
Total	100.00

[a]The basal diet was formulated to .65% lysine, .65% Ca, .55% P, and 1.56 Mcal DE/lb.
[b]KSU vitamin mix (.25%), KSU mineral mix (.10%), and KSU selenium mix (.05%).
[c]Antibiotic supplied 100 g/ton chlortetracycline.

To prepare the corn treatments, a single lot of corn was purchased from the 1991 harvest and milled through either a hammermill or roller mill to approximately 450 µm. The milled corn was incorporated into the same corn-soybean meal–based diet used in Exp. 1. The diet was fed as a meal and pelleted to determine if mill type would affect pelleting characteristics and(or) growth performance. Furthermore, pelleting can increase the incidence and severity of stomach lesions, and we wanted to know if mill type would prevent or aggravate that condition. This resulted in a 2 × 2 factorial arrangement of treatments.

Five weeks after initiation of the experiment, chromic oxide was added to the diets (.20%) as an indigestible marker. After a 5–d adjustment period, fecal samples were collected from each pig and pooled within pen. The fecal and diet samples were dried; ground; and analyzed for Cr, DM, energy, and N concentrations so that apparent digestibilities of DM, energy, and N could be calculated. The diets were fed until pigs in one pen of a wt block averaged 260 lb. The block was then slaughtered, and stomachs were scored using the same scale as in Exp. 1. Response criteria were ADG, ADFI, F/G, stomach keratinization, stomach lesions, and apparent digestibilities of DM, N, and GE.

Results and Discussion

The effects of particle size uniformity in diets for finishing pigs are given in Table 2. Targeted and actual particle sizes and Sgws were very similar. The actual particle size of the three corn treatments differed by only 28 µm, averaging 857 µm. Particle size of the complete diets averaged 804 µm. Growth performance of pigs was not affected by Sgw of the diets (P>.10). However, apparent digestibilities of DM, N, and GE were greater for diets with lower Sgws (linear, P<.01). These results indicated that digestibility values were more sensitive to the effects of particle size uniformity than growth performance.

One pig fed the most uniform diet (1.9 Sgw) died from a stomach ulcer during the experiment. No ulcers were present in the stomachs of the other barrows at slaughter, indicating that the fine particles in diets with high Sgws did not induce formation of stomach lesions.

Results from Exp. 2 are given in Table 3. Particle sizes of hammermilled corn and roller-milled corn were similar, differing by only 14 µm. The Sgws differed slightly, with the hammermilled corn having the most uniform particle size. This is contrary to the general rule (at larger particle sizes) that grains milled through a roller mill have lower Sgws than grains milled through a hammermill. Pellet durabilities were similar for diets with corn processed in either the hammermill or roller mill (i.e., 91 vs 94%).

Growth performance was not affected by mill type. However, apparent digestibilities of DM (P<.01) and N (P<.05) were greatest for the hammermill treatment. Although grain milled through a roller mill had greater nutrient digestibilities in Exp. 1, in both experiments, the grain with the lowest Sgw (roller milled in Exp. 1 and hammermilled in Exp. 2) had the greatest nutrient digestibilities. Pigs fed pelleted diets had 9% greater ADG (P<.01) and were 5% more efficient (P<.05) than pigs fed diets in meal form. Pigs fed pelleted diets had greater lesion scores than pigs fed meal diets (P<.001). There were no interactions among mill type and diet form.

In conclusion, these data indicate that particle size uniformity and(or) mill type have minimal effect on growth performance. However, the discrepancies in nutrient digestibilities (i.e., greater for roller milled grain in Exp. 1 and greater for hammermilled grain in Exp. 2) warrant further investigation. Finally, although growth and health status of pigs in Exp. 2 was not compromised with any grain treatment, the lower lesion scores for stomachs from pigs fed corn ground through a roller mill may be of biological significance.

Table 2. Effects of Particle Size Uniformity on Performance and Nutrient Digestibility in Finishing Pigs[a]

	Uniformity of particle size, Sgw			
Item	2.7	2.3	1.9	CV
Grain characteristics				
Mean particle size,µm	868	862	840	—
Diet characteristics				
Mean particle size, µm	801	817	793	—
Variation in particle size (Sgw)	2.5	2.3	2.0	—
Pig performance				
ADG, lb	1.83	1.83	1.85	4.1
ADFI, lb	6.39	6.39	6.79	5.2
F/G	3.49	3.49	3.67	5.6
Fat thickness, in.	1.06	1.18	1.13	16.6
Apparent nutrient digestibility, %				
DM[b]	80.2	80.3	83.1	1.4
N[b]	72.4	76.5	78.5	2.5
GE[bc]	79.6	79.1	82.6	1.6
Stomach keratinization	.56	.88	.76	8.4

[a]120 pigs (8 pigs/pen and 5 pens/trt) with an avg initial wt of 105 lb, and an avg final wt of 209 lb.
[b]Linear effect of Sgw (P<.01).
[c]Quadratic effect of Sgw (P<.05).

Table 3. Influence of Diet Form and Mill Type on Finishing Pigs[a]

	Hammermill		Roller mill		
Item	Meal	Pellet	Meal	Pellet	CV
Grain characteristics					
Mean particle size, µm	457	457	443	443	-
Variation in particle size, Sgw	1.8	1.8	2.0	2.0	-
Diet characteristics					
Mean particle size, µm	460	-	491	-	-
Variation in particle size, Sgw	1.7	-	1.9	-	-
Pellet durability	-	91	-	94	-
Pig performance					
ADG, lb[e]	1.82	1.93	1.83	2.04	4.1
ADFI, lb	6.69	6.93	6.61	6.79	5.2
F/G[f]	3.68	3.59	3.61	3.33	4.2
Apparent nutrient digestibility, %					
DM[b]	87.2	88.2	85.2	85.5	1.5
N[c]	83.7	84.3	82.5	82.4	1.2
GE	87.8	88.2	86.2	86.4	2.0
Stomach keratinization	2.19	1.63	1.00	1.63	15.3
Stomach lesions[bd]	.44	1.31	.19	.63	11.4

[a]128 pigs (8 pigs/pen and 4 pens/trt) with an avg initial wt of 150 lb and an avg final wt of 263 lb.
[bc]Mill effect (P<.01 and P<.05, respectively).
[def]Form effect (P<.001, P<.01, and P<.05, respectively).

EXTRUDED CORN, SORGHUM, WHEAT, AND BARLEY FOR FINISHING PIGS

J. D. Hancock, R. H. Hines, B. T. Richert, and T. L. Gugle

Summary

Eighty barrows (113.7 lb average initial weight) were used to determine the effects of extruding corn, sorghum, wheat, and barley on growth performance, carcass merit, nutrient digestibility, and changes in stomach morphology of finishing pigs. Treatments were grain source (corn, sorghum, wheat, and barley) and processing procedure (grinding vs extrusion) arranged as a 4 × 2 factorial. Grinding was in a Jacobson hammermill and extrusion was in an Insta-Pro® extruder. Pigs fed corn had improved average daily gain (ADG), feed/gain (F/G), DM digestibility, and N digestibility compared to the other grain sources. Diets with barley supported the poorest growth performance and nutrient digestibilities, with sorghum and wheat intermediate. Extrusion of the cereal grains did not affect ADG but increased efficiency of gain by 4, 9, 6, and 3% for corn, sorghum, wheat, and barley, respectively. Digestibilities of DM and N were also increased on average by extrusion processing, with barley responding the most (9 and 12% increases for DM and N digestibilities) and wheat responding the least (no improvement). Overall, extrusion processing improved nutritional value of cereal grains for finishing pigs. However, swine producers must be careful to evaluate the overall economic benefits before adopting this or any other new technology.

(Key Words: Process, Extrusion, Sorghum, Wheat, Barley, Corn, Performance, G-F.)

Introduction

There is considerable interest in use of extrusion processing to prepare ingredients for swine diets. Previous articles in KSU Swine Day Reports indicated improved utilization of protein in weanling pigs fed conventional and low-inhibitor soybeans, soy flour, soy protein concentrates, and soybean flakes when extruded rather than toasted. However, much less is known about the effects of extruded cereal grains when used in swine diets. In the 1990 and 1991 KSU Swine Day Reports [Reports of Progress No. 610 (page 76) and 641 (page 92), respectively] we reported 5 to 20% improvements in growth performance and nutrient digestibility in finishing pigs fed diets with extruded sorghum and(or) soybeans compared to ground sorghum and soybean meal. These results suggest that extrusion processing might be used to increase the feeding value of cereal grains that have less digestible energy than corn. The data reported herein result from an experiment to determine the effects of extrusion processing on nutritional values of corn, sorghum, wheat, and barley for finishing pigs. In particular, the utility of extrusion compared to grinding to improve the nutritional values of sorghum, wheat, and barley relative to ground corn was of interest.

Procedures

Eighty barrows, with an average initial weight of 113.7 lb, were assigned to eight

dietary treatments based on weight and ancestry. There were two pigs per pen and five pens per treatment. The pigs were housed in a totally enclosed, environmentally regulated building with slatted flooring. Each pen (5 ft × 5 ft) had a single-hole self-feeder and nipple waterer, so feed and water could be consumed on an ad libitum basis.

Treatments were grain source (corn, sorghum, wheat, and barley) and processing procedure (grinding vs extrusion), so that the overall treatment arrangement was a 4 × 2 factorial. The ground grain treatments were processed through a Jacobson Pulverator® hammermill with a targeted mean particle size of 750 µm. The hammermill had a screen with 3/16 in. openings and yielded particle sizes of 780, 720, 783, and 711 µm for corn, sorghum, wheat, and barley, respectively. All diets were supplemented with extruded soybeans as a protein source. For the extruded grain treatments, ground cereal grains were tempered to 18% moisture and blended with extruded soybeans, and the mixture was extruded. Extrusion was in an Insta-Pro® extruder with a targeted barrel temperature of 145°F. Actual barrel temperatures and throughputs for the corn, sorghum, wheat, and barley were 136°F (1,320 lb/hr), 137°F (1,320 lb/hr), 160°F (1,272 lb/hr), and 153°F (1,272 lb/hr), respectively. Previous experiments with sorghum indicated reduced feed intake in finishing pigs fed extruded grain, so a diet with .70% lysine (wheat-based) was formulated to ensure adequate intakes of amino acids. All other grain treatments were substituted for the ground wheat on an equal weight basis with crystalline lysine used to bring all diets to .70% (Table 1).

The pigs were fed to an average ending weight of 249 lb and slaughtered for collection of carcass measurements and stomach tissues. The esophageal regions of the stomachs were scored on a scale of 0 to 3 (0 = normal and 3 = severe) for keratinization and lesions. Additionally, 5 d before slaughter, .1% chromic oxide was added to the diets as an indigestible marker. The day before slaughter, fecal samples were collected. The fecal samples were dried; pooled within pen; and analyzed for Cr, DM, and N to allow calculation of DM and N digestibilities.

The data were analyzed for effects of grain source (corn vs others, sorghum and wheat vs barley, and sorghum vs wheat), processing procedure (grinding vs extrusion), and interactions of grain source with processing procedure. Dressing percentage and last rib fat thickness for each pig were adjusted to an average hot carcass weight (using regression analysis) before being pooled within pen. Also, stomach scores for keratinization and lesions were transformed (square root transformation) before statistical analyses.

Results and Discussion

The diets were formulated with equal weight substitutions of the cereal grains; thus, differences in nutrient concentrations of the grains were apparent in the diets (Table 1). Crude protein concentrations ranged from 13% for the corn-based diets to 16.2% for the wheat-based diets. The calculated metabolizable energy (ME) concentrations ranged from 1,519 kcal/lb for the corn-based diets to 1,385 kcal/lb for the barley-based diets. The sorghum and wheat diets were very similar in ME concentrations, with values of 1,468 and 1,481 kcal/lb, respectively. Fiber concentrations were similar for the diets with corn, sorghum, and wheat (average of 2.8%), but diets with barley had much more fiber (4.9%), that was largely responsible for the lower ME concentrations.

Diets with corn supported greater average daily gain (ADG) than the other cereal grains ($P<.01$), and diets with barley supported lower ADG than diets with sorghum and wheat ($P<.01$). As would be expected, the diets with greatest calculated ME concentrations (i.e., corn-based diets) gave the greatest efficiencies of gain ($P<.01$). Pigs fed barley were least efficient ($P<.01$), and pigs fed sorghum were more efficient than pigs fed wheat

(P<.05). Extrusion did not affect ADG, but improved (P<.01) feed/gain (F/G) with increases of 4, 9, 6, and 3% for corn, sorghum, wheat, and barley, respectively. Because extrusion has been reported to improve starch, protein, and fiber digestibilities, we anticipated that feedstuffs typically lower in feeding value might benefit most from extrusion. This did result with sorghum and wheat, with larger improvements from extrusion than with corn. However, the smaller response (i.e., only 3% improvement) to extrusion in barley-based diets was disappointing.

Dressing percentage was not affected by grain source, but pigs fed extruded grains had 2% greater dressing percentages than pigs fed ground grains (P<.01). Last rib fat thickness was not affected by dietary treatment (P>.23).

Digestibilities of DM and N closely paralleled differences in F/G. Corn had greater DM and N digestibilities than the other grains, sorghum and wheat were more digestible than barley, and extruded grains were more digestible than ground grains (P<.01). There was an interaction between grain source and extrusion (P<.05), with DM digestibility of the barley-based diet responding more to extrusion than digestibilities of the sorghum- and wheat-based diets. However, even with the marked improvements from extrusion processing, the barley-based diet still had lower DM and N digestibilities than other treatments.

A final consideration in evaluation of extrusion processing of cereal grains is any adverse effects on stomach morphology. Reports in the 1960s suggested that extruded cereal grains caused marked increases in the incidence and severity of stomach ulcers. In the present experiment, extrusion increased stomach keratinization (P<.01). However, only two of the 80 pigs had stomach lesions, and both of those pigs were fed ground grain rather than extruded grain (i.e., one was fed the ground corn treatment and one was fed the ground barley treatment).

In conclusion, extrusion processing of cereal grains improved nutrient digestibility and efficiency of gain in finishing pigs. The greatest increase in nutrient digestibility was for pigs fed barley-based diets, and the greatest improvement in efficiency of gain was for pigs fed sorghum-based diets. This technology offers promise in terms of improved nutritional value of cereal grains, provided that costs of processing and equipment continue to decrease.

