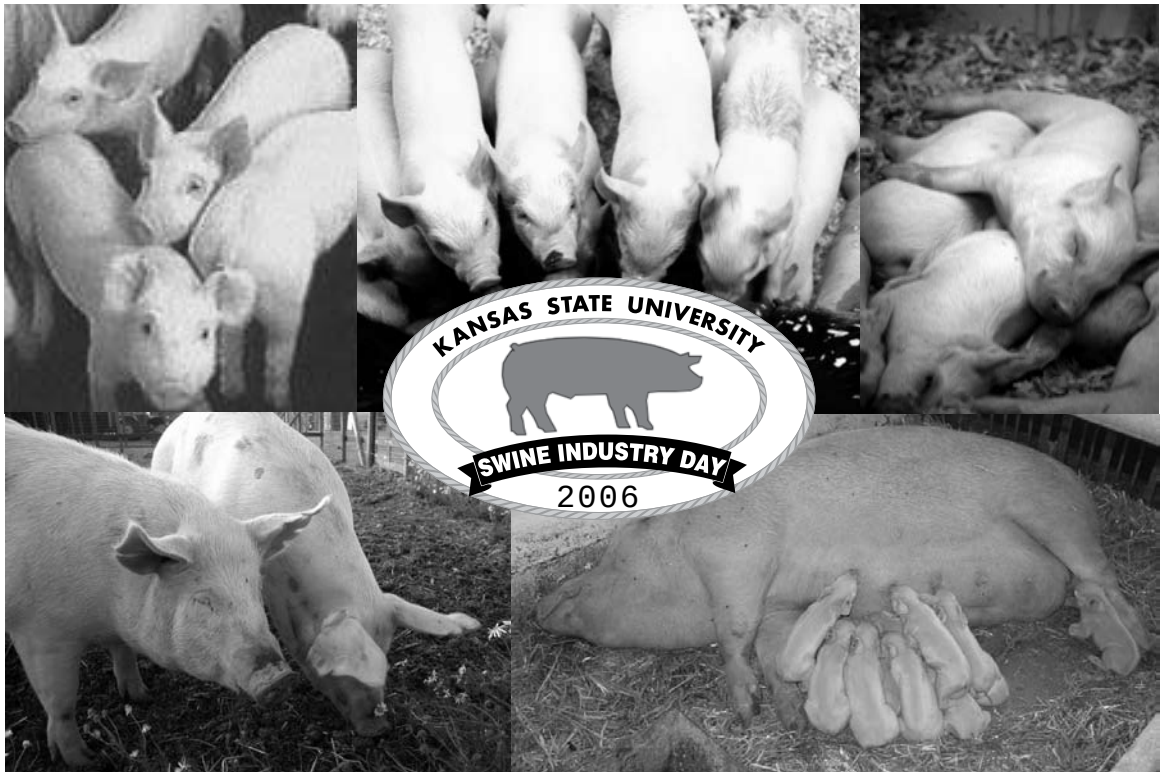
Kansas State University

SWINE DAY 2006



Report of Progress 966

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

FOREWORD

It is with great pleasure that we present to you the 2006 Swine Industry Day Report of Progress. This report contains updates and summaries of applied and basic research conducted at Kansas State University during the past year. We hope that the information will be of benefit, as we attempt to meet the needs of the Kansas swine industry.

Editors, 2006 Swine Day Report of Progress,

Bob Goodband Mike Tokach Steve Dritz Joel DeRouchey

ABBREVIATIONS USED IN THIS REPORT

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

NCR, 1998. Nutrient Requirements of Swine. 10th Ed. National Academy Press, Washington, DC.

KSU VITAMIN AND TRACE MINERAL PREMIXES

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

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

Vitamin premix: each lb of premix contains vitamin A, 2,000,000 IU; vitamin D_3, 300,000 IU; vitamin E, 8,000 IU; menadione, 800 mg; riboflavin, 1,500 mg; pantothenic acid, 5,000 mg; niacin, 9,000 mg; and vitamin B_{12}, 7 mg.

Sow add pack: each lb of premix contains choline, 100,000 mg; biotin, 40 mg; folic acid, 300 mg; and pyridoxine, 900 mg.

NOTICE

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

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

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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<0.05." 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 ± 0.1. The 2.5 is the average; 0.1 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.

PORCINE UMBILICAL CORD MATRIX STEM CELLS

R. Carlin[1], D. Troyer[1], M. Weiss[1], B. Schultz[1], and D. Davis

Summary

Since their discovery in 2000, pig umbilical cord stem cells have been studied at K-State. The studies have been expanded to included other species, including humans. In addition, other research groups around the world have published scientific studies with these cells. Their unique attributes include being plentiful, easily collected, and (in humans) non-controversial. Initial work in the pig has concentrated on characterizing the cells to understand how they compare with other populations of stem cells. Results indicate that they have several characteristics in common with other primitive stem-cell populations, and that they are relatively easy to work with in the laboratory.

(Key Words: Pigs, Stem Cell, Umbilical Cord, Wharton's Jelly.)

Introduction

The goal of the stem-cell group at K-State is to integrate education and commercialization with research on umbilical cord and related stem cells in humans and with research on umbilical cord stem cells and other stem-cell sources in agricultural, companion, and competitive animals. The pig is currently the primary agricultural animal subject. Umbilical cord matrix stem cells (UCMSC) were first isolated from Wharton's jelly in pig umbilical cords in 2000 in K-State laboratories. These cells have been shown be abundant, easily isolated and grown in vitro, and potentially valuable in clinical medicine. Less recognized is their potential for cell-based technologies in animals, including agriculturally important species. Their large numbers and ease of collection open possibilities not previously considered. Their discovery is timely because the applications of knowledge of the genome will require cells for applications in animals and humans. The stem-cell group at K-State is small, but is establishing a record of scientific accomplishment. A major step was establishment of the Midwest Institute for Comparative Stem Cell Biology in the fall of 2005 (http://www.vet.ksu.edu/research/stemcell/index.htm). Some information on the initial characterization of pig UCMSC is presented herein.

Procedures

Three key regulators of gene transcription in mouse and human embryonic stem cells are Nanog, Oct-4, and Sox-2. These transcription factors regulate the expression of other genes during embryonic development. Down-regulation of these three transcription factors is thought to be key for the loss of pluripotency and self-renewal, and for the beginning of subsequent differentiation. For this reason,

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we studied the expression of these transcription factors in porcine UCMSC.

Cells were isolated from Wharton's jelly of porcine umbilical cords and were histochemically assayed for the presence of alkaline phosphatase. Reverse-transcriptase polymerase-chain reaction (RT-PCR) assays were used to study expression of Nanog, Oct-4, and Sox-2 genes. The synthesis of Oct-4 and Nanog protein was analyzed by using immunocytochemistry, and fluorescence-activated cell-sorting (FACS) analysis was used to evaluate Hoechst 33342 dye-stained cells. Many stem-cell populations have the ability to exclude this dye.