Table 1. Diet Composition[a]

Item	Corn	Sorghum	Wheat	Barley
Cereal grain[bc]	80.11	80.08	80.46	80.42
Extruded soybeans	16.81	16.81	16.81	16.81
Lysine-HCl	.15	.18	—	—
Monocalcium phosphate	1.21	1.21	1.02	.94
Limestone	.82	.82	.81	.93
Vitamins and minerals[d]	.70	.70	.70	.70
Antibiotic[e]	.20	.20	.20	.20
Total	100	100	100	100
Calculated values				
CP, %	13.0	13.3	16.2	15.3
Lysine, %	.70	.70	.70	.70
ME, kcal/lb	1,519	1,468	1,481	1,385
Fiber, %	2.7	2.7	3.0	4.9

[a]All diets were formulated to .65% Ca and .55% P.
[b]The grains were fed ground (mean particle sizes of 780, 720, 783, and 711 µm for corn, sorghum, wheat, and barley, respectively) and extruded. Extruded soybeans were blended with the grains before extrusion.
[c]The extruded grain-soybeans mixture replaced ground grain and extruded soybeans on an equal weight basis.
[d]KSU vitamin mix (.25%), KSU mineral mix (.10%), selenium mix (.05%), and salt (.3%).
[e]Supplied 100 g chlortetracycline per ton of diet.

Table 2. Effects of Extrusion on the Nutritional Value of Corn, Sorghum, Wheat, and Barley for Finishing Pigs[a]

	Corn		Sorghum		Wheat		Barley		
Item	Ground	Extruded	Ground	Extruded	Ground	Extruded	Ground	Extruded	CV
ADG, lb[bd]	2.22	2.22	2.19	2.13	2.12	2.09	1.97	1.95	5.0
ADFI, lb[g]	6.58	6.29	6.83	6.05	6.80	6.34	6.54	6.30	4.5
F/G[bdfg]	2.96	2.83	3.12	2.84	3.21	3.03	3.32	3.23	4.4
Dressing percentage[g]	72.4	74.7	73.2	74.7	73.3	74.4	72.6	73.8	1.9
Fat thickness, in.	1.21	1.27	1.17	1.28	1.30	1.29	1.18	1.23	10.8
DM digestibility, %[bdfgi]	86.7	91.4	88.8	90.2	86.0	85.9	75.9	82.4	3.4
N digestibility, %[bdegh]	81.8	88.0	79.7	84.4	85.4	85.4	70.5	78.8	4.8
Stomach keratinization[cg]	.92	1.37	1.07	1.25	.56	1.25	.17	1.09	17.1

[a]A total of 80 barrows (two pigs/pen and five pens/treatment) were fed from an average initial weight of 114 lb to an average final weight of 249 lb.
[b]Corn vs other grains (P<.01).
[cd]Sorghum and wheat vs barley (P<.05 and P<.01, respectively).
[ef]Sorghum vs wheat (P<.10 and P<.05, respectively).
[g]Ground vs extruded (P<.05).
[hi]Sorghum and wheat vs barley × ground vs extruded (P<.10 and P<.05, respectively).

EVALUATION OF EXPELLED SOYBEAN MEAL IN SWINE FINISHING DIETS

J. L. Lauren, R. D. Goodband, M. D. Tokach, and J. L. Nelssen

Summary

Thirty crossbred finishing gilts (initial weight = 150 lb) were used to evaluate the effects of feeding expelled soybean meal (41% analyzed CP) or conventionally extracted soybean meal (46.5% analyzed CP) on growth performance. Gilts were fed a control diet containing conventionally processed soybean meal or diets containing expelled soybean meal formulated to replace conventionally extracted soybean meal on either a guaranteed protein basis or an analyzed protein basis. Thus, the effects of possible variation in the protein content and quality of expelled soybean meal as a result of expeller processing could be established. Gilts fed either diet containing expelled soybean meal had decreased average daily gain (ADG) and average daily feed intake (ADFI) and tended to have poorer feed efficiency (F/G) than gilts fed conventionally processed soybean meal. Although not statistically different, gilts fed the expelled soybean meal diet formulated on a guaranteed protein content basis tended to have poorer ADG than those fed the expelled soybean meal formulated on an analyzed protein content. These results suggest that improper processing and the potential variation present in expelled soybean meal used in this experiment resulted in decreased pig performance.

(Key Words: G-F, Performance, SBM, Process.)

Introduction

Prior to solvent extraction, soybeans were processed by expeller procedures to remove the oil. Today, solvent extraction is the most common method of extracting soybean oil; however, the expeller process is still being used in some areas. In the expeller process, the soybeans are cracked, dried, and transported to a tempering device, which stirs them for uniform heat processing. The soybeans are then fed into an expeller barrel, which presses the oil from the beans. The soybeans leave the barrel and are ground. The expeller process leaves the beans with approximately 5% fat. In solvent extraction, the beans are cracked and then heated to 140°F for 10 min. Soybeans are then allowed to cool to 113°F, hexane extracted, volatilized, and dried. From the dryer, the beans are conveyed to a toaster, cooled, and ground, leaving them with less than 1% fat. This experiment was conducted because of producer inquiries as to the value of expelled soybean meal as a replacement for conventional soybean meal.

Procedures

Expelled soybean meal was purchased at a local elevator in northeast Kansas. The expelled and conventional soybean meals were analyzed for percentage protein and diets formulated to .65% lysine (Table 1). Lysine was assumed to be a fixed percentage of total protein in both soybean meals. A third treatment was formulated using the guaranteed protein content of the expelled soybean meal to provide an equal protein (lysine) substitution for the protein in conventionally processed soybean meal. This arrangement of treatments allowed for a direct comparison of the protein quality of the two soybean meal sources (replacement on analyzed values), as well as assessing the effect on pig performance of potential varia-

tion in protein content. Thirty gilts averaging 150 lb were assigned randomly by ancestry and weight to one of three dietary treatments in a randomized complete block.

Results and Discussion

Gilts fed either diet containing expelled soybean meal had decreased (P<.05) average daily gain compared to gilts fed conventionally processed soybean meal. Although not statistically different, gilts fed the expelled soybean meal diet formulated on a guaranteed basis tended to have decreased ADG compared to expelled soybean meal formulated on an analyzed basis. This indicates that improper processing was the primary factor resulting in decreased pig performance; however, because the actual protein content was below the guaranteed value, this also tended to influence pig performance. This resulted in an 18 to 24% reduction in ADG. Gilts fed either expelled soybean meal diet had decreased (P<.10) average daily feed intake compared to those fed conventionally processed soybean meal. Feed efficiency was 10 to 14% poorer for gilts fed the expelled soybean meal diets. These results indicate that the expelled soybean meal used in this experiment was an inferior protein source compared to conventionally processed soybean meal. This does not apply to all expelled soybean meals; however, like any alternative feed ingredient, it should be thoroughly tested and analyzed before inclusion in swine diets.

Table 1. Diet Composition[a]

Ingredient, %	Conventional SBM	Expelled SBM[b] guaranteed basis	Expelled SBM[c] analyzed basis
Milo	81.93	80.82	79.97
Soybean meal (46.5% CP)	15.39	—	—
Expelled soybean meal	—	16.40	17.26
Monocalcium phosphate	1.05	1.07	1.06
Limestone	.93	1.01	1.01
Salt	.30	.30	.30
Vitamin premix	.25	.25	.25
Trace mineral premix	.15	.15	.15
Total	100.00	100.00	100.00

[a]All diets were formulated to contain .65% lysine, .65% Ca, and .55% P.
[b]Conventional SBM replaced with expelled SBM on guaranteed protein (43%) content basis.
[c]Conventional SBM replaced with expelled SBM on an analyzed protein (41%) basis.

Table 2.Effect of Expelled Soybean Meal on Pig Performance[a]

Ingredient, %	Conventional SBM	Expelled SBM[b] guaranteed basis	Expelled SBM[c] analyzed basis	CV
Daily gain, lb[d]	2.11	1.61	1.72	6.7
Daily feed intake, lb[e]	6.85	5.71	6.23	8.7
Feed efficiency	3.27	3.59	3.73	9.0

[a]A total of 30 gilts; two gilts per pen and five pens per treatment. Trial duration was 28 days.
[b]Conventional SBM replaced with expelled SBM on guaranteed protein (43%) content basis.
[c]Conventional SBM replaced with expelled SBM on an analyzed protein (41%) basis.
[d]Conventional SBM vs either Expelled SBM (P<.05).
[e]Conventional SBM vs either Expelled SBM (P<.10).

THE EFFECTS OF DIETS FORMULATED ON AN IDEAL PROTEIN BASIS ON GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF FINISHING GILTS HOUSED IN A HOT DIURNAL ENVIRONMENT[1]

J. Lopez[2], R. D. Goodband, G. W. Jesse[2], J. L. Nelssen, M. D. Tokach, D. Spiers[2], and B. A. Becker[3]

Summary

Forty-eight finishing gilts (initial weight = 155 ± 2 lb) were randomly assigned to one of eight experimental treatments in a 2 × 2 × 2 factorial arrangement with main effects including dietary lysine (.60 vs 1.00%), source of amino acid fortification (intact protein vs synthetic amino acids formulated on an ideal protein basis) and environmental temperature (thermoneutral (TN): 68°F vs hot, diurnal (HS): 82 to 95°F). The ideal protein diets were formulated by using corn and soybean meal to meet the 5th limiting amino acid with additions of synthetic lysine, threonine, tryptophan, methionine, or isoleucine to meet the pigs estimated requirement. The ratios of other total amino acids relative to lysine were: threonine 66%, tryptophan 17%, methionine and cystine 56%, and isoleucine 63%. Average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G) were similar for gilts fed the intact and ideal proteins diets. Increasing dietary lysine improved d 0-14 ADG and resulted in a numerical improvement for the overall study. Gilts in the HS environment ate less feed and had lower ADG than gilts at TN. A temperature × lysine interaction was observed for F/G. Increasing dietary lysine had no effect on F/G of gilts in the TN environment, but improved F/G of gilts in the HS environment. Carcass protein and lipid contents were improved for gilts in the HS environment and by increased dietary lysine. Accretion rates for protein and lipid, backfat thickness, and longissimus muscle area were improved in gilts fed 1.00% lysine. The source of amino acid fortification did not influence carcass characteristics. In conclusion, increased dietary lysine improved F/G and carcass leanness in gilts to a greater extent in HS than TN environments. However, no improvements were observed in growth performance or carcass traits from feeding ideal protein diets.

(Key Words: Pigs, Lysine, Growth, Heat Stress.)

Introduction

When diets are formulated on an ideal protein basis, amino acids are provided in the exact proportions necessary for maintenance and protein accretion in a pattern in which every amino acid is equally limiting. Because all essential amino acids are equally limiting, this should reduce the amount of excess amino acids that must be metabolized. Theoretically, this would allow energy used in the breakdown and catabolism of excess amino acids to be used for growth, thus improving pig performance. Therefore, the objective of this experiment was to determine the effects of diets fortified with synthetic

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[1]This experiment was a cooperative research project between the University of Missouri and Kansas State University. The authors wish to thank Murphy Farms, Inc., Rose Hill, NC and Pig Improvement Co., Franklin, KY for providing the pigs used in this experiment and Nutri-Quest Inc., Chesterfield, MO for donating synthetic amino acids.

[2]Dept. of Anim. Sci., Univ. of Missouri, Columbia 65211.

[3]USDA-ARS, Animal Physiol. Unit, Columbia, MO.

amino acids to produce an "ideal" amino acid pattern (NRC, 1988) in two types of environments (thermoneutral and heat stress) on performance of finishing gilts.

Experimental Procedure

A total of 56 crossbred gilts (Line 26, Pig Improvement Company, Franklin, KY) with initial BW of 155 ± 2 lb was used in the experiment. Eight gilts were slaughtered at the start of the study for determining initial carcass composition. Forty-eight gilts were blocked by weight and randomly assigned to one of eight experimental treatments in a 2 × 2 × 2 factorial arrangement with six replicate pens per treatment. The independent variables were temperature (thermonuetral: 68°F vs hot, diurnal: 82 to 95°F), dietary lysine (.60 vs 1.00%), and source of amino acid fortification (intact protein vs synthetic amino acids formulated on an ideal protein basis). The ideal protein diets (Table 1) were formulated by using corn and soybean meal to meet the 5th limiting amino acid. The synthetic amino acids added to achieve the desired dietary level were L-lysine. HCl, L-threonine, L-tryptophan, L-isoleucine, and D-L methionine. In the .60 and 1.00% lysine ideal protein diets, the order of limiting amino acids changed as the level of lysine increased; thus, the fifth limiting amino acids were calculated to be methionine and isoleucine, respectively. The ideal amino acid ratio used to formulate the diets was suggested for 110 to 240 lb pigs by NRC (1988) and used total amino acid values. The ratios of other amino acids relative to lysine were: threonine 66%, tryptophan 17%, methionine and cystine 56%, and isoleucine 63%. All diets were processed through a pellet mill equipped with a 4/16 in. die.

The facilities for this experiment consisted of four environmental chambers in the Samuel Brody Climatology Laboratory in the Animal Sciences Research Center at the University of Missouri. The two thermoneutral (TN) chambers were maintained at 68°F with an average relative humidity of 50%. The other two chambers used for the heat stress treatment (HS) cycled from a low of 82°F between 12:00 am to 10:00 am to a high of 95°F between 11:00 am to 7:00 pm (an increase of 2°F/h). The relative humidity in these chambers fluctuated between 50 and 75%, inversely related to temperature. Each environmental chamber contained 12, 4 ft × 4 ft pens in order to individually house pigs. Each chamber room contained three pens per dietary treatment.

Gilts were electrically stunned and exsanguinated when live weight reached approximately 225 lb. The carcass was weighed and standard carcass measurements were recorded. In addition, the longissimus muscle area was evaluated for color, firmness, and marbling. The left side of the carcass was passed twice through a grinder equipped with a 1/4 in. die, and samples were analyzed for DM, CP, lipid, and ash content. Protein, lipid, moisture, and ash accretion rates were determined by differences between the average of the initial eight gilts and final individual carcass composition.

Results and Discussion

Growth Performance. No temperature × lysine × amino acid source interactions were observed ($P > .05$) for average daily gains (ADG), average daily feed intake (ADFI), and feed efficiency (F/G). A temperature × amino acid source interaction ($P<.10$) was found for ADG during d 0-14. Gilts in the TN environment consuming the ideal and intact protein diets had ADGs of 2.25 and 2.03 lb; however, gilts in the HS environment had ADGs of 1.5 and 1.68 lb, respectively. Also, a tendency for a temperature × dietary lysine interaction was observed ($P = .07$) for ADG d 0-28 (Table 2). Average daily gain increased for gilts in the HS environment as dietary lysine increased from .60 to 1.00% (1.39 and 1.68 lb, respectively), whereas gilts at TN were not affected (2.09 and 2.05 lb, respectively). During d 0-14, ADG for gilts fed the 1.00% lysine diet was higher ($P = .01$) compared to gilts fed

the .60% lysine diet (2.03 and 1.65 lb) regardless of environmental temperature. Average daily gain was similar for gilts fed either .60 or 1.00% lysine during d 0-28 and the overall test period, (P = .23 and .38, respectively). Gain for gilts consuming the intact and ideal protein diets were 1.76 and 1.83 lb, respectively (P = .68). Overall, gilts in the HS environment grew slower than gilts at TN (P = .01; 1.50 and 2.07 lb)

A temperature × amino acid source interaction (P = .01) was observed for ADFI d 0-14. Average daily feed intakes for gilts fed ideal protein in the HS environment were lower than those of gilts fed intact protein diets (5.66 and 4.67 lb), whereas at TN, the opposite occurred (6.17 and 7.19 lb). Overall, feed intakes for gilts fed the intact and ideal protein diets were 5.66 and 5.77 lb (P = .64). As expected, gilts in the HS environment consumed less feed than gilts at TN (P = .01; 4.96 and 6.48 lb).

Over the entire study, a temperature × dietary lysine interaction (P = .01) for feed efficiency was observed (Table 2). Feed efficiency was improved when dietary lysine increased from .6 to 1.00% in the HS environment; however, no differences were noted for gilts in the TN environment. Feed efficiencies for gilts fed the intact and ideal protein diets were 3.22 and 3.13, respectively. Gilts in the HS environment tended (P = .16) to have poorer feed efficacy than gilts at TN. Because pigs were removed at a constant final weight, the number of days on trial varied from 28 to 49. Pigs in the HS environment required 9.9 additional days (P = .01) to reach 225 lb (Table 2).

Carcass Composition and Tissue Accretion Rates. A tendency (P = .07) for a temperature × dietary lysine × amino acid source interaction was observed for carcass protein composition (Table 3). Carcasses from gilts in the HS environment consuming the 1.00% lysine protein diets had the highest percentage of carcass protein. A tendency (P = .07) for a lysine × amino acid source interaction also was observed for carcass protein composition. The amount of carcass protein with the .60% lysine ideal protein diets was reduced when compared to carcasses from gilts fed the .60% lysine intact protein diets (15.89 and 16.05%); however, carcass protein was found to higher in the gilts fed the 1.00% lysine ideal protein diets vs the 1.00% lysine intact protein diets (16.94 vs 16.50%). An inverse relationship for carcass fatness resulted in a dietary lysine × amino acid source interaction (P = .05). Percentages carcass lipid for the .60% lysine intact and ideal protein diets and the 1.00% lysine intact and ideal protein diets were 28.49, 29.83, 27.05, and 25.74, respectively.

Carcass of gilts fed 1.00 vs .60% dietary lysine contained (P = .01) higher amounts of moisture (54.13 and 51.89%), protein (16.72 and 15.97%) and less lipid (26.39 and 29.17%). Also, carcasses from gilts in the HS environment contained higher amounts of moisture (54.19 and 51.83%), protein (16.70 and 15.99%), and less lipid (26.29 and 29.27%). As a result of the reduced growth rate for the gilts raised in the HS environment, accretion rates for moisture (132.52 and 166.52 g/d), protein (45.24 and 57.50 g/d) and lipid (110.77 and 201.72 g/d) were reduced (Table 3). Gilts fed 1.00% lysine vs .60% dietary lysine also had increased protein accretion (P = .15; 54.97 vs 47.76 g/d) and decreased lipid accretion (P = .08; 139.30 vs 173.11 g/d).

Carcass Characteristics. An interaction for dietary lysine × amino acid source occurred for average backfat thickness (P = .07). Gilts fed the ideal and intact protein diets with .60% dietary lysine had average backfat thicknesses of 1.20 and 1.10 in., respectively (Table 4), whereas diets with 1.00% dietary lysine resulted in less average backfat for the ideal vs the intact protein diets (1.06 vs 1.10 in., respectively). Gilts fed 1.00% dietary lysine had less (P = .01) leaf fat, backfat thickness, and tenth rib fat thickness; larger longissimus muscle area; and decreased dressing percentage (P = .05) than

gilts fed .60% dietary lysine. Also, gilts in the HS environment had a higher (P = .01) dressing percentage than gilts at TN (73.59 and 71.64%, respectively). Marbling (P = .10) and firmness (P = .32) scores for gilts fed .60 and 1.00% were 1.93 vs 1.65 and 2.54 vs 2.40, respectively. Gilts fed the intact compared with the ideal protein diets had marbling scores of 1.85 and 1.71, respectively (P = .33).

Our data indicate that HS was primarily responsible for altering ADG and ADFI with little influence from lysine level and source of amino acids. The depressed ADG observed in the HS gilts can be largely attributed to the 23.7% decrease in ADFI and resulting in lower lysine intakes. Feeding the ideal compared to the intact protein diets at TN numerically increased ADG and ADFI, but not at HS (P > .05). Increasing dietary lysine had no effect on feed efficiency in gilts housed in a TN environment, but improved feed efficiency in gilts in a HS environment. Source of amino acid fortification did not influence feed efficiency. Dietary lysine influenced carcass composition and characteristics to a greater degree than did source of amino acid fortification. Carcasses from gilts fed .60% dietary lysine contained more lipid and less protein than carcasses from gilts consuming the 1.00% dietary lysine. Consequently, carcass characteristics for lipid (i.e., average backfat, leaf fat, tenth rib fat, and marbling) and protein (longissimus muscle area) were affected accordingly (P < .10).

In conclusion, results of this experiment indicate that gilts (150 lb) respond to increased dietary lysine with improved feed conversion and carcass leanness under heat stress; however, source of amino acid fortification did not influence growth performance, carcass characteristics, or quality. Thus, low-protein amino acid-fortified diets may be efficiently utilized by the ad libitum fed finishing pig. The future application of such diets will be evaluated on an economic basis. It would appear that the potential energy conservation from minimizing excess amino acids may not be great enough to influence pig performance or that minor excesses or deficiencies possible by formulating on a total amino acid basis in this study prevented expression of superior performance. However, factors such as growth rate and lean accretion, feed intake, environmental temperature, and gender may influence requirements to such an extent that one definitive ideal protein is impractical.

Table 1. Diet Composition[a]

	Percentage			
	.60% lysine		1.00% lysine	
Item	Intact	Ideal[b]	Intact	Ideal
Corn	84.48	93.85	70.53	79.58
Soybean meal, 48% CP	11.80	1.52	26.05	16.24
Monocalcium phosphate	1.12	1.31	.87	1.05
Soybean oil	1.00	1.00	1.00	1.00
Limestone	.94	.97	.88	.92
Vitamin premix	.25	.25	.25	.25
Salt	.25	.25	.25	.25
Trace mineral premix	.10	.10	.10	.10
Selenium premix	.05	.05	.05	.05
L-Lysine. HCl	-	.36	-	.35
L-Threonine	-	.10	-	.14
L-Isoleucine	-	.04	-	-
L-Tryptophan	-	.03	-	.01
DL-Methionine	-	-	-	.03
Calculated analysis				
ME, Mcal/lb	1.52	1.51	1.52	1.51
CP, %	12.74	8.69	18.29	14.46
Crude fat, %	4.40	4.68	3.99	4.25
Ca, %	.65	.65	.65	.65
P, %	.55	.55	.55	.55
Chemical analysis, %				
Lysine	.60	.60	1.00	1.00
Arginine	.75	.44	1.18	.88
Histidine	.36	.25	.52	.41
Isoleucine	.54	.38	.83	.63
Leucine	1.33	1.04	1.71	1.44
Methionine	.22	.17	.29	.28
Phenylalanine	.65	.44	.94	.74
Threonine	.45	.40	.67	.66
Tryptophan	.13	.10	.22	.17
Valine	.66	.44	.95	.75

[a]As fed basis.
[b]According to NRC (1988) suggested estimates, a .60 and a 1.00% lysine ideal protein diet would contain the following amino acid levels, Arg:.10, .17; His: .18, .30; Iso: .38, .63; Leu: .50, .83; Meth & Cys: .34, .56; Phe & Tyr: .55, .91; Thr: .40, .66; Try: .10, .17; Val: .40, .66%, respectively.

Table 2. Effects of Environmental Temperature, Dietary Lysine, and Amino Acid Source on Performance of Finishing Gilts[a]

	Thermoneutral[b]				Heat Stress										
	.60% Lysine		1.00% Lysine		.60% Lysine		1.00% Lysine			Contrasts					
Item	Intact[c]	Ideal[d]	Intact	Ideal	Intact	Ideal	Intact	Ideal	SE	Temp (T)	Lysine (L)	Source (S)	T×L	T×S	L×S
ADG, lb															
0-14 d	1.87	2.05	2.16	2.40	1.54	1.17	1.78	1.82	.15	.01	.01	.88	.56	.10	.29
0-28 d	2.03	2.18	1.98	2.12	1.43	1.32	1.61	1.74	.13	.01	.23	.44	.07	.57	.54
Overall	2.03	2.16	2.03	2.12	1.41	1.39	1.61	1.61	.13	.01	.38	.63	.22	.58	.88
ADFI, lb															
0-14 d	5.91	7.01	6.43	7.38	5.58	4.80	5.75	4.56	.57	.01	.60	.95	.55	.01	.71
0-28 d	6.19	6.76	6.26	6.67	5.11	4.87	5.22	4.78	.37	.01	.99	.77	.97	.12	.72
Overall	6.22	6.74	6.33	6.64	4.91	5.03	5.18	4.70	.33	.01	.93	.64	.93	.22	.39
Feed/gain															
0-14 d	3.13	3.33	2.94	2.85	3.57	4.00	3.13	2.50	.33	.46	.01	.67	.19	.49	.12
0-28 d	3.03	3.13	3.13	3.13	3.57	3.70	3.23	2.78	.25	.25	.07	.36	.02	.34	.22
Overall	3.13	3.13	3.13	3.13	3.57	3.57	3.23	2.85	.15	.16	.06	.49	.02	.38	.27
Avg days on trial	36.16	35.00	33.83	35.00	49.00	45.50	42.00	43.16	3.00	.01	.18	.78	.41	.78	.41

[a]A total of 48 gilts with an average initial weight of 156 lb. Pigs were removed from the experiment when weight reached 225 lb.
[b]Thermoneutral: 68°F, relative humidity 50%. Heat stress: 82° to 95°F.
[c]Soybean meal was the primary source of amino acid fortification to the diet.
[d]Synthetic amino acids were the primary sources of amino acid fortification to the diet.

Table 3. Effects of Environmental Temperature, Dietary Lysine, and Amino Acid Source on Carcass Chemical Composition and Tissue Accretion Rates of Finishing Gilts[a]

	Thermoneutral[b]				Heat Stress										
	.60% Lysine		1.00% Lysine		.60% Lysine		1.00% Lysine			Contrasts					
Item	Intact[c]	Ideal[d]	Intact	Ideal	Intact	Ideal	Intact	Ideal	SE	Temp (T)	Lysine (L)	Source (S)	T×L	T×S	L×S
Carcass Composition, %															
Moisture	51.76	50.51	51.76	53.28	53.51	51.78	55.55	55.94	.77	.01	.01	.63	.13	.47	.03
Protein[d]	16.01	15.50	15.88	16.58	16.10	16.28	17.13	17.31	.22	.01	.01	.40	.09	.78	.07
Lipid	29.33	30.81	29.51	27.41	27.70	28.85	24.56	24.06	.93	.01	.01	.98	.08	.63	.05
Ash	2.60	2.96	2.81	3.03	2.85	2.85	2.83	2.88	.12	.98	.42	.09	.47	.16	.78
Tissue accretion, g/d															
Moisture	167.41	156.53	172.99	169.17	113.63	118.06	144.20	154.20	24.11	.05	.23	.99	.49	.68	.85
Protein	58.28	53.48	57.66	60.56	36.27	43.02	48.22	53.45	7.13	.01	.15	.61	.44	.50	.75
Lipid	207.87	225.56	205.61	167.83	110.60	148.39	88.58	95.51	26.30	.01	.08	.74	.84	.40	.25
Ash	7.50	12.31	10.50	12.36	6.83	7.47	9.06	6.63	2.37	.06	.51	.47	.80	.22	.37

[a]Data collected from 48 gilts with a final weight of 102.7 kg.
[b]Thermoneutral: 68°F, relative humidity 50%. Heat stress: 82 to 95°F.
[c]Soybean meal was the primary source of amino acid fortification to the diet.
[d]Synthetic amino acids were the primary sources of amino acid fortification to the diet.
[e]Temperature × lysine level × source interaction (P=.07).

Table 4. Effects of Environmental Temperature, Dietary Lysine, and Amino Acid Source on Carcass Characteristics and Organ Weights of Finishing Gilts[a]

	Thermoneutral[b]				Heat Stress										
	.60% Lysine		1.00% Lysine		.60% Lysine		1.00% Lysine			Contrasts					
Item	Intact[c]	Ideal[d]	Intact	Ideal	Intact	Ideal	Intact	Ideal	SE	Temp (T)	Lysine (L)	Source (S)	T×L	T×S	L×S
Carcass characteristics															
Avg backfat, in.	1.12	1.17	1.09	.98	1.10	1.24	1.09	1.44	.06	.17	.01	.33	.36	.06	.07
Tenth rib fat, in.	.83	.99	.80	.46	.89	.89	.80	.77	.06	.92	.01	.68	.62	.55	.10
Leaf fat, lb	2.40	2.65	2.24	2.16	2.38	2.77	2.11	1.98	.26	.61	.01	.45	.51	.84	.17
Carcass length, in.	30.00	30.40	29.60	30.80	31.00	30.40	30.80	30.10	.40	.21	.92	.76	.67	.01	.83
Longissimus muscle area, in.^{2}	4.99	4.88	5.57	5.37	5.23	5.32	5.51	6.11	.28	.15	.01	.60	.97	.21	.58
Dressing percentage	71.88	72.23	70.99	71.47	73.84	74.06	73.04	73.41	.53	.01	.05	.36	.90	.87	.85
Color[d]	2.00	2.08	2.16	2.25	2.33	2.08	2.00	2.01	.20	.90	.90	.90	.22	.50	.66
Firmness[e]	2.25	2.41	2.50	2.33	2.75	2.75	2.25	2.53	.19	.16	.32	.61	.11	.61	.92
Marbling[f]	1.83	2.16	1.90	1.50	2.08	1.66	1.66	1.47	.24	.46	.10	.33	.97	.46	.46

[a]Data collected from 48 gilts with a final weight of 102.7 kg. Final weight was used as a covariate for leaf fat, avg backfat, tenth rib fat, carcass length, longissimus muscle area and organ weights.
[b]Thermoneutral: 68°F, relative humidity 50%. Heat stress: 82 to 95°F.
[c]Soybean meal was the primary source of amino acid fortification to the diet.
[d]Synthetic amino acids were the primary sources of amino acid fortification to the diet.
[e]Based on a scale with 1 = extremely pale, 3 = normal, 5 = extremely dark.
[f]Based on a scale with 1 = extremely soft, 3 = normal, 5 = extremely firm.
[g]Based on a scale with 1 = trace, 3 = small, 5 = abundant.