Results and Discussion

Porcine UCMSC isolates were maintained in culture and formed colonies of cells that expressed alkaline phosphatase, a marker of primitive stem cells. The FACS analysis revealed a side population of Hoechst dye-excluding cells. Quantitative and non-quantitative RT-PCR reactions revealed expression of Nanog, Oct-4, and Sox-2 in d 15 embryonic discs, porcine UCMSC cell isolates, and porcine fibroblasts. Immunocytochemical analysis detected Nanog immunoreactivity in PUC cell nuclei, and detected faint labeling in fibroblasts. Oct-4 immunoreactivity was detected in the nuclei of some PUC cells, but not in fibroblasts.

Therefore, cells isolated from pig umbilical cord matrix express transcription factors considered to be pluripotent stem-cell markers, both at the mRNA and protein level. The presence of these transcription factors, along with the other characteristics of pig UCMSC, such as their colony-forming ability, Hoechst dye-excluding side population, and alkaline phosphatase expression, suggests that UCMSC have properties of primitive pluripotent stem cells. Furthermore, UCMSC are an easily and inexpensively obtained source of stem cells that are not hampered by the ethical or legal issues associated with human embryonic stem cells. In addition, these cells can be stored frozen in liquid N_2 and are viable and grow in culture after thawing.

This area of biotechnology in agricultural animals is in it’s infancy, but stem cells eventually may provide tools to enhance food safety, prevent/treat disease, enhance reproduction, improve carcass characteristics, and increase growth rate and feed efficiency in pigs and other agricultural animals.

L-CARNITINE SUPPLEMENTATION TO GESTATING GILTS ALTERS THE IGF AXIS IN PORCINE EMBYRONIC MYOBLASTS[1]

K. R. Brown, B. J. Johnson, R. D. Goodband, M.D. Tokach, J. L. Nelssen, and J. C. Woodworth[2]

Summary

We determined the effects of supplemental L-carnitine on the insulin-like growth factor (IGF) system in porcine embryonic myoblasts (PEM) from gilts. Forty gilts (BW = 303.6 lb) were allotted to 1 of 4 treatments that were arranged in a 2 × 2 factorial, with main effects of L-carnitine (0 or 50 ppm) and day of gestation (55 or 70). All gilts were fed 3.86 lb/day and a top-dress containing either 0 or 50 ppm of L-carnitine, starting on the first day of breeding and continuing through the allotted gestation length. At d 55 or 70 of gestation, fetuses were removed for isolation of PEM from the hind-limb muscles. Real-time quantitative PCR was used to determine growth factor messenger RNA (mRNA) expression in cultured PEM at 72-, 96-, 120-, and 144-h after plating. Flow cytometry was used to analyze percentage of myogenic cells with a myoblast/myotube-specific monoclonal antibody 5.1H11, and for determination of cell cycle stage. There was no treatment differences (P>0.10) for the expression of IGF-I, IGF-II, or IGFBP-5 mRNA levels. But PEM isolated from fetuses collected from gilts fed diets with L-carnitine had lower (P = 0.08) IGFBP-3 mRNA levels, compared with levels in the controls. Myoblasts isolated from fetuses from gilts fed diets with added L-carnitine had greater (P = 0.09; 8.8%) 5.1H11 monoclonal antibody attachment, compared with the controls, after 72 hours in culture (91.8% vs. 87.4%). Although not significant (P = 0.31), the total number of PEM in the S phase of the cell cycle was 4.7% greater in PEM collected from fetuses obtained from gilts fed diets with L-carnitine, compared with numbers from the control-fed gilts (37.5% vs. 34.2%). These data suggest that L-carnitine influences the IGF system, stage of the cell cycle, and recognition of muscle development, resulting in enhanced proliferation and delayed differentiation of PEM.

(Key Words: Insulin-like Growth Factor, Insulin-like Growth Factor Binding Proteins, L-carnitine, Messenger RNA, Myoblasts, Pigs.)

Introduction

The addition of L-carnitine to gestation diets has positive effects on sow reproductive performance. Specifically, providing supplemental L-carnitine to gestating sows increases average pig weight and litter weight at birth. This may be due to L-carnitine's role in β-oxidation, glucose disposal, and carbohydrate metabolism. Other researchers have alluded to the effect of L-carnitine on the insulin-like growth factor system.

[1]The authors thank Lonza, Inc., Allendale, NJ, for their financial support.
[2]Lonza, Inc., Allendale, NJ.

Insulin-like growth factors (IGF) and insulin-like growth factor binding proteins (IGFBP) stimulate cellular proliferation and differentiation of myogenic cells. These components of the IGF system are involved in several aspects of fetal growth and development, and seem to be modulators of muscle development in the pig fetus.

In previous data, we reported an increase in fetal weight at d 70 of gestation in fetuses collected from gilts fed diets with supplemental L-carnitine, and we have observed an increase in IGF-I, IGFBP-3, and IGFBP-5 mRNA expression in the endometrium of gilts fed diets containing supplemental L-carnitine. In addition, we observed a decrease in hepatic IGF-I expression in fetuses collected from gilts fed diets with supplemental L-carnitine. Changes in IGF-I, IGFBP-3, and -5 in the maternal endometrium and IGF-I in fetal hepatic tissue provide support for an altered maternal-fetal exchange of IGF system components due to supplementation of L-carnitine to the gilt. This may or may not explain the increased weight of pigs born to dams fed supplemental L-carnitine.

During pregnancy, growth factors and binding proteins play a role in fetal muscle development in the pig. Although data are limited, studies have observed decreased levels of IGF-II, IGFBP-3, and myogenin in PEM collected from fetuses from sows fed supplemental L-carnitine up to d 55 of gestation. Further evidence to support enhanced proliferation of porcine myogenic cells is the increase in the cross-sectional area of the semitendinosus, increased primary muscle fiber numbers, and a lower secondary:primary fiber ratio at birth in offspring of sows fed diets containing supplemental L-carnitine. Therefore, our experiment was designed to determine the effects of providing supplemental L-carnitine to gestating gilts on fetal muscle development *in vitro* by using real-time quantitative polymerase chain reaction (PCR) techniques and flow cytometry.

Procedures

All animal procedures used in this study were reviewed and approved by the Kansas State University Animal Care and Use Committee. Forty gilts (PIC, Franklin, KY; L327 × 1050; BW = 303.6 lb) were artificially inseminated (PIC; MQ 280) 12, 24, and 36 h after the onset of the second observed estrus. Gilts were randomly allotted to 1 of 2 dietary treatments and 1 of 2 harvesting dates (d 55 or 70 of gestation), based on weight at breeding. All gilts were fed a corn-soybean meal gestation diet (Table 1) once daily (3.86 lb/day) and received a 50-g top-dress containing either 0 (control, n = 30) or 88 mg (equivalent to approximately 50 ppm on an as-fed basis) of L-carnitine (Carniking 10; 10% L-carnitine, Lonza Group, Inc., Allendale, NJ, n = 29) from d 1 to d 54 or 69 gestation.

Gilts were harvested on d 55 or 70 of gestation. Gilts were allowed *ad libitum* access to water until harvest. Gilts were harvested by electrical stunning, followed by exsanguination. A mid-lateral incision was made to gain access to the abdominal cavity. The ovarian pedicles and uterine stump, at the level of the cranial cervix, were cut for removal of the uterus. Once the uterus was removed, the number of fetuses was determined on both sides.