SUSTAINED EFFECTS OF PORCINE SOMATOTROPIN ADMINISTERED DURING THE GROWING PERIOD ON GROWTH AND CARCASS CHARACTERISTICS OF FINISHING PIGS

G. E. Fitzner, R. H. Hines, and D. H. Kropf

Summary

Forty six barrows were fed a common diet after completing a 35 d growth trial in which 50% received 5 mg/d of pST and the other 50% a placebo injection. At the conclusion of the growing trial (130 lb), the pST-injected pigs were leaner (22%) and yielded carcasses with larger longissimus muscle area (21%). However, pigs fed to a slaughter weight of 225 lb yielded carcasses that were not different from control pigs in length, longissimus muscle area, or belly weights. Pigs administered pST during the growing phase continued to have 10% less backfat, which resulted in a 1.6% greater yield of lean cuts. Postinjection growth rate of pST-treated pigs was significantly reduced for the initial 2 wk to cause an overall reduced ADG during the finishing period. Days to reach slaughter did not differ with treatment because those pigs previously receiving pST were heavier initially. There is no advantage to injecting pigs with pST during the growing phase to improve overall growth. However, pST administration during the growing phase appears to have a sustained effect on carcass fat thickness of pigs slaughtered at 225 lb.

(Key Words: GF, Performance, Carcass, Repartition.)

Introduction

Exogenous administration of porcine somatotropin (pST) has been reported (1991 KSU Swine Day Report of Progress 641) to increase average daily gain (ADG), reduce average daily feed intake (ADFI), and improve feed efficiency (F/G) of growing pigs from 68 lb to 130 lb. In addition, injection of pST (5 mg/d) resulted in reduced average backfat thickness and tenth rib fat depth and increased longissimus area compared to control pigs receiving a placebo injection. The question of carryover effect of these observed parameters for growth and carcass characteristics in the growing pig has not been routinely evaluated at market weight. Therefore, the purpose of this trial was to determine if pST can be given in the growing phase and improve finishing performance and carcass characteristics at a final weight of 225 lb.

Procedure

Growing Phase. One hundred and twenty crossbred (Chester White × Hampshire × Yorkshire) barrows were allotted by weight and ancestry in a 2 × 6 factorial arrangement. Six diets were formulated to contain .7, 1.1, 1.5, 1.9, 2.3, or 2.7% lysine and fed to barrows receiving either a placebo (0 mg/d) or pST (5 mg/d) injection. Results of the performance and carcass characteristics of this trial are reported in the 1991 KSU Swine Day Report of Progress 641. The pigs started on the 5 wk trial at 68 lb; the 72 head slaughtered at termination weighed 130 lb.

Finishing Phase. On d 36, the 46 remaining pigs were fed a common diet formulated to contain .9% lysine (Table 1). Pigs were fed to a live wt of 225 lb, at which time they were removed individually for slaughter to determine carcass characteristics. Carcasses were chilled for 24 hr at 40°C before obtaining standard carcass measurements (carcass length, average backfat thickness, tenth rib fat depth, and longissimus muscle area). The right half of each carcass was broken into

wholesale cuts with weights of closely trimmed ham, loin, Boston butt, and picnic shoulder determined to calculate percentage of lean cuts. Belly weight was also recorded to determine the carryover effect of pST administration during the growing phase on a fatter wholesale cut.

Table 1. Composition of Finishing Diet[a]

Ingredient	%
Ground corn	77.87
Soybean meal (48% CP)	19.45
Monocalcium phosphate	.75
Limestone	.88
Salt	.50
L-lysine ·HCl	.15
Selenium premix	.05
Vitamin premix	.25
Mineral premix	.10

[a]Calculated composition: 16.0% crude protein, .90% lysine, .60% calcium, .50% phosphorous, and 3.32 ME, Mcal/kg.

Pigs were housed in an environmentally controlled building with a totally slatted floor. Pigs were fed ad libitum from self feeders and had access to a nipple waterer. Pigs were weighed at wk 1, 2, and 3 to determine the carryover effect of pST on growth. Pigs were then weighed once every 2 weeks to monitor performance before slaughter.

Results and Discussion

Postinjection Finishing Performance. Because pigs were assigned to experimental treatment for a fixed time (35 d) during the growing period, the postinjection initial weight was greater for the pST-treated pigs. Pigs were slaughtered at a constant weight (225 lb), thus, the overall gain was inversely affected by the initial weight.

During the first week, pigs previously given pST had reduced (P<.01) ADG compared to control pigs. The reduction in ADG (P<.01) continued through wk 2 for the pST pigs. Although not significant, the trend in lower ADG continued through wk 3. During the overall finishing period, ADG of pigs previously treated with pST was reduced (P<.01) by 9% compared to control pigs. Days to slaughter were not affected by pST treatment or by dietary lysine treatment during the growing period.

Carcass Characteristics of Finishing Pigs. Dressing percentage, carcass length, longissimus muscle area, and belly weight of finishing pigs were not affected by treatment with pST during the 35 d growing period (Table 2). Tenth rib fat depth and average backfat thickness were reduced (P<.05) in pigs treated with pST compared to control pigs. The leaner carcasses resulted in an increased (P<.05) percentage of lean cuts for those pigs that were given pST during the growing period. Weights of liver and heart were not affected by treatment with pST; however, kidneys were heavier in the pST-treated pigs.

Pigs administered pST (5 mg/d) during the growing phase gained 13% faster and were 22% leaner as measured by average backfat thickness. In addition, the loin eyes were 21% larger. Only a 10% reduction in average backfat thickness carried over through the finishing phase to slaughter weight after the 35 d injection period.

Table 2. Effect of Porcine Somatotropin (pST) Administration to Growing Pigs on Postinjection Growth Performance of Finishing Pigs[a]

	Grower treatment	
Item	Placebo	5 mg/d pST
Post injection initial wt, lb[b]	124.3	131.1
Average daily gain, lb		
Wk 1[b]	1.43	1.00
Wk 2[b]	1.79	1.34
Wk 3	1.67	1.50
Overall[b]	1.53	1.38
Days to slaughter	67.2	68.5
Slaughter wt, lb	225.5	225.1
Dressing percentage	74.5	74.0
Carcass length, in.	31.4	31.5
Tenth rib fat depth, in.[b]	1.23	1.07
Average backfat thickness, in.[b]	1.26	1.14
Longissimus muscle area, sq. in.	4.74	4.80
Lean cuts, %[b]	54.6	56.2
Belly wt, lb	15.4	15.0

[a]Means represent 23 pigs/treatment.
[b]$P<.05$.

INTERACTIVE EFFECTS OF PORCINE SOMATOTROPIN AND THE BETA-AGONIST SALBUTAMOL ON GROWTH AND CARCASS CRITERIA OF THREE GENOTYPES OF SWINE

J. A. Hansen, J. T. Yen[1], J. L. Nelssen, J. A. Nienaber[1], T. L. Wheeler[1], J. Klindt[1], and R. D. Goodband

Summary

The objective of this research was to examine the interactive effects of porcine somatotropin (pST) and the beta-agonist salbutamol on the growth and carcass characteristics of three genotypes of pigs differing in lean and fat deposition potential. Thirty-two pigs each of either 1/4 Duroc-3/4 white composite (Duroc crossbred), purebred Meishan, or 1/4 Meishan-3/4 white composite (Meishan crossbred) breeding were injected daily with 0 or 4 mg pST and fed a diet containing 0 or 2.75 ppm salbutamol for approximately 34 d and subsequently slaughtered. As the percentage Meishan in the genotype increased, loin muscle area, semitendinosus weight, average daily gain (ADG), and carcass gain decreased. There was an interaction between salbutamol and genotype for ADG, daily protein gain, and total carcass gain, resulting in Meishan crossbred pigs having similar rates to non-treated Duroc crossbred pigs. When Duroc crossbred pigs were treated with salbutamol, both daily protein gain and total carcass gain were greatest, whereas ADG was nonsignificantly greater than that of untreated Duroc crossbred and salbutamol-treated Meishan crossbred pigs. Meishan pigs did not respond to salbutamol treatment for the criteria mentioned. Both pST and salbutamol increased loin muscle area and semitendinosus weight across genotypes. Leaf fat was reduced more by pST treatment in purebred Meishan pigs than in the other two genotypes, and salbutamol treatment resulted in small reductions in leaf fat across genotypes. Efficiency of feed utilization was similar among genotypes but increased with either pST or salbutamol treatment. The results of this research indicate that porcine somatotropin and the beta-agonist salbutamol have additive effects on the growth and carcass criteria of pigs. However, both growth modifiers appear to have differing degrees of response in different genotypes of swine.

(Key Words: G-F, Performance, Carcass, Repartitioning, Hormone)

Introduction

Porcine somatotropin (pST) is an effective modifier of swine growth. In general, pST increases both daily protein accretion and total carcass protein mass, while causing reductions in carcass fat percentage and daily fat accretion. The efficiency of feed utilization is greater for pST-treated pigs than non-treated pigs as well. To a lesser degree, beta-agonists (in particular salbutamol) increase both daily protein accretion and carcass protein mass but have a less profound effect on carcass fat content and accretion. Improvements in feed efficiency have been observed when salbutamol is included in the diet. Limited research is available concerning the combined use of pST and a beta-agonist on pig performance and carcass criteria. Thus, the purposes of this research were to determine if the combined use of porcine

[1]This was a cooperative research study with researchers at the USDA-ARS, Roman L. Hruska Meat Animal Research Center, Clay Center, NE. Appreciation is expressed to S. Cummins for technical assistance, data collection, and sample analyses.

somatotropin and the beta-agonist salbutamol would result in additive or interactive changes in growth and carcass criteria and to evaluate these responses in three genotypes of pigs differing in lean and fat deposition potential.

Procedures

A total of 120 pigs was used in an experiment lasting approximately 34 d. The three genotypes equally represented were of the following ancestry: 1/4 Duroc - 3/4 white composite (Duroc crossbred); purebred Meishan; and 1/4 Meishan - 3/4 white composite (Meishan crossbred). Because purebred Meishan pigs exhibit a slow growth rate, all pigs were placed on test at a similar age (130 to 140 d). The biological treatments imposed were 0 or 4 mg pST/d in combination with 0 or 2.75 ppm salbutamol in the diet resulting in a 2 × 2 × 3 factorial treatment arrangement. Pigs were housed in 4 ft × 4 ft pens and allowed ad libitum access to feed and water. A 1.20% lysine corn-soybean meal diet containing 5% each select menhaden fish meal and porcine plasma protein and 2% soybean oil was fed throughout this research (see Hansen et al., 1991; KSU Swine Industry Day, Report of Progress 641, p. 112 for details). Initial carcass composition was estimated from the composition of eight pigs from each genotype slaughtered at the beginning of the study. The remaining 96 pigs were randomly allotted to one of four biological treatment groups and placed on test at weekly intervals. Average daily gain (ADG), average daily feed intake (ADFI), and feed:gain (F/G) were measured from 0 to 28 d. Organ weights were obtained immediately postmortem, whereas loin muscle area and semitendinosus weight were obtained at approximately 6 h postmortem. The right half of each carcass was ground for analysis of water, fat, protein, and ash and computation of daily component accretion rates.

Results and Discussion

No interactions were observed between pST and salbutamol. However, significant interactions were observed between genotype and both pST and salbutamol. Therefore, results are presented in two tables. Table 1 represents the means for the criteria where a significant pST or salbutamol × genotype interaction was observed. Consequently, those values are not presented in Table 2, which shows the main effect means for each genotype and biological treatment.

Meishan pigs consumed the least amount of feed ($P<.05$) among genotypes, resulting in the slowest rate of growth and accretion of carcass components ($P<.05$). Average daily gain, daily protein accretion, and daily total carcass gain were similar for Meishan crossbred pigs treated with salbutamol and the untreated Duroc crossbred pig. When Duroc crossbred pigs consumed salbutamol, both daily carcass accretion and daily protein accretion were greatest ($P<.05$) among treatments, whereas ADG was nonsignificantly greater than that of untreated Duroc crossbred pigs. Salbutamol increased the proportions of protein and water in the carcass at the expense of both carcass fat and ash ($P<.05$) across genotypes. Daily water accretion was increased across genotypes with salbutamol treatment, although daily accretions of fat and ash were unaltered by salbutamol feeding. Salbutamol did not influence ADG, daily carcass gain, or daily protein gain in purebred Meishan pigs. Porcine somatotropin injection resulted in a greater proportion of the carcass being protein, water, and ash ($P<.05$) at the expense of carcass fat. Consequently, accretion rates for these components were increased ($P<.05$) at the expense of carcass fat. Although no differences were detected between genotypes for carcass composition, it is important to realize that purebred Meishan pigs would have been considerably fatter at a similar weight compared to the other two genotypes.

Both pST and salbutamol improved (P<.05) the efficiency of feed utilization independently of genotype. Although purebred Meishan pigs consumed less feed than the other two genotypes, no differences were observed in feed efficiency across genotypes. Loin muscle area and semitendinosus weight increased with a decreasing proportion of purebred Meishan in the genotype (P<.05), and both were increased with pST and salbutamol treatment (P<.05), resulting in an additive response. Both liver and kidney weights were higher (P<.05) in purebred Meishan pigs and with pST treatment, whereas salbutamol decreased liver mass. Leaf fat weight was reduced with salbutamol treatment across genotypes, but reduced more in purebred Meishan pigs than others with pST treatment, suggesting a more profound effect in fattier genotypes.

In summary, no interactions between pST and salbutamol were observed for the criteria presented. Consequently, these data indicate that the combined use of pST and salbutamol results in an additive response to each growth modifier. Furthermore, these data indicate that both growth modifiers have differential effects in different genotypes of swine.

Table 1. Mean Differential Response to Somatotropin and Salbutamol Treatment among Genotypes[ab]

	D × Wc		M		M × Wc		
Item	Buffer Basal	pST Salb	Buffer Basal	pST Salb	Buffer Basal	pST Salb	SD
Somatotropin							
Leaf fat, %	1.56^{vw}	1.05^{xy}	2.12^{z}	1.01^{x}	1.82^{v}	1.31^{wy}	.41
Salbutamol							
ADG, lb (0 to 28 d)	2.01^{w}	2.18^{w}	1.30^{x}	1.17^{x}	1.70^{y}	2.01^{w}	.33
Protein accretion, g/d	78^{w}	102^{x}	39^{y}	47^{y}	62^{z}	95^{x}	17
Total accretion, g/d	496^{w}	567^{x}	233^{y}	225^{y}	376^{z}	493^{w}	83

[a]Values are means of 15 (D × Wc-Basal and M-Basal) or 16 pigs each. Values are presented for traits only observing a significant (P<.05) interaction.

[b]D × Wc = Duroc × white composite; M = Meishan; M × Wc = Meishan × white composite; Buffer = 0 mg/d somatotropin; pST = 4 mg/d somatotropin; Basal = 0 ppm salbutamol; Salb = 2.75 ppm salbutamol.

[vwxyz]Values in the same row lacking a common superscript are different (P<.05).

Table 2. Least Square Main Effect Means for Growth and Carcass Criteria[ab]

	Genotype			Injection		Diet			Significance[c]
Item	D × Mc	M	M × Wc	Buffer	pST	Basal	Salb	SD	P<.05
Initial wt, lb	137	108	141	130	128	130	128	13	G1,2
Slaughter wt, lb (d-34)	198	141	194	174	181	179	176	18	G1,2
ADG, lb (0 to 28 d)	-	-	-	1.65	1.81	-	-	.33	G × S; P
ADFI, lb (0 to 28 d)	2.63	1.66	2.56	2.59	1.98	2.31	2.26	.79	G1,2; P
Feed/gain (0 to 28 d)	2.70	2.86	2.94	3.45	2.44	2.94	2.78	.51	P; S
Dressing percentage	64	51	62	60	58	59	60	2	G1,2,3; P; S
Loin muscle area, in^2	5.20	2.55	4.76	3.90	4.39	3.91	4.42	.66	G1,2,3; P; S
Semitendinosus wt, %	.42	.21	.33	.30	.34	.30	.33	.04	G1,2,3; P; S
Leaf fat, %	-	-	-	-	-	1.56	1.39	.41	G × P; S
Liver, %	1.71	1.86	1.70	1.53	1.98	1.82	1.69	.23	G1,2; P; S
Kidney, %	.36	.43	.35	.33	.43	.38	.38	.11	G1,2; P
Water, %	53.8	53.4	52.2	49.1	57.2	51.8	54.5	3.6	P; S
Fat, %	27.4	27.8	29.4	33.7	22.7	30.0	26.4	4.9	P; S
Protein, %	15.7	15.5	15.3	14.2	16.8	15.0	16.0	1.1	P; S
Ash, %	2.9	3.1	2.9	2.8	3.2	3.0	2.9	0.3	P; S
Water accretion, g/d	77	129	241	158	273	186	246	56	G1,2,3; P; S
Fat accretion, g/d	150	50	100	173	27	111	89	76	G1,2,3; P
Protein accretion, g/d	-	-	-	53	88	-	-	17	G × S; P
Ash accretion, g/d	14	7	14	9	15	12	12	5	G1,2; P
Total accretion, g/d	-	-	-	393	404	-	-	83	G × S

[a]For genotype values are means of 31 pigs (D × Wc and M) or 32 pigs (M × Wc). For injection, values are means of 48 pigs (Buffer) or 46 pigs (pST). For diet values are means of 46 (Basal) or 48 pigs (Salb).

[b]D × Wc = Duroc × white composite; M = Meishan; M × Wc = Meishan × white composite; Buffer = 0 mg/d somatotropin; pST = 4 mg/d somatotropin; Basal = 0 ppm salbutamol; Salb = 2.75 ppm salbutamol.

[c]Comparison for pST (P), salbutamol (S) and genotype [G (1 = D × Wc vs M; 2 = M vs M × Wc; 3 = D × Wc vs M × Wc)]. Values are presented separately for criteria involving significant interactions (P<.05).

EFFECTS OF THE INTERRELATIONSHIP OF PORCINE SOMATOTROPIN ADMINISTRATION AND DIETARY PHOSPHORUS ON BONE PROPERTIES IN DEVELOPING GILTS[1]

T. L. Weeden, J. L. Nelssen, R. D. Goodband, J. A. Hansen, K. G. Friesen, and B. T. Richert

Summary

Seventy-two gilts (initial weight = 127 lb) were used to determine effects of the interrelationship of porcine somatotropin (pST) administration and dietary phosphorus (P) on bone mechanical properties and mineralization in finishing gilts (127 to 235 lb) and for a 35-d postfinishing phase following withdrawal of pST administration. Gilts were injected daily with placebo (control) or 4 mg pST and fed .4, .6, or .8% P in the finishing phase. When each block weight averaged 235 lb, half of the gilts were slaughtered and the first rib, femur, and third and fourth metacarpals were collected. Stress; modulus of elasticity; and ash content of rib, femur, and metacarpals were reduced and femur wall thickness was increased in pST-treated gilts. Increasing dietary P increased bending moment, stress, and ash content for all bones collected, with the exception of metacarpal stress, which was not affected. The remaining 36 gilts were individually fed 4 lb/d of a common diet to assure P intake of 22.8 g/d for the 35 d postfinishing phase. Gilts receiving higher levels of dietary P during the finishing phase had increased bending moment and ash content for the rib and femur; rib stress and femur wall thickness were also increased following the postfinishing phase. Gilts administered pST during the finishing phase exhibited a compensatory increase in mineralization as evidenced by equal stress values for rib, femur, and metacarpals compared to control gilts by the end of the postfinishing phase. Although bone strength and mineralization were lower in pST-treated gilts than controls at the end of the finishing phase, if pST-treated gilts were fed at least a .6% P diet (16.5 g/d P) during the finishing phase, then bone strength and mineralization similar to those of control gilts could be attained with a diet containing at least 18 g P and 22.5 g Ca daily during the postfinishing phase.

(Key Words: Somatotropin, Phosphorus, Gilts, Bone.)

Introduction

In the event that porcine somatotropin (pST) is approved for use and adapted by swine producers, gilts treated with pST may ultimately be kept in the breeding herd. This may alter how these gilts must be fed during the finishing phase and prior to breeding. Previous research at Kansas State University has established that pST-treated pigs have decreased bone strength at the end of the finishing phase. Therefore, the major question in using pST-treated gilts in the sow herd would be longevity. In a previous study, we confirmed that pST-treated gilts had decreased bone strength and mineralization at the end of the finishing phase and that even feeding 300% of NRC (1988) estimates for Ca and P could not maximize bone strength. However, gilts treated with pST had greater bone wall thickness and exhibited a compensatory increase in bone strength and mineralization during a 35-d postfinishing period when fed at least .8% P during the finishing

[1]The authors would like to thank Pitman-Moore, Inc. for providing the pST used in this experiment.

phase. Gilts fed .4% P during the finishing phase were unable to fully compensate and never attained bone strength values equal to the control gilts. Therefore, the objective of this experiment was to determine the minimum dietary P intake needed during the finishing phase, in order that compensatory mineralization would occur and pST-treated gilts would be able to attain similar bone stress and mineralization as control gilts by the end of the postfinishing phase.

Procedures

A total of 72 crossbred gilts (Hampshire × Chester White × Yorkshire × Duroc) with an initial average weight of 127 lb was used in a randomized complete block design with a 2 × 3 factorial arrangement. Gilts were blocked by weight, allotted by ancestry to pens, and randomly assigned to experimental treatments. There were two gilts per pen and six replications per treatment. Gilts were housed in 5 ft × 5 ft pens in an environmentally controlled building with total concrete slatted flooring. They were given ad libitum access to feed and water.

Experimental treatments consisted of daily injections of placebo or 4 mg pST and a corn-soybean meal diet (1.2% lysine; Table 1) containing either .4, .6, or .8% P. These correspond to 100, 150, and 200% of NRC (1988) estimates for P in finishing diets (110 to 240 lb). Dietary P levels were attained by replacing corn with monocalcium P and limestone. A constant Ca:P ratio of 1.25:1 was maintained throughout the entire experiment. All other nutrients were formulated to be at least 200% of NRC (1988) estimates for finishing pigs. Gilts were slaughtered at 235 lb (six per treatment, 36 total). The femur, first rib, and third and fourth metacarpals were removed from the right side of each carcass 24 h following slaughter.

Table 1. Composition of Diets

	Finishing phase[a]	Postfinishing[b]
Ingredient, %	.4% P	1.2% P
Corn	62.98	78.69
Soybean meal (48% CP)	29.77	14.53
Soybean oil	5.00	—
L-lysine HCl	.16	—
Monocalcium phosphate	.16	4.22
Limestone	.78	1.66
Salt	.30	.50
Vitamin premix	.50	.25
Trace mineral premix	.20	.10
Selenium premix[c]	.05	.05
Antibiotic[d]	.10	—
Total	100.00	100.00
Calculated analyses, %		
Lysine	1.20	.65
Ca	.50	1.50

[a]Monocalcium phosphate and limestone were added in place of corn to provide P levels of .6 and .8%. Finishing diets were fed from 127 to 235 lb.
[b]Postfinishing, fed for 35 d following the finishing phase.
[c]Provided 10 mg chlortetracycline per lb of complete diet.

Bones were manually cleaned of connective tissues, but otherwise were stored continually in plastic bags to prevent exposure to air. Bones were thawed for 36 h at 40°F prior to determination of mechanical properties by an Instron Universal Testing Machine (Instron Corp., Canton MA). Calculations were derived for bending moment, stress, strain, and modulus of elasticity. Bending moment refers to the actual force required to "break" or more appropriately bend a bone, adjusted for differences in the span over which the force is applied. Stress adjusts the force for the area and shape of the bone at the point where the force is applied. Stress actually gives a better estimate of the bones overall strength and mineralization than other measurements. Modulus of elasticity gives a measure of the ability of the bone to return to its original shape, which is an indicator of the stiffness or rigidity of the bone. Strain is a measure of the amount of deformation that takes place in the bone while it is being tested.

Bones were cleaned of remaining residues and marrow was removed prior to lipid extraction. Femur samples were extracted and used for determination of percentage ash. Ash is expressed as a percentage of dried, fat-free bone.

The remaining 36 gilts (six per treatment) were mixed and placed 18 per 150 ft × 100 ft pen in dirt lots. Gilts were individually fed 4 lb/d of a common diet (Table 1) to ensure daily intakes of 22.8 g of P. This corresponds to 200% of the NRC (1988) recommended daily intake for P in developing gilts. An additional 1.5 lb/d of corn was offered to all gilts that consumed the initial 4.0 lb feeding. Individual feed intake was determined by weighing back remaining feed daily for the entire 35 d postfinishing phase. On d 35, all gilts were slaughtered. Bones and carcass data were collected as described for the finishing phase.

Results and Discussion

A pST × P interaction ($P<.03$) was observed for femur modulus of elasticity (Table 2). Modulus of elasticity of control gilts was higher and increased more as dietary P was increased compared to pST gilts, indicating that femurs of control gilts were more rigid than those of pST-treated gilts. No pST × P interactions ($P>.10$) were observed for any of the other bone criteria measured. There was no effect ($P>.42$) of pST administration on rib bending moment; values were similar between control gilts and pST-treated gilts. Gilts receiving pST had decreased ($P<.06$) stress; modulus of elasticity; and ash content for rib, femur, and metacarpals and decreased bending moment for femur and metacarpals compared to control gilts. Administration of pST resulted in increased ($P<.03$) rib, femur, and metacarpal strain and increased ($P<.01$) femur wall thickness. As dietary P was increased from .4 to .8%, linear ($P<.05$) increases occurred in bending moment; stress; modulus of elasticity; and ash content of rib, femur, and metacarpals, with the exception of metacarpal stress ($P>.14$). Femur wall thickness was also increased (linear, $P<.02$) with increasing dietary P, whereas metacarpal wall thickness was not affected ($P>.38$) by dietary P.

A pST × P interaction ($P<.07$) was observed for rib bending moment in the postfinishing phase. Gilts that received pST and were fed .6 or .8% dietary P in the finishing phase exhibited a greater increase in bending moment to equal or exceed that of control gilts by the end of the postfinishing phase (Table 3). Gilts administered pST in the finishing phase still exhibited decreased ($P<.05$) femur modulus of elasticity and metacarpal bending moment following the postfinishing phase. However, gilts that received pST in the finishing phase had attained ($P>.16$) stress values and ash contents for rib, femur, and metacarpals similar to those of control gilts by the end of the postfinishing period. Gilts that were fed the higher P diets in the finishing phase continued to exhibit higher ($P<.01$) values for rib stress, rib and femur bending moment, and rib and femur ash following the postfinishing phase. Perhaps the pST-treated gilts have higher requirements for Ca and P early in the finishing

phase because of the rapid increase in bone growth stimulated by pST administration.

Stress has been determined to be the most sensitive indicator of mineralization, because ash content requires a longer period of time to reflect changes in bone strength. Because bones of the axial skeleton are more responsive to demineralization than long bones of the extremities, rib bones would be expected to be more sensitive than the femur or metacarpals in determining treatment differences in stress. Rib bones were more responsive to our experimental treatments and, consequently, were used to determine Ca and P intakes required to maximize bone stress values.

It has been suggested that pST-treated gilts may have limited longevity in the breeding herd because of their decreased bone strength and mineralization at the end of the finishing phase. Recent research confirms that pST-treated pigs have decreased mineralization and bone strength, but have thicker bone walls, indicating a larger collagen matrix compared to controls at the end of the finishing phase. In a previous experiment, we determined that pST-treated gilts were able to exhibit a compensatory increase in bone strength and mineralization to values equaling those of control gilts during a 35-d postfinishing period. The present data substantiate that compensatory response and indicate that pST-treated gilts consuming at least 16.5 g of P per day in the finishing phase are able to increase bending moment and stress values for rib, femur, and metacarpals during a 35-d postfinishing phase to reach levels attained by control gilts. From this experiment, we are unable to determine the optimum daily intake of Ca and P required during the postfinishing phase for compensatory mineralization to occur, because only one level was fed during this period. However, the present data indicate that daily intakes of at least 18 g of P and 22.5 g of Ca during a 35 d postfinishing phase are effective in stimulating a compensatory increase in bone stress for gilts previously administered pST.

Based on these data, pST-treated gilts should be able to attain satisfactory bone strength and mineralization through compensatory increases following withdrawal of pST injections, if they consume at least 16.5 g of P and 20.5 g of Ca per day (.6% P diet) in the finishing phase.

Table 2. Effect of Porcine Somatotropin and Dietary Phosphorus on Bone Mechanical Properties and Mineralization of Finishing Gilts[a]

	Placebo			4 mg pST			
Item	.4% P	.6% P	.8% P	.4% P	.6% P	.8% P	SE
Rib							
Bending moment, kg[b]	61.6	79.2	89.7	59.0	86.4	95.2	5.1
Stress, kg/cm^2[bc]	348	482	606	288	371	404	47.5
Strain[c]	.18	.15	.17	.21	.22	.24	.02
Modulus of elasticity, kg/cm^2[bc]	2,012	3,482	3,881	1,404	1,735	1,727	402
Ash, %[bc]	46.18	50.72	52.11	43.54	47.95	51.26	1.00
Femur							
Bending moment, kg[bc]	435	549	601	381	509	571	24.5
Stress, kg/cm^2[bc]	276	296	412	171	189	234	32.3
Strain[bc]	.22	.21	.17	.26	.28	.27	.02
Modulus of elasticity, kg/cm^2[bce]	1,333	1,386	2,497	691	751	908	190
Bonewall thickness, cm[bc]	.77	.80	.84	.83	1.04	1.04	.05
Ash, %[bcd]	68.41	68.84	69.21	65.73	68.16	68.38	.34
Metacarpal[f]							
Bending moment, kg[bc]	165	181	165	136	158	172	8.7
Stress, kg/cm^2[c]	933	867	955	637	775	799	75.1
Strain[c]	.34	.31	.30	.37	.36	.34	.02
Modulus of elasticity, kg/cm^2[bc]	2,645	2,962	3,170	1,744	2,175	2,243	291
Bonewall thickness, cm	.51	.52	.51	.49	.52	.54	.03
Ash, %[bc]	54.47	57.01	58.34	53.64	55.61	55.99	.83

[a]Values are least squares means and represent six observations per treatment.
[b]Effect of pST (P<.05).
[c]Effect of P (linear, P<.05).
[d]Effect of P (quadratic, P<.10).
[e]pST × P interaction (P<.05).
[f]Average values for 3rd and 4th metacarpals.