The hindlimb muscles from the right side of the fetus were aseptically excised, washed, minced with a scissor, and pooled for each of the gilts. All cultures were maintained at 37°C, 5% CO_2, and 95% air in a water-saturated environment. After a 24-h attachment period, the plates were rinsed three times with 2.5 mL of DMEM. At 72, 96, 120, and 144 h after plating, total RNA was isolated from the cells on the 29.26 cm^2 plates (Absolutely RNA Microprep kit, Stratagene, La Jolla, CA). The concentration of total RNA was determined at an absorbance of 260 nm. TaqMan reverse transcription reagents and MultiScribe reverse transcriptase (Applied

Biosystems, Foster City, CA) were used to produce cDNA from 1 μg of total RNA. Random hexamers were used as primers in cDNA synthesis.

Table 1. Diet Composition Fed During Gestation (As-fed Basis)[a]

Item	Amount
Ingredient, %	
Corn	81.22
Soybean meal, 46.5%	14.55
Monocalcium phosphate, 21% P	2.03
Limestone	1.05
Salt	0.50
Vitamin premix[b]	0.25
Trace mineral premix[c]	0.15
Sow add pack[d]	0.25
Total	100.00
Calculated Analysis	
Lysine, %	0.65
ME, Mcal/kg	3.27
Protein, %	13.7
Calcium, %	0.85
Phosphorus, %	0.75
Available P, %	0.48

[a]Gestation feeding levels of 1.75 kg/d, with a top-dress providing either 0 or 50 ppm added L-carnitine.

[b]Supplied per kilogram of diet: 11,025 IU of vitamin A, 1,654 IU of vitamin D_3, 55.1 mg of niacin, 44.1 IU of Vitamin E, 33.1 mg of pantothenic acid, 9.9 mg of riboflavin, 4.4 mg of vitamin K (menadione), and 0.04 mg of vitamin B_{12}.

[c]Supplied per kilogram of diet: 165 mg of Zn (oxide), 165 mg of Fe (sulfate), 39.7 mg of Mn (oxide), 16.5 mg of Cu (sulfate), 0.30 mg of I (as Ca iodate), and 0.30 mg of Se (as Na selenite).

[d]Supplied per kilogram of diet: 551.3 mg of choline, 15.2 mg pyridoxine, 1.65 mg of folic acid, and 0.22 mg of biotin.

Real-time quantitative-PCR was used to measure the quantity of mRNA for IGF-I, IGF-II, IGFBP-3, and IGFBP-5 and 18S rRNA in total RNA isolated from cell cultures. Measurement of the relative quantity of cDNA was carried out by using TaqMan Universal PCR Master Mix (Applied Biosystems). Sequences for primers and probes for IGF-I, IGF-II, IGFBP-3, and IGFBP-5 are represented in Table 2. Commercially available eukaryotic 18S rRNA primers and probes were used as an endogenous control (Applied Biosystems; Genbank Accession no. X03205).

Relative expressions of mRNA for IGF-I, IGF-II, IGFBP-3, and IGFBP-5 were normalized to the 18S rRNA endogenous control by using the Δ-CT method, and were expressed in arbitrary units.

For analysis of myogenic cells, we analyzed muscle cell preparations by using a myoblast/myotube-specific monoclonal antibody 5.1H11 obtained from the Developmental Studies Hybridoma Bank (The University of Iowa, Iowa City, IA).

The statistical analysis for gene expression was performed as a repeated measure by using the MIXED Procedure of SAS. Fixed effects of treatment, day of gestation, and hour after plating were included in the model, with hour after plating as the repeated measure. Kenward-Roger adjustment was used for the degrees of freedom. Flow cytometric analysis was performed by using the MIXED Procedure of SAS. The model contained the effects of treatment, day of gestation, and their interaction. Kenward-Roger was used to adjust the degrees of freedom.

Results and Discussion

Primary mononucleated myoblasts or muscle cells are destined to have three specific roles. They may differentiate into primary muscle fibers, promote secondary muscle fiber development, or may be reserved as a population of satellite cells aiding in skeletal muscle hypertrophy in the post-natal animal. The IGF system is instrumental in skeletal muscle development, specifically muscle cell proliferation and differentiation.

In our study, we found IGF-I and IGFBP-3 mRNA expression increased in PEM as day of gestation increased from day 55 to 70 (65%

and 50%, respectively; Table 3). Insulin-like growth factor-I and IGFBP-3 play a role in proliferation and terminal differentiation of PEM. As day of gestation increased from day 55 to day 70 of gestation, IGF-I mRNA expression increased 70%, and IGFBP-3 mRNA expression increased 72%, in skeletal muscle tissue. In our experiment, we found IGFBP-3 mRNA expression was reduced at 96 h after plating, suggesting that the initiation of terminal differentiation of PEM began at 96 h after plating. In addition, IGF-I and IGF-II mRNA levels were found to be increased at 120 h after plating. We found that levels of IGFBP-3 mRNA were increased in the control gilts at 120 h after plating. Other researchers have found, at 120-h after plating, that IGFBP-3 mRNA expression was reduced in differentiating porcine embryonic cell cultures. The increase in IGF-I and IGF-II mRNA levels at 120 h and the reduced IGFBP-3 mRNA levels at 96 h that we observed confirm the roles of IGF-I, IGF-II, and IGFBP-3 mRNA in proliferation and terminal differentiation of PEM. Therefore, we conclude that the reduced levels of IGFBP-3 mRNA we observed in the L-carnitine cultures, compared with those of the controls, are a result of PEM increased proliferative capacity, but delayed differentiation. This suggests that more nuclei may be available for muscle fiber development.

Data are limited on the effects of L-carnitine on IGF system changes in skeletal muscle development during fetal growth. In the current study, we found that mononucleated myoblasts isolated from hindlimb muscles of fetuses had changes in IGFBP-3 gene expression when their dams were fed diets with L-carnitine. Specifically, IGFBP-3 gene expression decreased 48% when L-carnitine was added to the diets.

We used flow cytometry analysis to determine if L-carnitine affected the percentage of PEM positive for the monoclonal antibody 5.1H11 and the stage of the cell cycle in proliferating myoblasts. The PEM isolated from fetuses obtained from gilts fed diets containing supplemental L-carnitine had 4.7% greater adhesion of 5.1H11. This indicates that the PEM isolated from fetuses from gilts fed diets with L-carnitine had a more enriched population of myogenic cells. This may suggest that L-carnitine has additional roles in fetal development, although direct conclusions cannot be drawn.

Similar observations were noted for flow cytometric analysis of the percentage of cells in the S phase of the cell cycle. Porcine embryonic myoblasts collected from fetuses from gilts fed diets with supplemental L-carnitine had 8.8% more PEM in the S phase of the cell cycle. A fluorescence-activated cell sorter determined this. Mitosis, the process of nuclear division, contains four distinct cycles, of which, in the S phase, synthesis of DNA occurs. In our study, 37.5% of the population of PEM collected from the fetuses from the gilts fed supplemental L-carnitine were in the S phase, and only 34.2% of the control PEM were in the S phase.

Providing supplemental L-carnitine to gestating gilts altered the IGF axis in PEM collected from fetuses. Specifically, we observed a decrease in IGFBP-3 mRNA expression in PEM collected from fetuses from gilts fed L-carnitine. Insulin-like growth factor binding protein-3 plays a role in terminal differentiation of PEM. We believe that providing supplemental L-carnitine to the dam suppresses the expression of IGFBP-3 in PEM, therefore enhancing muscle proliferation and suppressing differentation.