Table 3. Effect of Porcine Somatotropin Administration and Dietary Phosphorus Level during the Finishing Phase on Bone Mechanical Properties and Mineralization Following a 35-d Postfinishing Phase[a]

	Placebo			4 mg pST			
Item	.4% P	.6% P	.8% P	.4% P	.6% P	.8% P	SE
Rib							
Bending moment, kg[bcd]	88	105	121	90	117	144	4.4
Stress, kg/cm^2[c]	431	568	538	426	581	659	56
Strain[bc]	.19	.23	.22	.23	.24	.26	.02
Modulus of elasticity, kg/cm^2	2,429	2,633	2,430	1,938	2,563	2,626	344
Ash, %[cd]	49.91	48.47	51.66	45.86	50.33	51.41	1.2
Femur							
Bending moment, kg[c]	524	604	733	482	643	721	26
Stress, kg/cm^2	274	247	309	213	274	255	25
Strain[b]	.18	.16	.21	.22	.21	.25	.02
Modulus of elasticity, kg/cm^2[b]	1,660	1,681	1,579	999	1,366	1,190	253
Bonewall thickness, cm[c]	.88	1.01	.97	.86	.99	1.11	.05
Ash, %[c]	68.67	68.96	69.15	68.01	69.16	69.22	.42
Metacarpal[e]							
Bending moment, kg[b]	215	243	240	202	203	216	12.6
Stress, kg/cm^2	806	876	968	836	906	901	75
Strain	.41	.41	.41	.44	.38	.39	.03
Modulus of elasticity, kg/cm^2	2,099	2,124	2,249	1,888	2,213	2,309	233
Bonewall thickness, cm	.58	.62	.61	.58	.62	.64	.03
Ash, %	58.14	57.97	58.98	57.79	58.19	58.67	.7

[a]Values are least squares means and represent six observations per treatment.
[b]Effect of pST administration during the finishing phase ($P<.05$).
[c]Effect of dietary P fed during the finishing phase (linear, $P<.07$).
[d]pST × P interaction for finishing phase treatments ($P<.07$).
[e]Average of 3rd and 4th metacarpals.

EFFECTS OF THE INTERRELATIONSHIP OF PORCINE SOMATOTROPIN ADMINISTRATION AND DIETARY PHOSPHORUS ON GROWTH PERFORMANCE IN DEVELOPING GILTS[1]

T. L. Weeden, J. L. Nelssen, R. D. Goodband, J. A. Hansen, K. G. Friesen, and B. T. Richert

Summary

Seventy-two gilts (initial weight = 127 lb) were used to determine effects of the interrelationship of porcine somatotropin (pST) administration and dietary phosphorus (P) on growth performance of finishing gilts (127 to 235 lb) and for a 35 d postfinishing phase following withdrawal of pST administration. Gilts were injected daily with placebo (control) or 4 mg pST and fed .4, .6, or .8% P in the finishing phase. Administration of pST increased average daily gain (ADG), improved feed efficiency (F/G), and decreased average daily feed intake (ADFI) during the finishing phase. Increasing dietary P resulted in increased ADG from d 0 to 28 of the finishing phase; however, dietary P had no effect on ADG, F/G, or ADFI for the overall finishing phase. When each block weight averaged 235 lb, half of the gilts were slaughtered. Administration of pST decreased backfat thickness, dressing percentage, and kidney fat weight and increased longissimus muscle area and carcass length. Dietary P had no effect on carcass criteria measured. The remaining 36 gilts were individually fed 4 lb/d of a common diet to assure P intake of 22.8 g/d for the 35 d postfinishing phase. Gilts that received pST in the finishing phase had decreased ADG and poorer feed conversion in the postfinishing phase. Dietary P level in the finishing phase had no effect on postfinishing performance. From d 0 to 28 of the finishing phase, pST-treated gilts required a diet with more than .4% P (10.3 g/d P) to maximize growth performance. However, a .4% P diet (12.4 and 10.7 g/d P, control and pST-treated, respectively) is adequate for growth performance during the overall finishing phase (127 to 235 lb).

(Key Words: Somatotropin, Phosphorus, Performance, Gilts.)

Introduction

Previous research at Kansas State University has established that pST-treated pigs have higher lysine requirements than non-pST-treated pigs to maximize growth performance. Dietary percentages of calcium (Ca) and phosphorus (P) may also need to be adjusted, because pST-treated pigs require at least the same daily intakes of Ca and P as control pigs, but consume less because of reduced feed intake. Therefore, the present study was designed to determine if pST-treated gilts have higher daily requirements for Ca and P than non-pST-treated gilts for maximum growth performance.

Procedures

A total of 72 crossbred gilts (Hampshire × Chester White × Yorkshire × Duroc) with an initial average weight of 127 lb was used in a randomized complete block design with a 2 × 3 factorial arrangement. Gilts were blocked by weight, allotted by ancestry to pens, and randomly assigned to experimental treatments. There were two gilts per pen and six replications per treatment. Gilts were

[1]The authors would like to thank Pitman-Moore, Inc. for providing the pST used in this experiment.

housed in 5 ft × 5 ft pens in an environmentally controlled building with total concrete slatted flooring. They were given ad libitum access to feed and water.

Experimental treatments consisted of daily injections of placebo or 4 mg pST and a corn-soybean meal diet (1.2% lysine; Table 1) containing either .4, .6, or .8% P. These correspond to 100, 150, and 200% of NRC (1988) estimates for P in finishing diets (110 to 240 lb). Dietary P levels were attained by replacing corn with monocalcium P and limestone. A constant Ca:P ratio of 1.25:1 was maintained throughout the entire experiment. All other nutrients were formulated to be at least 200% of NRC (1988) estimates for finishing pigs. When the mean weight of gilts in a block reached 235 lb, daily injections were terminated and one gilt per pen was slaughtered. Following slaughter, standard carcass measurements were recorded.

The remaining 36 gilts (six per treatment) were mixed and placed 18 per 150 ft × 100 ft pen in dirt lots, but without direct contact with boars. Gilts were individually fed 4 lb/d of a common diet (Table 1) to ensure daily intakes of 22.8 g of P. This corresponds to 200% of the NRC (1988) recommended daily intake for P in developing gilts. An additional 1.5 lb/d of corn was offered to all gilts that consumed the initial 4 lb feeding to ensure adequate energy intake to tolerate cold stress in the outdoor lots. On d 35, all gilts were weighed to determine live weight gain and feed/gain and then slaughtered. Carcass data were collected as described for the finishing phase. Reproductive tracts were also collected and evaluated to determine if gilts had reached puberty and exhibited estrus.

Results and Discussion

No pST × P interactions (P>.15) were observed for any of the growth response criteria measured (Table 2). Gilts administered pST exhibited increased (P<.01) ADG, improved feed/gain (F/G) and reduced (P<.01) feed intake from d 0 to 28 and for the overall finishing phase. From d 0 to 28, ADG responded (quadratic, P<.04) to increasing dietary P, with the highest ADG being achieved on the .6% P diet regardless of whether gilts received pST or not. However, dietary P had no effect (P>.23) on ADG, F/G, or average daily feed intake (ADFI) for the overall finishing phase.

Gilts administered pST had decreased (P<.03) dressing percentage, backfat thickness, and kidney fat weight (Table 3). Administration of pST also increased (P<.01) longissimus muscle area and carcass length. Dietary P had no effect (P>.13) on carcass traits.

Gilts that were administered pST in the finishing phase had decreased (P<.01) ADG and poorer feed conversions following withdrawal of pST injections during the 35-d postfinishing phase (Table 4). Dietary P level received during the finishing phase had no effect (P>.23) on postfinishing performance. Percentages of gilts attaining puberty and exhibiting estrus by the end of the postfinishing phase were not affected (P>.32) by pST-treatment or dietary P level fed in the finishing phase.

Following the 35 d postfinishing phase, gilts that received pST in the finishing phase had decreased (P<.02) backfat and kidney fat and increased (P<.02) carcass length (Table 3). Carcass weight was also decreased (P<.02) for gilts that received pST in the finishing phase because of decreased growth during the postfinishing phase. Dietary P level received in the finishing phase had no effect (P>.10) on postfinishing carcass measurements with the exception of dressing percentage, which tended (quadratic, P<.08) to be slightly lower for gilts that received the .6% P diet during the finishing phase.

Our results support previous findings in that 98% of maximum ADG and feed efficiency were achieved at 99.8% of NRC (1988) estimates for P intake in non-pST-treated pigs. In a previous experiment at

Kansas State University, growth of finishing gilts was not maximized in either control or pST-treated gilts, when daily P intakes were 82 and 78%, respectively, of NRC (1988) estimates (12.4 g/d P) for finishing pigs. Researchers at Kentucky suggested that dietary percentages of P may need to be increased because of decreased feed intake. Therefore, the major obstacle in formulating diets to meet the requirement of P for growth in pST-treated pigs is determining how much their feed intake will be reduced. The reduction in feed intake when pigs are administered pST is highly variable, ranging from 4 to 32%. When energy is limiting, protein accretion is slowed; thus, energy density of the diets would also need to be increased in order to maximize growth performance when feed intake is reduced by substantial amounts.

Fewer gilts had reached puberty by the end of the postfinishing phase in this experiment compared to our previous study, although no differences were due to treatments received during the finishing phase. The reduced number of gilts reaching puberty in this experiment may be attributed to their slower adaptation to being housed outdoors than gilts in the previous experiment, because these gilts did not consume their entire daily feed allotments until the third week. To attain normal reproductive function, pST treatment must be withdrawn at the end of the finishing period, because continued pST-treatment results in inhibition of puberty.

In conclusion, the NRC (1988) requirement estimates of .5% Ca and .4% P (15.5 g/d Ca, 12.4 g/d P) appear adequate in meeting the needs of control and pST-treated pigs for maximum growth performance during the finishing phase. Also gilts administered pST during the finishing phase should have reproductive performance comparable to that of non-pST-treated gilts, if pST treatment is terminated at the end of the finishing phase.

Table 1. Composition of Diets

	Finishing phase[a]	Postfinishing[b]
Ingredient, %	.4% P	1.2% P
Corn	62.98	78.69
Soybean meal (48% CP)	29.77	14.53
Soybean oil	5.00	—
L-lysine HCl	.16	—
Monocalcium phosphate	.16	4.22
Limestone	.78	1.66
Salt	.30	.50
Vitamin premix	.50	.25
Trace mineral premix	.20	.10
Selenium premix	.05	.05
Antibiotic[c]	.10	—
Total	100.00	100.00
Calculated analyses, %		
Lysine	1.20	.65
Ca	.50	1.50

[a]Monocalcium phosphate and limestone were added in place of corn to provide P levels of .6 and .8% finishing diets were fed from 127 to 235 lb.
[b]Postfinishing, fed for 35 d following the finishing phase.
[c]Provided 10 mg chlortetracycline per lb of complete diet.

Table 2. Effect of Porcine Somatotropin and Dietary Phosphorus on Growth Performance of Gilts from 127 to 235 Pounds[a]

	Placebo			4 mg pST			
Item	.4% P	.6% P	.8% P	.4% P	.6% P	.8% P	SE
Initial wt, lb	127.6	127.7	127.8	127.6	127.6	12.6	2.64
ADG, lb							
0 to 28 d[bc]	2.36	2.43	2.29	2.42	2.76	2.66	.08
Overall[b]	2.21	2.22	2.15	2.36	2.49	2.47	.07
ADFI, lb							
0 to 28 d[b]	6.62	7.05	6.72	5.67	5.96	5.74	.27
Overall[b]	6.86	7.24	6.96	5.88	6.04	5.87	.23
Feed/gain							
0 to 28 d[b]	2.82	2.92	2.93	2.35	2.16	2.17	.09
Overall[b]	3.13	3.27	3.26	2.50	2.43	2.40	.10
Phosphorus intake, g/d							
0 to 28 d[bd]	12.0	19.2	24.4	10.3	16.2	20.8	.77
Overall[bd]	12.4	19.7	25.3	10.7	16.5	21.3	.64
Calcium intake, g/d							
0 to 28[bd]	15.0	24.0	30.5	12.9	20.3	26.0	.97
Overall[bd]	15.6	24.6	31.6	13.3	20.6	26.7	.81

[a]Values are least squares means, data were collected from a total of 72 gilts, two gilts per pen, six pens per treatment.
[b]Effect of pST (P<.01).
[c]Effect of P (quadratic, P<.04).
[d]Effect of P (linear, P<.01).

Table 3. Effect of Porcine Somatotropin and Dietary Phosphorus on Carcass Measurements[a]

	Placebo			4 mg pST			
Item	.4% P	.6% P	.8% P	.4% P	.6% P	.8% P	SE
Finishing phase[b]							
Live wt, lb[f]	236.1	236.6	233.0	243.1	249.5	248.6	5.14
Hot carcass wt, lb	177.2	176.8	169.9	171.7	181.7	179.2	4.36
Chilled carcass wt, lb	174.2	173.3	166.7	168.4	177.7	175.7	4.32
Dressing percentage[g]	73.9	73.7	73.6	73.1	71.8	71.3	.79
Average backfat thickness, in[ceg]	1.33	1.33	1.33	1.01	.93	.99	.06
Longissimus muscle area, in^{2}[eg]	5.54	5.43	5.66	6.61	6.95	6.23	.33
Carcass length, in[eg]	30.94	31.01	31.11	31.17	32.29	31.75	.26
Kidney fat, g[eg]	1,739	1,792	1,677	1,082	806	984	137
Postfinishing phase[d]							
Hot carcass wt, lb[g]	192.1	194.4	196.2	185.4	180.1	177.3	5.9
Chilled carcass wt, lb[g]	187.4	188.3	191.5	180.8	175.4	173.1	5.7
Dressing percentage[h]	72.8	70.9	71.9	70.1	70.0	70.7	.62
Average backfat thickness, in[ceg]	1.22	1.19	1.21	.98	1.12	.96	.05
Longissimus muscle area, in^{2}[e]	5.65	6.22	5.80	6.41	6.11	6.06	.31
Carcass length, in[eg]	31.93	32.19	31.77	32.54	32.51	32.61	.27
Kidney fat, g[eg]	1,367	1,550	1,853	1,238	1,181	1,125	174

[a]Values are least squares means.
[b]Data collected from six gilts per treatment, average final weight of 235 lb.
[c]Mean of measurements taken at the first rib, the last rib, and the last lumbar vertebra.
[d]Data collected from six gilts per treatment following a 35 d period on a common diet without daily injections of pST or placebo.
[e]Values were adjusted by using live weight as a covariate.
[f]Effect of pST (P<.07).
[g]Effect of pST (P<.03).
[h]Effect of P (quadratic, P<.10).

Table 4. Effect of Porcine Somatotropin Administration and Dietary Phosphorus Levels during the Finishing Phase on Postfinishing Performance[ab]

	Placebo			4 mg pST			
Item	.4% P	.6% P	.8% P	.4% P	.6% P	.8% P	SE
Initial wt, lb	245.1	245.2	247.6	257.0	257.1	252.6	5.3
Final wt, lb	278.2	287.3	287.5	278.7	277.1	267.6	9.7
ADG, lb[c]	.95	1.19	1.15	.62	.57	.42	.20
Feed/gain[c]	4.55	4.35	4.76	7.69	6.25	10.0	.93
ADFI, lb	4.97	5.19	5.30	5.74	5.02	4.91	.33
Phosphorus intake, g/d	18.81	19.45	19.61	20.90	18.91	18.33	.91
Percentage exhibiting estrus	50.00	66.67	66.67	50.00	66.67	50.00	—

[a]Values are least squares means.
[b]Data collected from six gilts per treatment during a 35-d period on a common diet without daily injections of pST or placebo.
[c]Effect of pST administration in the finishing phase (P<.01).

KSU SWINE ENTERPRISE RECORD SUMMARY[1]

M. R. Langemeier[2], R. D. Goodband, and M. D. Tokach

Summary

Approximately 35 swine operations are enrolled in the 1992 Kansas Swine Enterprise Record Program. This program evaluates physical and economic performance and is part of a cooperative record-keeping project with extension personnel and swine producers in Kansas, Nebraska, and South Dakota. Records are summarized every 6 months, and the corresponding data are pooled to form state and regional averages.

This paper summarizes the data for 22 farrow-to-finish operations in Kansas that kept records during the first 6 months of 1992. Profit per cwt. of pork produced for these 22 producers averaged $1.13. Profits varied substantially between producers. Producers in the top one-third in terms of profitability had average profits of $8.25 per cwt., whereas producers in the bottom one-third had average losses of $7.02 per cwt. Critical factors separating low and high profit producers included feed costs, unpaid labor, fixed costs, and productivity.

Introduction

Production and financial records have become essential management tools of many swine producers. An accurate set of records allows producers to compare their efficiency levels with other producers and to track performance over time. Records are particularly useful when making capital purchases of buildings and equipment and in evaluating whether a change in an operation (e.g., buying higher quality breeding stock) will pay for itself. Production records measure the productivity of an operation. Financial records measure economic performance.

Kansas State University joined the University of Nebraska and South Dakota State University in a cooperative record-keeping program in January of 1991. This program compiles individual producer records on production and financial factors into state and regional summaries. Enterprise summaries are provided for farrow-to-finish, feeder pig producing, feeder pig finishing, combination (less than 70% of pigs sold as either market hogs or feeder pigs), and purebred operations. Many of the items are recorded on the basis of per cwt. of pork produced. Recording costs on a per cwt. basis facilitates comparisons between producers of various sizes. This paper summarizes the records of 22 farrow-to-finish operations and the six combination operations in Kansas that completed an analysis for the first half of 1992.

Kansas Group Summary

Individual producers collect data on hog inventories, hog sales, hog purchases, feed inventories, feed purchases, operating expenses, labor, fixed expenses, and herd performance. These individual producer data

[1]The authors wish to thank Mike Brumm and Dale Kabes, University of Nebraska, for their assistance with the program and the many Kansas County Agricultural Extension Agents for their assistance.

[2]Dept. of Agricultural Economics.

were used to compile the summaries reported in Table 1. Profit per cwt. on an economic life depreciation basis (Line 20) is used to separate producers into top and bottom one-third profit groups. Thus, all other items represent the means for that particular profit group. The information in Table 1 allows producers to compare the performance of their operation to that of other producers in the program. The discussion below will focus on the semi-annual summary for farrow-to-finish producers.

Profit per cwt. on an economic life depreciation basis is computed by dividing the return to management figure found on Line 3 by the net pounds of pork produced (Line 1). Profit per cwt. produced for the 22 farrow-to-finish producers in the program averaged $1.13 per cwt. over the first 6 months of this year. However, profits varied substantially between producers. Producers in the top one-third in terms of profitability had average profits per cwt. of $8.25. Producers in the bottom one-third had average losses of $7.02 per cwt.

Notice that returns over cash costs (Line 2) were positive for all three profit groups. This is fairly typical. Most producers can cover cash costs, even when prices are relatively low. However, producers in the bottom one-third profit group were not able to cover unpaid labor and fixed costs; thus, their return to management was negative. These producers will need to cover unpaid labor and fixed costs to stay in business in the long-run.

Line 4 presents the annual rate of return on capital invested in the swine operation. This rate should be compared to the rates that can be earned on other investments. The return on capital for producers in the high one-third profit group was more than two and one-half times larger than the average return on capital for all 22 producers. Note that the return on capital for producers in the bottom one-third group was negative.

Variable costs per cwt. (Line 10) can be broken down into four categories: feed costs (Line 5), other operating expenses (Line 6), interest costs on operating capital (Line 9), and unpaid labor and management (Line 38). Total costs per cwt. include variable costs, interest charges on investments in buildings and equipment (Line 12), and economic life depreciation (Line 13). Producers in the top one-third profit group had lower costs per cwt. for each of the total and variable cost categories.

There was a $15.04 per cwt. difference in total costs between producers in the top and bottom one-third profit groups. Feed costs per cwt. accounted for $3.65 or 24.3% of the difference in total costs for the two profit groups. Cheaper diets do not directly correspond to lower feed costs. The bottom one-third group of producers actually had less expensive diets (Line 52). As indicated by the supplement to grain ratio, the top one-third group of producers seemed to feed a higher quality diet. This may partially explain the lower whole herd feed conversion for this group.

Other operating expenses and interest costs on capital accounted for 14.5% and 3.2% of the difference in total costs between producers in the high and low profit groups. Other operating expenses include utilities, hired labor, supplies, repairs, veterinarian costs, and professional dues.

Unpaid labor and management were $5.14 per cwt. higher for producers in low profit group than for producers in the high profit group. This difference in unpaid labor and management accounted for 34.2% of the difference in total costs per cwt. between the two groups.

Differences in fixed costs per cwt. accounted for the remaining 23.8% of the difference in total costs between producers in the high and low profit groups. This difference in fixed costs is not related to operation size. On average, producers in the bottom

one-third were slightly larger than producers in the top one-third. Producers in the top one-third group weaned more pigs/litter (line 28) and pigs/female (line 29) and had lower finishing pig death loss (line 33). As a result, the number of pigs sold per litter farrowed (line 31) was 1.2 pigs greater for the top one-third profit group compared to the bottom one-third group. Producers in the bottom one-third group had relatively more capital invested in facilities on a per cwt. of pork produced basis. There was a 18.0% improvement in feed efficiency between producers in the top vs bottom one-third profit groups. Finally, swine enterprise records provide an opportunity to monitor individual herd economic performance. By comparing an individual's records to the group summary, key economic criteria can be identified and management strategies implemented to improve profitability.

Lyell Nelson, Dr. Don Kropf, and John Wolf evaluate carcasses in the KSU Meats Lab.

Table 1. Kansas Group Summary Averages

	Farrow to Finish Operations						Combination Operations*		
	Semi-Annual Data (22 Farms)			Annual Data (7 Farms)			Semi-Annual Data (6 Farms)		
	Average	High1/3	Low1/3	Average	High1/2	Low1/2	Average	High1/2	Low1/2
1. Net pork produced, lbs.	203,091	150,138	112,192	303,033	321,312	302,254	111,308	149,568	73,048
2. Income over feed, oper. exp., oper. int., & hired labor	22,809	22,577	11,564	19,112	31,138	7,861	17,646	28,904	6,388
3. Profit or return to management, ELD	4,139	11,846	(6,977)	(14,357)	961	(30,684)	6,783	16,022	(2,457)
4. Annual rate of return on capital, ELD	11.20	30.48	-7.18	-4.11	9.46	-16.83	20.14	46.28	-5.99
Variable Expenses:									
5. Total feed expense/cwt. pork produced	25.58	24.08	27.73	25.14	23.69	27.14	27.95	23.80	32.10
6. Other oper. expenses (total)/cwt. pork produced	6.40	4.65	6.84	5.62	5.47	5.40	7.96	4.85	11.07
a. Utilities; fuel, electricity, phone/cwt. pork produced	1.47	0.95	2.10	1.13	0.92	1.53	1.34	0.88	1.79
b. Vet. expenses and medications/cwt. pork prod.	0.85	0.85	0.61	0.71	0.62	0.57	1.30	1.25	1.34
c. Remainder of other oper. expenses/cwt. prod.	4.08	2.85	4.13	3.78	3.93	3.30	5.32	2.71	7.93
7. Total cost of labor/cwt. of pork produced	6.80	4.36	10.32	6.34	4.51	7.94	7.35	6.03	8.66
8. Total oper. capital inv./cwt. of pork produced	19.74	17.71	21.67	18.31	17.37	19.52	15.11	12.01	18.22
9. Int. cost on oper. invest./cwt. pork produced	2.37	2.12	2.60	2.20	2.08	2.34	1.81	1.44	2.19
10. Total variable cost/cwt. of pork produced	39.86	34.44	45.89	38.52	35.19	41.59	44.32	34.93	53.71
Fixed and Total Costs:									
11. Total fixed cap. inv. (ELD)/cwt. pork produced	21.97	17.42	29.86	25.01	24.74	26.89	24.76	18.44	31.09
12. Int. chg. on fixed inv., (ELD)/cwt. pork produced	2.20	1.74	2.99	2.50	2.47	2.69	2.48	4.84	3.11
13. E.L. deprec., taxes and ins. cost/cwt. pork prod.	3.48	2.50	4.84	3.33	3.34	3.69	2.98	2.64	3.32
14. Tax deprec., taxes and ins. cost/cwt. pork prod.	2.35	1.50	3.22	2.51	2.41	2.59	2.44	1.68	3.20
15. Fixed cost (ELD)/female/period	98.32	80.00	117.96	193.44	202.36	189.28	71.77	71.70	71.84
16. Fixed cost (ELD)/crate/period	469.92	320.11	587.84	987.71	855.56	1141.44	258.73	246.42	271.05
17. Total cost (ELD)/cwt. or pork produced	45.54	38.68	53.72	44.35	41.01	47.96	49.78	39.41	60.14
18. Total cost (ELD)/female/period	805.87	753.22	799.05	1513.93	1494.49	1421.99	694.18	681.54	706.81
19. Total cost (ELD)/crate/period	3852.03	3008.57	3984.83	7865.50	6564.22	8759.76	2536.18	2350.78	2721.58
Income and Profit:									
20. Profit based on Econ. Life Deprec./cwt. pork prod.	1.13	8.25	-7.02	-4.60	1.51	-10.75	1.42	10.63	-7.80
21. Profit based on Tax Depreciation/cwt. pork prod.	2.71	9.84	-4.92	-3.68	2.62	-9.83	2.65	12.26	-6.97
22. Profit based on Econ. Life Deprec./female/period	32.73	159.64	-101.50	-148.60	29.15	-311.88	53.24	184.74	-80.26
23. Profit based on Econ. Life Deprec./crate/period	118.47	627.20	-491.55	-933.38	70.77	-1933.94	195.66	685.98	-294.65

*Combination operations have > 30% of hogs marketed as feeder pigs and < 70% sold as market hogs.

	Farrow to Finish Operations						Combination Operations		
	Semi-Annual Data (22 Farms)			Annual Data (7 Farms)			Semi-Annual Data (6 Farms)		
	Average	High1/3	Low1/3	Average	High1/2	Low1/2	Average	High1/2	Low1/2
Production Summary:									
24. Average female inventory	110	78	81	91	88	106	71	84	57
25. Number of litters weaned/female/period	0.92	0.89	0.85	1.79	1.85	1.67	0.96	1.01	0.91
26. Number of litters weaned/crate/period	4.30	3.52	4.06	8.93	8.00	9.63	3.55	3.60	3.51
27. Number of live pigs born/litter farrowed	10.10	10.71	9.25	9.43	9.28	8.95	10.33	10.52	10.14
28. Number of pigs weaned/litter farrowed	8.54	8.75	8.10	8.27	7.84	8.33	9.04	9.75	8.33
29. Number of pigs weaned/female/period	8.08	8.20	7.14	14.86	15.04	13.52	8.97	10.23	7.71
30. Number of pigs weaned/crate/period	38.22	32.21	35.30	75.54	65.35	80.79	32.81	35.74	29.88
31. Number of pigs sold/litter farrowed	7.24	7.68	6.48	7.39	6.93	7.43	9.78	9.04	10.52
Death Loss:									
32. Birth to weaning (% of no. born)	13.65	13.23	13.38	13.89	12.45	14.08	12.80	14.15	11.46
33. Weaning to market (% of no. weaned)	5.82	4.38	8.26	5.24	3.25	6.41	2.36	2.86	1.86
34. Breeding stock (% of breeding herd maintained)	3.34	3.56	4.64	2.59	4.42	1.08	1.89	0.67	3.11
Labor:									
35. Labor hours/cwt. of pork produced	0.92	0.58	1.43	0.86	0.61	1.08	0.89	0.65	1.14
36. Labor hours/female/period	15.78	11.44	21.32	28.97	22.36	32.01	12.12	11.17	13.07
37. Labor hours/litter weaned/period	17.73	13.36	25.33	16.60	11.92	20.03	13.02	10.99	15.04
38. Cost of unpaid labor & mgmt./cwt. pork produced	5.52	3.58	8.72	5.57	3.95	6.71	6.60	4.84	8.36
39. Total cost of labor (paid + unpaid)/cwt. pork prod.	6.80	4.36	10.32	6.34	4.51	7.94	7.35	6.03	8.66
40. Total cost of labor (paid + unpaid)/female/period	116.79	85.44	153.32	213.58	163.64	235.57	103.58	108.22	98.94
41. Return/hour for all hours of labor and management	11.56	21.93	2.67	3.62	10.24	-2.69	14.33	26.14	2.51
Marketing and Purchases:									
42. Number of market hogs sold	754	529	398	1089	1131	1078	378	517.67	237.33
43. Average weight/head for market hogs sold	239	242	241	238	238	238	243	240.93	244.84
44. Average price received for market hogs/cwt.	41.12	41.11	40.47	43.83	44.95	42.81	42.00	42.02	41.98
45. Number of feeder pigs sold	12.14	9.00	17.71	14.71	14.00	20.33	267.67	280.67	254.67
46. Average weight/head of feeder pigs sold	61.9	49.4	61.2	59.5	61.0	58.4	51.50	48.67	54.33
47. Average price received/head for feeder pigs sold	45.18	34.86	51.29	39.15	35.83	41.53	36.50	36.13	36.88
48. Average price received/cwt. for feeder pigs sold	70.73	60.44	79.83	65.33	58.79	68.59	71.18	74.77	67.59
Feed Cost and Consumption:									
49. Total pounds of feed fed/cwt. of pork produced	368	333	407	370	342	401	399	357	441
50. Total pounds of grain fed/cwt. of pork produced	293	333	329	294	276	319	316	288	344
51. Total pounds of supplement fed/cwt. of pork prod.	75	70	79	76	69	82	83	69	97
52. Average costs of diets/cwt.	6.99	7.25	6.85	6.83	7.02	6.77	6.98	6.67	7.23

Final Group Averages October 1, 1992.