Table 2. Primers and Probes Used for Real-time Quantitative PCR

Gene	Genbank Accession Number		Sequence
IGF-I	M31175	Forward	TCTTCTACTTGGCCCTGTGCTT
		Reverse	GCCCCACAGAGGGTCTCA
		Probe	6FAM-CCTTCACCAGCTCTGCCACGGC-TAMRA
IGF-II	X56094	Forward	CCGGACAACTTCCCCAGATA
		Reverse	CGTTGGGCGGACTGCTT
		Probe	6FAM-CCCGTGGGCAAGTTCTTCCGC-TAMRA
IGFBP-3	AF085482	Forward	AGCACGGACACCCAGAACTT
		Reverse	CGGCAAGGCCCGTATTC
		Probe	6FAM-TCCTCTGAGTCCAAGCGCGAGA-TAMRA
IGFBP-5	U41340	Forward	GGCAGAGGCCGTGAAGAAG
		Reverse	CAGCTCCCCCCACGAACT
		Probe	6FAM-CCGCAGAAAGAAGCTGACCCAGTCC-TAMRA

Table 3. Growth Factor Messenger RNA Levels in Porcine Embryonic Myoblasts at Day 55 of Gestation[a]

	Hour After Plating								
	72		96		120		144		
	L-carnitine, ppm								
Gene	0	50	0	50	0	50	0	50	SED
IGF-I	0.13	0.21	0.17	0.05	0.30	0.35	0.18	0.30	0.277-0.330
IGF-II	199.8	179.0	58.7	133.9	415.6	558.9	123.7	568.5	353.87-387.62
IGFBP-3	40.8	13.9	1.8	0.3	5.0	1.9	14.0	16.2	15.92-16.38
IGFBP-5	147.3	69.5	74.3	27.9	47.4	69.8	45.6	57.2	87.88-93.50

[a]Gene expression levels are expressed in arbitrary units (millions).

Table 4. Growth Factor Messenger RNA Levels in Porcine Embryonic Myoblasts at Day 70 of Gestation[a]

	Hour After Plating								
	72		96		120		144		
	L-carnitine, ppm								
Gene	0	50	0	50	0	50	0	50	SED
IGF-I	0.42	0.29	0.22	0.41	0.87	1.01	0.65	0.98	0.277-0.298
IGF-II	862	41,127	599	41,017	3,655	42,280	634	41,508	29211-30,014
IGFBP-3	43.6	5.7	6.0	3.9	32.7	18.7	41.6	35.1	15.92-16.67
IGFBP-5	146.2	62.3	52.2	82.9	376.9	121.3	53.7	55.7	87.88-101.23

[a] Gene expression levels are expressed in arbitrary units (millions).

Table 5. Statistical Analysis of Growth Factor Messenger RNA Levels in Porcine Embryonic Myoblasts at Day 55 and 70 of Gestation[a]

	Probability, P <						
	TRT	Day	Hour	TRT × Day	TRT × Hour	Day × Hour	TRT × Day × Hour
IGF-I	0.58	0.01	0.01	0.73	0.84	0.29	0.83
IGF-II	0.34	0.32	0.01	0.35	0.33	0.07	0.56
IGFBP-3	0.08	0.07	0.01	0.54	0.21	0.28	0.99
IGFBP-5	0.28	0.27	0.10	0.56	0.48	0.11	0.24

Table 6. Flow Cytometric Analysis

	Day of Gestation							
	55		70					
	L-carnitine, ppm[b]					Probability, P <		
Item	0	50	0	50	SED	Trt[c]	Day[d]	Trt × Day
5.1H11, %	84.1	89.4	90.8	94.2	2.92-3.63	0.09	0.20	0.77
Cell cycle stage, %								
G_1	60.1	55.7	56.9	55.8	3.42-3.82	0.44	0.67	0.65
S	34.0	37.7	34.4	37.4	2.84-3.60	0.31	0.99	0.91
G_2	6.01	7.29	8.72	7.38	1.74-1.95	0.99	0.45	0.48

PREDICTING GROWTH RATES OF ADULT WORKING BOARS IN A COMMERCIAL BOAR STUD

R. C. Sulabo, J. Quackenbush[1], R. D. Goodband, M. D. Tokach, S. S. Dritz[2], J. M. DeRouchey, and J. L. Nelssen

Summary

There is almost no information on ideal growth rates for adult boars, but estimates can be made if the relationship between boar weight and age is known. Therefore, this study was aimed to predict growth rates in adult working boars in a commercial boar stud. A total of 214 adult working boars from two genetic lines in a commercial boar stud were individually weighed on a platform scale. Age of the boar was recorded at the time of weighing. A regression equation to predict boar weight as a function of age was developed by using PROC REG of SAS. The model was used to predict BW on a daily basis, and ADG was derived as the difference between two predicted BW values. Factorial estimates of daily ME requirement and feeding rates were determined. The energy requirement for weight gain was computed by using the predicted ADG as a guide in setting target weight gains. Results showed a positive curvilinear response ($P<0.01$) to describe the relationship between boar weight and age. Predicted ADG decreased in a curvilinear manner as the boars aged. In conclusion, on-farm growth rates can be predicted effectively by relating weight with age, taken from a representative number of boars in a given farm population. These data can then be used to develop farm-specific feeding programs or to set different growth curves for experimental purposes.

(Key Words: Boars, Growth Rate, Prediction Equations.)

Introduction

Weight gain is inevitable in breeding boars because they enter the boar stud at a young age and light weight. It is typical for working boars to start their reproductive life between 300 and 350 lb, and gain more than 250 lb throughout their lifetime. The relationship between growth rate and reproductive performance of breeding boars may be important. In previous studies, slow-growing boars fed at maintenance have shown significantly decreased libido, semen volume, and sperm output. On the other hand, fast-growing boars fed at high rates are thought to have increased leg and libido problems. Rate of weight gain may also have an impact on longevity, and thus affect lifetime semen production. But the ideal growth rate for adult working boars remains unclear. This lack of information on growth rates of adult boars during their lifetime is a major challenge, but estimates can be made if the relationship between body weight and age of the boar is known. Moreover, predicting growth rates can be very helpful in developing

[1]Zoltenko Farms, Inc., Hardy, NE 68943.
[2]Food Animal Health and Management Center, College of Veterinary Medicine.

appropriate feeding programs that can be used to set different growth curves. Therefore, this study aimed to predict growth rates in adult working boars in a commercial boar stud.

Procedures

A total of 214 adult working boars from two genetic lines (180 TR4 and 34 L-380 PIC, Franklin, KY) were used in this study. Boars were selected to obtain the widest possible range in age and weights. Boars were individually weighed on a platform scale, and age of the boar was recorded at the same time. Boars were fed and housed in a commercial boar stud according to standard procedures of the farm. Diets were not manipulated for this study. All boars were fed a corn-soybean meal diet with 10% soy hulls and 5% dehydrated alfalfa, formulated to meet or exceed suggested lysine and energy requirements.

A regression equation to predict boar weight by using age of the boar was developed by using PROC REG of SAS. This model was used to predict BW for a specific age on a daily basis. Then, ADG was derived as the difference between consecutive predicted BW values. The ADG for a specific weight range is computed by taking the average of the predicted ADG of the lowest and highest value of the weight range desired.

Daily ME requirement (Mcal ME/d) and feeding rates (lb/d) under thermoneutral conditions were estimated by using the factorial approach. Requirements for maintenance, weight gain, mating activity, and sperm production were individually determined by using regression equations, and were added to estimate total daily ME requirement. The energy requirement for weight gain was determined by using the predicted ADG as a guide in setting target weight gains. The accuracy of feed drops in the facility was previously tested, and an average of 12% overage from the desired feed setting was determined. This was then used to adjust the feed box setting to obtain the desired feed allocation for each weight range. Finally, a phase-feeding program for adult working boars was developed from the estimates for daily ME requirement.

Results and Discussion

The modeled live-weight curve in boars as a function of age exhibited a positive curvilinear response ($P<0.01$; Figure 1). The model was:

$$\text{BW, lb} = [(8 \times 10^{-7} \times \text{Age}^3) - (0.0023 \times 10^{-2} \times \text{Age}^2) + (2.2561 \times \text{Age})] - 63.1$$

The predicted BW increased from 330 to 642 lb from an age of 220 to 620 d; that is an 80 lb increase for every 100 d. But the increase in BW decreased dramatically to a total of 50 lb from 620 to 1000 d of age. The developed equation was used to derive ADG from the predicted BW, and showed a negative curvilinear response as the boars aged (Figure 2). Predicted ADG decreased from 1.24 lb/d at 350 lb to 0.12 lb/d at 700 lb (Table 1). There are very few studies evaluating boar growth, but scientists from the Netherlands combined experimental and field data, and suggested a growth rate of 1.10, 0.88, 0.66, 0.44, 0.22, and 0.11 lb/d for boars weighing 330, 440, 550, 660, 770, and 880 lb, respectively. In this study, predicted ADG was 23, 20, and 6% higher than the Dutch recommendations at 330, 440, and 550 lb, respectively (Table 2). At 660 lb, the predicted ADG was 50% less than the Dutch recommendations.

Table 1. Predicted ADG for Adult Working Boars

BW, lb		Predicted ADG
Initial	Final	lb/d
350	400	1.24
400	450	1.10
450	500	0.95
500	550	0.79
550	600	0.61
600	650	0.40
650	700	0.12

Table 2. Comparison of Predicted ADG with Dutch Recommendations

BW		Recommended ADG, lb/d		
lb	kg	Dutch Study[1]	Current Study	% difference
330	150	1.10	1.36	+ 23%
440	200	0.88	1.06	+ 20%
550	250	0.66	0.70	+ 6%
660	300	0.44	0.22	- 50%
770	350	0.22	-	-
880	400	0.11	-	-

[1]Kemp and Soede, 2001.

There may be a number of reasons that can explain the differences in growth rates, such as genetic, dietary, environmental, and even procedural differences, but the predicted ADG in this study is similar to the Dutch recommendations. This may indicate that relating BW and age of an appropriate sample of boars from a given farm population can be a practical method in predicting on-farm growth rates. This agrees with previous research at Kansas State University in finishing pigs, in which real-time ultrasound scans of backfat and longissimus muscle area across different age groups of pigs were used effectively to determine daily protein and lipid accretion rates. Therefore, the data-collection method described herein can be employed to either determine farm-specific nutrient requirements or to develop appropriate feeding programs.

As an example, a phase-feeding program for adult working boars was developed from the predicted growth rates in this study. Factorial estimates of daily ME requirement and feeding rate were made for adult working boars from 300 to 700 lb (Table 3). The target values for weight gain indicated that the energy requirement for growth decreased from 2.89 to 0.44 Mcal ME/d as growth rate decreased from 1.30 to 0.20 lb/d at 300 and 700 lb, respectively. But daily energy needs of boars increased from 7.94 Mcal ME/d at 300 lb to 9.27 Mcal ME/d at 700 lb. At a dietary energy concentration of 1.4 Mcal ME/lb, the calculated daily feed allowance was 6.1, 6.3, 6.5, and 6.7 lb/d at 300 to 400, 400 to 500, 500 to 600, and 600 to 700 lb, respectively. This feed allocation provided 8.2, 8.4, 8.7, and 9.0 Mcal ME/d. These represented the four phases of the proposed feeding program. The daily ME intake of boars in the phase-feeding program fitted well with their daily ME requirement (Figure 3). Finally, the feed allocation was adjusted according to the accuracy of feed drops in the farm. An average of 12% overage from the desired feed setting was determined, and this was accounted for in the final feed allocation. The proposed phase-feeding program in boars, with the appropriate adjustments in feed allocation, is shown in Table 4.

In conclusion, relating age and body weights of boars in a given farm population can be an efficient and accurate method to model on-farm growth and predict growth rates. These data can then be used to develop farm-specific feeding programs or to set different growth curves for experimental purposes.

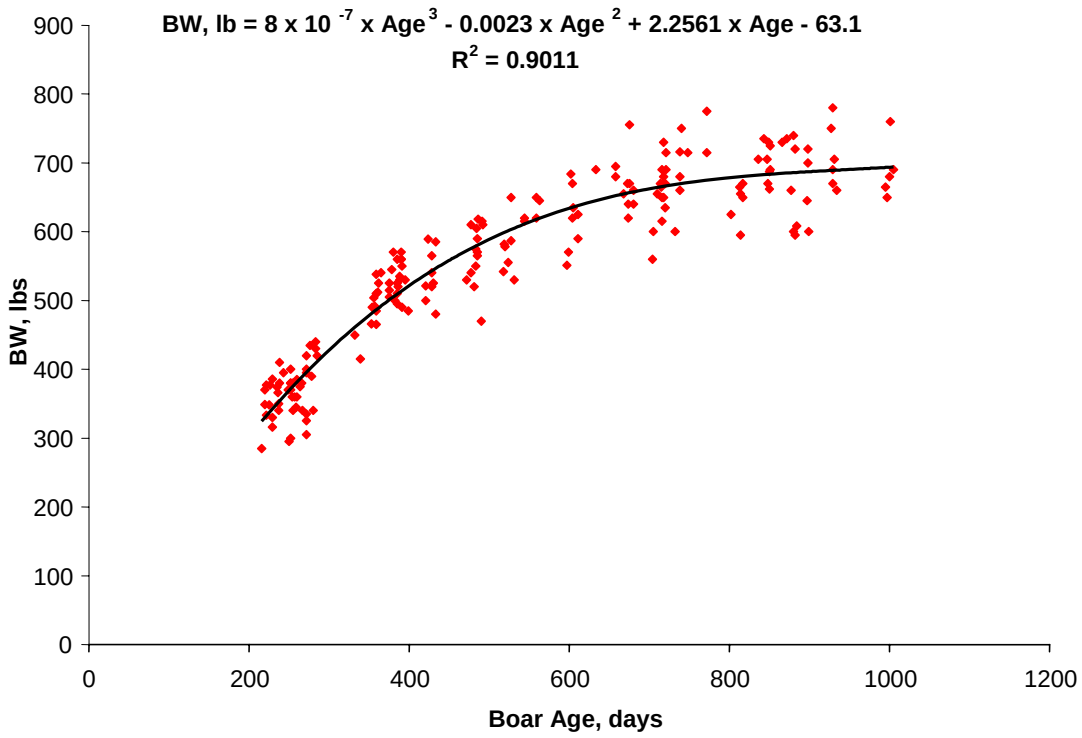

Figure 1. Relationship of Boar Age and Body Weight (214 boars).