Profit, fixed and total costs are based on Econ. Life Deprec. unless stated otherwise.

ENDOTOXIN, AMMONIA, AND TOTAL AND RESPIRABLE DUST IN SWINE CONFINEMENT BUILDINGS: THE EFFECT OF RECIRCULATED AIR AND RESPIRATORY PROTECTIVE MASKS

J. A. Pickrell[1], A. J. Heber[2], J. P. Murphy[2], M. M. May[1], D. Nolan[1], F. W. Oehme[1], D. Schoneweis[1], J. R. Gillespie[1], and S. C. Henry[3]

Summary

Caretakers and pigs in dusty environments with particles and toxic gases may sustain health consequences. We studied concentrations of ammonia, endotoxin, and total and respirable dust particles in four mechanically ventilated swine nurseries and two grower facilities using an ammonia sampler, filter, and British cyclone. In two of the nursery facilities, we determined the protection offered by respiratory masks that were mounted on glass funnels with filters or British cyclones and sampled for dust. In response to the increasing summer ventilation, large, nonrespirable particle concentrations in swine building atmospheres were reduced more completely by ventilation air movement than smaller respirable particles or ammonia. Total airborne endotoxin concentrations were similar to those eliciting pulmonary reactions. Total airborne endotoxin correlated with total suspended particles rather than respirable particles. Smaller respirable fecal particles enriched in endotoxin apparently stick to larger nonrespirable particles or are agglomerated before they became airborne. Internal recirculated air partially limited the mass concentration of respirable particles in the breathing zone of swine caretakers at lower but not higher ventilation rates. Respiratory protection limited the potential total dust exposures of swine caretakers in such atmospheres (<25%, 2-tie masks; <50%, 1-tie masks of the total suspended particles). Respirable particles were reduced to <55% by 2-tie masks. Properly worn 2-tie masks protect against both large and small respirable particles in swine confinement facilities.

(Key Words: Dust, Respirable Dust, Endotoxin, Recirculated Air, Respiratory Protective Masks.)

Introduction

Energy conservation and optimal rates of pig growth are economically important to the swine industry. Clouds of pollutant gases and particles can be detrimental to producers' and pigs' health but adequate air movement can reduce the caretaker-health-related consequences of inhaling particles, particle-adsorbed endotoxins, and toxic gases. Previous research at Kansas State University and by others has established that the average concentrations of organic dust measured in swine operations exceed allowable dust levels for human exposure.

This study investigated the effects of recirculated air on concentrations of ammonia, endotoxin, and total and respirable dust particles in swine nurseries and grower facilities. We also determined the protection offered by three types of respiratory masks.

[1]Dept. Clinical Sciences.
[2]Dept. Agricultural Enginering.
[3]Abilene Animal Hospital, P.A., Abilene, KS.

Procedures

Ammonia, endotoxin, and total and respirable particle mass were measured in four mechanically ventilated swine nursery (designated A, B, C, and D) and two grower facilities, using an ammonia sampler, filter, and British cyclone. The fractions of total airborne endotoxin contained in small respirable particles and large non-respirable particles were calculated.

Two nursery facilities (Buildings B and D) with mechanical ventilation were selected to determine the effect of vectorial air velocity (vertical air velocity^2 + horizontal air velocity^2)$^{.5}$ and internal recirculation rate on concentration of ammonia and on total and respirable particle and endotoxin concentrations. Ammonia and dust samples were collected at three levels in each facility—distances of 3.9 to 4.6 ft, 2.5 to 3.0 ft, and .7 to 1.6 ft from the floor. Vertical and horizontal air flow velocities were measured at the ammonia and dust locations using a hot-wire anemometer. A ceiling-mounted (.7 m/s) recirculation fan (Osborne Industries) was installed in Building B to add 9.7% (1,500 CFM) to the measured capacity for air movement (7.3 m/s) (15,500 CFM) measured by the air velocity traversing method.

At the same two nursery facilities (B and D), we determined the protection achieved by wearing respiratory protective masks. To measure this protection, filters or British cyclones were mounted in glass funnels and masks were mounted on these glass funnels and sealed. Stoppers were sealed into the funnels with tubing to draw indoor air samples through the mask using a calibrated battery-powered air pump (BGI Inc, Lexington, MA). Total and respirable dust were determined and compared to samples obtained at the same level and 30 to 50 cm (12 to 20 in.) from the samples taken through the mask. Percent reductions of total and respirable dust were calculated, and averages (means) determined for each type of respiratory protective mask.

Results and Discussion

Increased ventilation in summer relative to that in winter led to marked reductions in total suspended particles and more modest reductions in respirable particles and ammonia. Significantly greater ammonia concentrations and total suspended particulates were noted in grower facilities than in nurseries. We observed higher endotoxin concentrations in small respirable fecal particles relative to those in larger, nonrespirable mixed particles of feed-feces. Greatest variations in winter were between nursery and grower facilities (small vs large pigs), whereas in spring-summer these differences were attributed to increasing ventilation rates accompanying increasing environmental temperatures. The changes from winter to summer (temporal coefficients of variation [CV]) were twofold to sixfold larger than differences within a building (spatial CVs).

Total airborne endotoxin concentrations in facilities A, B, C, and D are shown in Table 1. No consistent differences occurred between facilities. Total airborne endotoxin concentrations were related with total suspended particles ($P \leq .01$, data not shown) and to the endotoxin in large nonrespirable particles that settle more rapidly in indoor atmospheres, but not to respirable particles. The close correlation between the large particle endotoxin and total airborne endotoxin ($P \leq .01$) and with the total suspended particles fraction ($P \leq .05$; data not shown) suggested a concentration-dependent interaction between small and large particles.

Vertical air velocity was reduced by warming inside the facility. Ammonia was reduced by high vertical and horizontal air velocity rates ($r^2 = .42$, $P \leq .05$) in nurseries during April-June at high ventilation rates.

Direct correlations occurred between increased air circulation and high ammonia (linear; $P \leq .01$; data not shown), respirable

dust (logarithmic) (P≤.05), and total dust (P≤.05; data not shown) concentrations. Increasing ammonia correlating to increasing airflow suggested that ammonia gas has been increasingly scoured from facility manure pits by air entering and leaving the pits. We believe that increased airflow also suspends large and small particles proportional to the air flow.

Table 2 shows total and respirable dust levels with and without fans, as well as the mass differences associated with using air recirculation at 9.7 to 31.9% of the operating facility capacity. Trends toward reduced quantity and relative amount of respirable dust concentrations (P≤.05) were noted 2 to 4 ft from floor, when fans were used. These trends were most prominent at lower air ventilations (4,640 to 9,710 CFM). Reduction was inversely proportionate to facility ventilation and was negatively correlated (P≤.05, r^2 = .38; data not shown) to respirable dust quantity and to the fraction of respirable dust (r^2 = .67; P<.05; data not shown). This suggests that controlled recirculation of air may produce cleaner indoor atmospheres, even in summer. It is important to note that the reductions in dust or ammonia were modest and worked best at lower air recirculation rates.

Table 3 shows the effect of three different types of respiratory protective masks on total and respirable dust. The 2-tie masks reduced total particle concentrations (96%) more than did 1-tie masks (77%). The 2-tie masks also reduced respirable particle concentrations by greater than 50%. The 1-tie masks afforded less protection from the small respirable particles capable of depositing in deep lung than did the 2-tie masks tested in this project. This suggests that 2-tie masks afford significant protection against large non-respirable and smaller respirable particles. Thus, appropriate respiratory protection will afford health advantages to the wearer.

Table 1. Total Suspended Particulates and Airborne Endotoxin Levels and Correlation to the Fraction of Rapidly Settling Endotoxin in Several Nursery-Grower Facilities

			Total airborne endotoxin		
Facility	Date/sample (1991)	Total suspended particulates (mg/m^3)[1]	Specific activity (ng/mg)	Quantity (ng/m^3)[2]	Large particle (%)[1,2,3]
A	Feb 04/A	135	.41	55	95
B	Mar 09/A	215	.79	171	94 ± 2(3)*
	Mar 09/B	175	.25	44	91 ± 8(3)*
	May 04/A	2.6	3.65	9.4	87 ± .4(2)*
C	Mar 11/A	85	1.19	101	86 ± 5(3)*
	Mar 11/B	34	1.25	42	82 ± .2(3)*
	May 28/A	.9	3.80	3.5	50
	May 28/B	2.3	2.90	6.7	81
D	Mar 12/A	32	11.60	373	97 ± 1(3)*
	Mar 14/A	8.8	.70	5.9	58 ± 12(3)*
	Mar 14/B	7.1	6.70	47	93 ± 3(2)*

*(N) = number of samples. [1]Correlation of percent large (rapidly settling) airborne endotoxin particles with total suspended particulates. [2]Correlation of percent large (rapidly settling) airborne endotoxin particles with total airborne endotoxin. [3]Calculated as 1–respirable endotoxin (on cyclone filters)/total airborne endotoxin.

Table 2. The Effect of Auxiliary Fan Ventilation on Concentrations of Total and Respirable Dust (Summer Conditions)

	Fans		Total dust			Respirable dust		
Date (1992)	Facility Ventilation[1] (CFM)	Amount Added (%)	Without fan (mg/m^3)	With Fan (mg/m^3)	Reduction (mg/m^3)	Without fan[1] (mg/m^3)	With fan[1] (mg/m^3)	Reduction (mg/m^3)
Human breathing zone (.75-1.1 m):								
May 15-16	15,300	9.7	2.23	1.65	.58	.81	.85	-.04
June 23-24	15,300	9.7	.12[2]	1.08	-.96	.04[2]	.03[2]	.01
July 2-3	15,300	9.7	1.41	.37	1.04	≤.00[2]	≤.00[2]	.00
July 16-17	9,710	15.2	1.63	1.40	.23	.53	.07[2]	.46
July 21-22	4,640	31.9	2.02	2.35	-.32	.42	.20	.22
July 21-22	4,640	31.9	ND	ND		.20	<.00[2]	.20
July 30-31	13,900	10.6	1.85	2.34	-.49	≤.00[2]	.32	-.32
July 30-31	13,900	10.6	ND	ND		<.00	<.00	.00
Mean ± Std Error			1.54±.31	1.53±.31	.01±.30	.25±.11	.18±.10	.07±.08
Swine breathing zone								
June 23-24	15,300	9.7	ND	ND	NC[4]	1.88	.97	.91
July 2-3	15,300	9.7	ND	ND	NC	.10[2]	1.05	-.95
July 16-17	9,710	15.2	ND	ND	NC	.03[2]	.15	.12
Mean ± Std Error						.67±.61	.72±.29	-.05±.53

[1]% reduction of respirable dust = 119 - .0073 (CFM). [r^2 = .684; P<.001. Student t statistic]. Absolute reduction of respirable dust (mg/m^3) = .42 - .000031 (CFM). [r^2 = .382; P<.01, Student t statistic].
[2]Weights not distinguishable from zero.
[3]ND = not determined.
[4]NC = not calculated.

Table 3. The Effect of Respiratory Protective Masks on Concentrations of Total and Respirable Dust

	Total dust			Respirable dust		
Date/ sample (1992)	Without mask (mg/m^3)	With mask (mg/m^3)	Reduction (%)	Without mask (mg/m^3)	With mask (mg/m^3)	Reduction (%)
Mask A (2-Tie):						
Feb 20/A	2.60	.08	96	ND[1]	.00	NC[2]
Feb 20/B	3.61	.11[3]	97	ND	.00[3]	NC
Feb 22/A	3.06	.00[3]	100	.17	.07[3]	60
Feb 22/B	4.25	.00[3]	100	.25	.10[3]	60
Mar 21/A	2.37	.07[3]	95	.15	.08[3]	55
Mar 21/B	4.94	.15	97	.33	.18	47
Apr 11/A	1.60	≤.00[3]	100	.11	≤.00[3]	100
Apr 11/B	3.14	<.00[3]	100	.23	.00[3]	100
Mean ± Std Error	3.20±.38	.05±.02[4]	98±1[5]	.21±.03	.07±.03[4]	67±14[5]
Mask B (2-Tie):						
Jul 2/A	.37	≤.00[3]	100	≤.00[3]	.04[3]	NC
Jul 3/A	1.41	≤.00[3]	100	≤.00[3]	≤.00[3]	NC
Jul 21/A	2.35	.58	75	.20	≤.00[3]	100
Jul 22/A	2.02	<.00	100	.42	<.00[3]	100
Jul 30/A	2.34	<.00[3]	100	.32	.17	47
Aug 1/A	1.85	<.00	100	<.00[3]	.13[3]	NC
Mean ± Std Error	1.72±.30	.10±.10[4]	94±6[5]	.31±.06	.06±.06[6]	81±19[5]
Mask C (1-Tie):						
May 15/A	1.65	.77	53	.81	.94	-16
May 16/A	2.23	.75	67	.85	.70	18
Jun 23/A	.57	≤.00[3]	100	.03[3]	≤.00[3]	NC
Jun 24/A	.12[3]	≤.00[3]	NC	.04[3]	.13[3]	NC
Jul 16/A	1.40	≤.00[3]	100	.07[3]	≤.00[3]	NC
Jul 17/A	1.63	.25	85	.53	<.00	100
Mean ± Std Error	1.60±.19	.35±.17[4]	77±11[5]	.73±.10	.55±.28	25±38[5]

[1]ND = not determined.
[2]NC = not calculated.
[3]Weights not distinguishable from zero.
[4]P<.05; Student t statistic.
[5]Calculated as reduction = mean with mask/mean without mask × 100; calculated as reduction. Std Error = Std Error (with mask)/mean without mask × 100.
[6]P≤.10; Student t statistic.

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