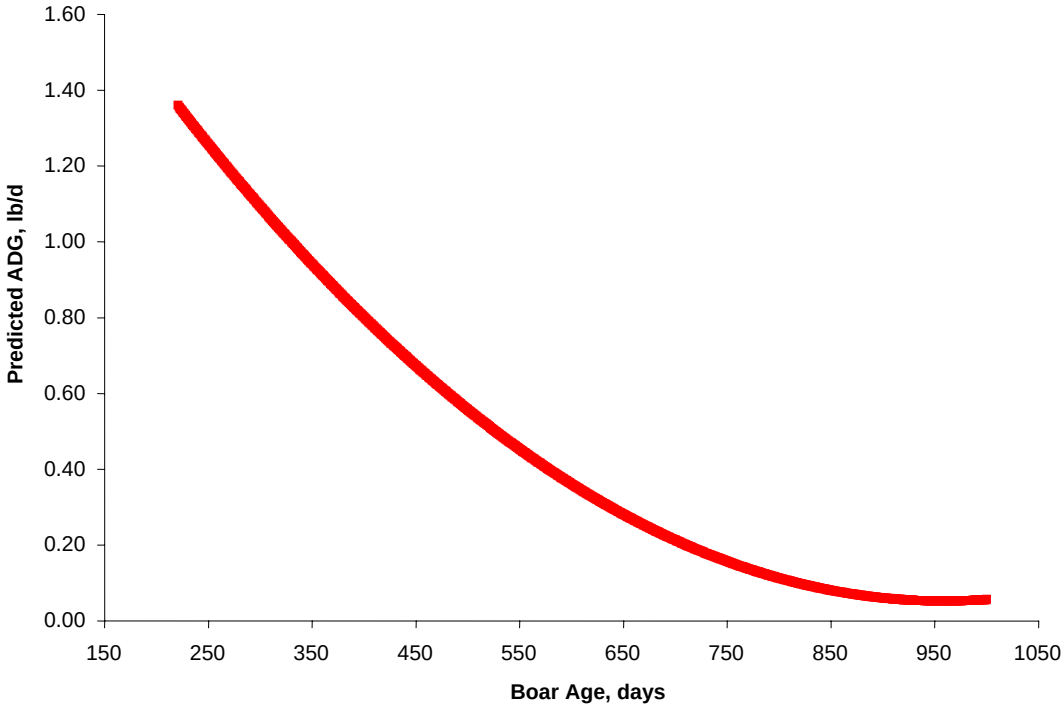

Figure 2. Predicted ADG of Adult Working Boars from 220 to 1000 d of Age.

Table 3. Daily ME Requirement (Mcal ME/d) and Feed Allowance (lb/d) for Adult Working Boars under Thermoneutral Conditions

Phase	BW	Maintenance[1]	Weight Gain[2]		Mating Activity[3]	Sperm Production[4]	Total ME Requirement	Daily Feed Allocation[5]		Feed Box Setting[6]
	lb	Mcal ME	Target, lb/d	Mcal ME	Mcal ME	Mcal ME	Mcal ME/d	lb/d	Mcal ME/d	lb/d
1	300	4.78	1.30	2.89	0.17	0.1	7.94	6.1	8.2	5.3
	340	5.20	1.20	2.66	0.19	0.1	8.15	6.1	8.2	5.3
	375	5.55	1.10	2.44	0.20	0.1	8.29	6.1	8.2	5.3
2	400	5.79	1.00	2.22	0.21	0.1	8.32	6.3	8.4	5.5
	430	6.08	0.90	2.00	0.22	0.1	8.40	6.3	8.4	5.5
	455	6.31	0.85	1.89	0.23	0.1	8.53	6.3	8.4	5.5
	480	6.54	0.80	1.78	0.24	0.1	8.66	6.3	8.4	5.5
3	500	6.72	0.70	1.55	0.25	0.1	8.62	6.5	8.7	5.7
	520	6.90	0.65	1.44	0.26	0.1	8.70	6.5	8.7	5.7
	540	7.07	0.60	1.33	0.27	0.1	8.77	6.5	8.7	5.7
	560	7.24	0.50	1.11	0.27	0.1	8.73	6.5	8.7	5.7
	575	7.37	0.50	1.11	0.28	0.1	8.86	6.5	8.7	5.7
	590	7.50	0.40	0.89	0.28	0.1	8.77	6.5	8.7	5.7
4	600	7.58	0.40	0.89	0.29	0.1	8.86	6.7	9.0	5.9
	620	7.75	0.30	0.67	0.30	0.1	8.81	6.7	9.0	5.9
	640	7.92	0.20	0.44	0.30	0.1	8.76	6.7	9.0	5.9
	660	8.08	0.20	0.44	0.31	0.1	8.93	6.7	9.0	5.9
	680	8.24	0.20	0.44	0.32	0.1	9.10	6.7	9.0	5.9
	700	8.40	0.20	0.44	0.32	0.1	9.27	6.7	9.0	5.9

[1]Maintenance = 0.1823 Mcal ME/kg $BW^{0.665}$.
[2]Weight gain = 2.22 Mcal ME/lb x target weight gain, lb.
[3]Mating activity = 4.3 kcal/kg $BW^{0.75}$.
[4]Sperm production = 0.1 Mcal ME/d.
[5]Diet energy used in calculating feed allocation was 1.4 Mcal ME/lb.
[6]Feed box setting = daily feed allocation, lb/d - (daily feed allocation, lb × 12% overage).

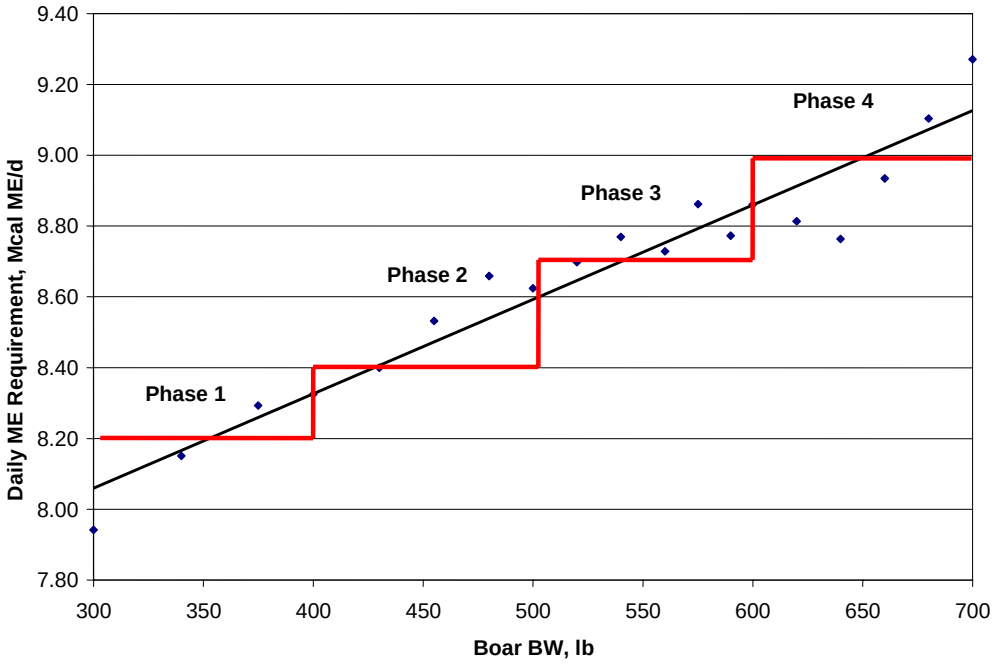

Figure 3. Relationship of Daily ME Intake (Mcal ME/d) and ME Requirement (Mcal ME/d) in Adult Working Boars under a Phase-feeding Program.

Table 4. Phase-feeding Program Developed for Adult Working Boars in a Commercial Boar Stud on the Basis of Predicted Growth Rates

Phase	BW, kg		Feed Allocation	Feeding Duration
	Initial	Final	lb/d	mo.
1	300	400	5.3	3
2	400	500	5.5	4
3	500	600	5.7	6
4	600	700	5.9	>12

VALIDATION OF FLANK-TO-FLANK MEASUREMENTS FOR PREDICTING BOAR WEIGHT

R. C. Sulabo, J. Quackenbush[1], R. D. Goodband, M. D. Tokach, S. S. Dritz[2], J. M. DeRouchey, and J. L. Nelssen

Summary

Allometric relationships, in which linear body dimensions are expressed as a function of body weight, are commonly used in growth studies. Previous work at Kansas State University showed a positive correlation between flank-to-flank measurement and sow body weight. Prediction equations were developed to estimate sow weight, but it is not known if the same equation will be valid in estimating body weight among other groups of pigs, such as boars. The objective of this study was to validate the use of flank-to-flank measurement in predicting boar weight, and to determine if the allometric equation for gestating sows can also be used for adult boars. A total of 100 adult working boars in a commercial A.I. stud were selected for this study. Flank-to-flank measurement and body weight were measured on each individual boar. Flank-to-flank measurement was positively correlated to boar body weight (R^2 = 0.84, P<0.01). The fit of the model improved slightly (R^2 = 0.86, P<0.01) when body weight was expressed as $BW^{0.333}$. The boar equation was: $BW^{0.333}$, kg = 0.0458 × flank-to-flank, cm + 1.1838. The comparison of residuals indicated that all three equations accurately predicted boar weight. The sow equation was also shown to be as accurate as the boar equations in estimating boar weight. Therefore, the sow allometric equation can be used as the final model to predict both sow and boar body weight.

(Key Words: Boars, Flank-to-flank, Allometry, Prediction Equations, Weight.)

Introduction

Allometry, which relates physical measurements such as body dimensions of an animal to its overall body size or weight, is frequently used in studies of animal growth. Assuming that the form of small and large pigs remains the same and that specific gravity of the body changes remain constant, then volume (or body weight) increases as the cube of linear dimensions. Linear body dimensions can then be expressed as $L = kBW^{0.333,}$ where L = linear dimension, k = appropriate coefficient, and BW = body weight. Kansas State University researchers previously developed a simple allometric equation to estimate sow weight by using flank-to-flank measurements. This provided a simple, yet more accurate, method of categorizing sows into weight categories, which can be useful in developing feeding programs, especially during gestation. It is unknown, however, if the same method is valid for other groups of pigs, such as adult working boars. Therefore, the objective of this study was to validate the use of flank-to-flank measurement in predicting boar weight and to

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determine if the allometric equation for gestating sows can also be used for working boars.

Procedures

A total of 100 adult working boars from two genetic lines (83 TR4, 17 PIC 380) in a commercial A.I. stud were used in the study. Boars were selected specifically to obtain the widest possible range in weights. A cloth tape measure was used to take a flank-to-flank measurement immediately in front of the hind legs of the boar (Figure 1). Measurement was from the bottom of the flank on one side to the bottom of the flank on the other side, with the cloth tape being placed over the top of the hip. Boars were then removed from the stall and weighed on a platform scale. The date of measurement, boar ID, age, body weight (BW), and flank-to-flank measurement were recorded.

Regression equations to predict boar weight using flank-to-flank measurement were developed by using PROC REG of SAS. Three equations were compared in the study: Equation 1 – boar model with BW having no scaling factor, Equation 2 – boar model with BW expressed as $BW^{0.333}$, Equation 3 – sow model with BW expressed as $BW^{0.333}$. Residuals were used to estimate the accuracy of the equations. The residuals were calculated as the absolute value of the difference between predicted weight by using the developed allometric equations and actual weight measured with the scale. Median residuals and sample quartiles were determined by using PROC UNIVARIATE of SAS.

Results and Discussion

The relationship between flank-to-flank measurement and boar weight is shown in Figure 2. Flank-to-flank measurement and boar body weight was positively correlated ($R^2 = 0.84$; $P<0.01$) with the equation:

$$\textbf{BW, kg} = 5.1793 \times \textbf{flank-to-flank, cm} - 322.87 \quad \text{(Eq. 1)}$$

When boar weight was expressed as $BW^{0.333}$, a similar relationship was observed (Figure 3). The second boar equation was:

$$\textbf{BW}^{0.333}\textbf{, kg} = 0.0458 \times \textbf{flank-to-flank, cm} + 1.1838 \quad \text{(Eq. 2)}$$

This allometric equation fit the weight data better than the first model ($R^2 = 0.86$; $P<0.01$). This result agrees with previous work on gestating sows, and indicates that flank-to-flank measurement can also be used to estimate boar body weight. Moreover, a better fit is obtained when boar BW is expressed in the model as $BW^{0.333}$.

The third model tested was the sow model:

$$\textbf{BW}^{0.333}\textbf{, kg} = 0.0511 \times \textbf{flank-to-flank, cm} + 0.5687 \quad \text{(Eq. 3)}$$

A comparison of the three models, on the basis of absolute residuals, is shown in Table 1. The average residual was 16.8 and 17.4 kg for Equations 1 and 2, respectively. When the sow model (Equation 3) was used to estimate boar weight, the average residual was 18.3 kg. The median residuals for Equations 1, 2, and 3 were 13.6, 13.8, and 14.5 kg, respectively. This indicates that the predicted weights of half of the boars were within 14 kg of their actual weights, whereas 75% of the boars were within 23 kg. On the other hand, predicted weights of 90% of the boars were within 35 and 40 kg of their actual weights when Equations 2 and 3 were used, respectively. Comparison of residuals indicates that all three equations accurately predicted boar weight. The prediction equation developed for gestating sows was also shown to be as accurate as the boar equations in estimating boar weight.

Although both the linear and allometric equations were suitable models for estimating pig weight, expressing BW as $BW^{0.333}$ in the model is preferred for a number of reasons. First, we are relating flank-to-flank measurement, which is a uni-dimensional concept, with a three-dimensional concept, body weight. The allometric coefficient (0.333), which describes the relationship between the two variables, is determined by dividing the dimensional exponent of flank-to-flank measurement (= 1) with the dimensional exponent of body weight (= 3). This means that flank-to-flank measurement increases at a lower rate than an increase in body weight. Second, previous data from sows and growing-finishing pigs suggest that the relationship between flank-to-flank measurement and body weight is non-linear in a lower weight range. With this, a linear model will not be appropriate for estimating a wider range of pig weights. The sow allometric equation can be used as the final model in estimating pig weights because it has been developed and tested on a larger database, a wide range of weights (50 – 350 kg), more genetic lines, and both sexes of pigs. The final model in estimating pig weights by using flank-to-flank measurement is the sow model (Equation 3).

Figure 1. Flank-to-flank Measurement.

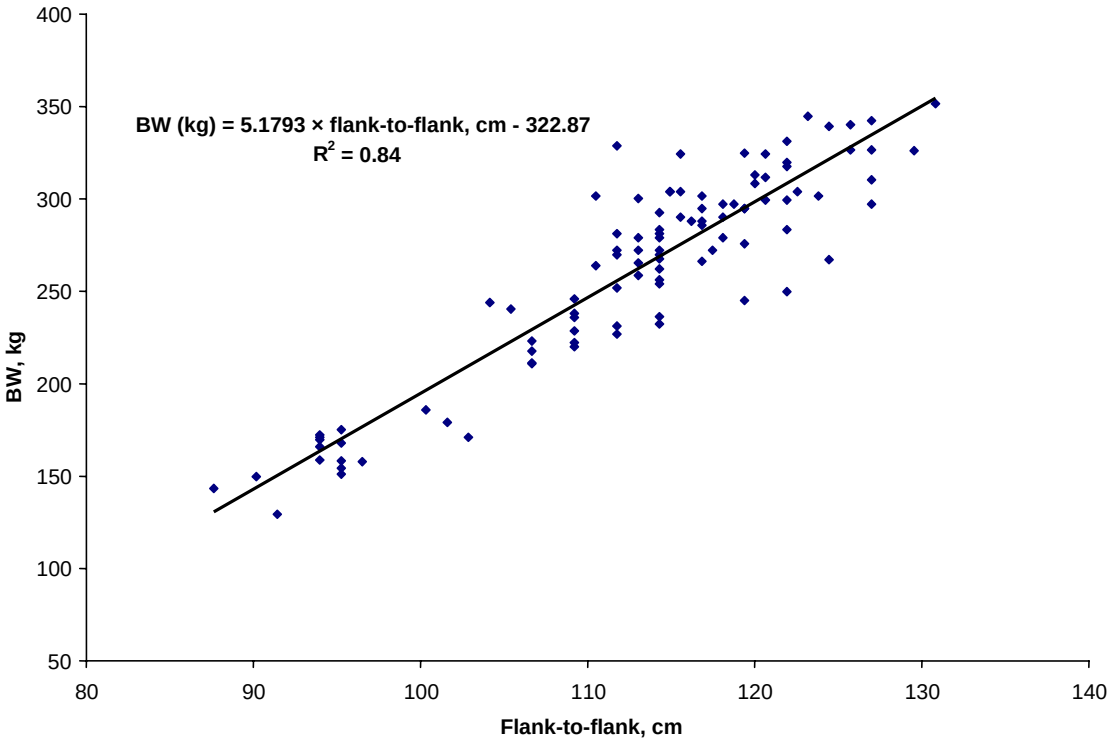

Figure 2. Relationship Between Flank-to-flank Measurement and Boar Weight (100 boars).

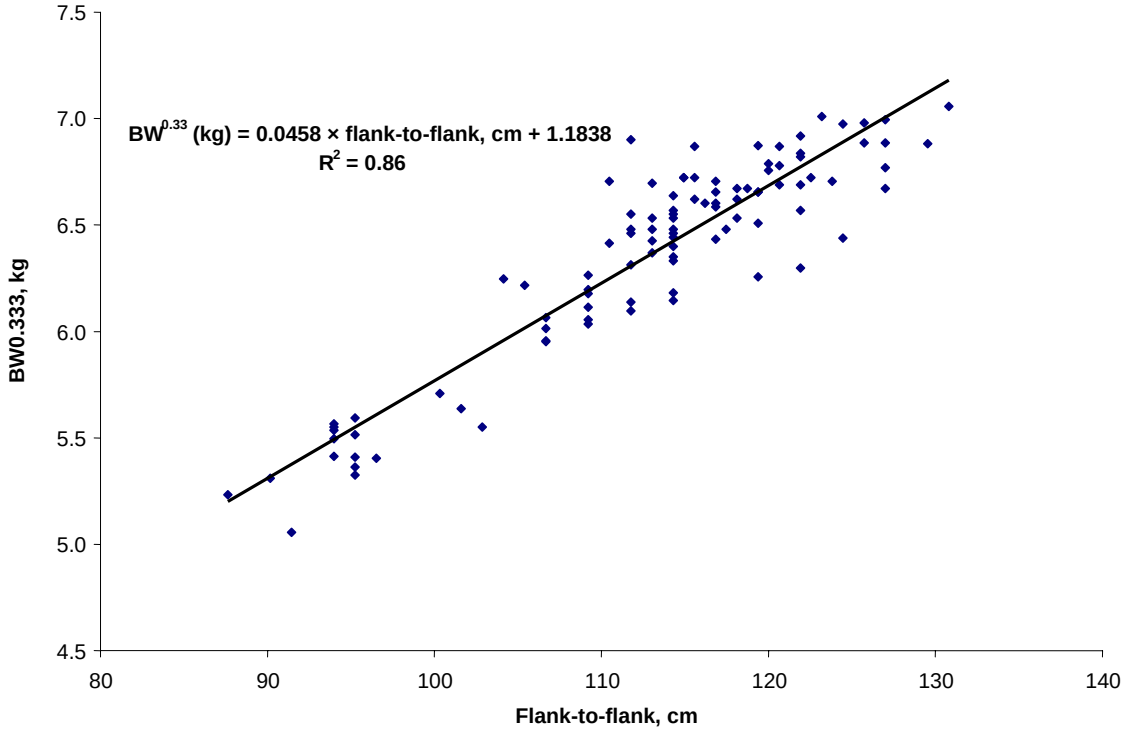

Figure 3. Relationship Between Flank-to-flank Measurement and Boar Weight Expressed on an Allometric Basis (kg $BW^{0.333}$).

Table 1. Comparison of Models Based on Absolute Residuals[a]

Percentile	Absolute Residual					
	Equation 1[b]		Equation 2[c]		Equation 3[d]	
	lb	kg	lb	kg	lb	kg
25th	15.0	6.8	15.0	6.8	15.0	6.8
50th	30.0	13.6	30.5	13.8	32.0	14.5
75th	50.0	22.7	50.5	22.9	54.5	24.7
90th	76.5	34.7	77.5	35.2	89.0	40.4

[a]Residuals = absolute difference between predicted and actual weight.
[b]Equation 1: BW, kg = 5.1793 × flank-to-flank, cm – 322.87.
[c]Equation 2: $BW^{0.333}$, kg = 0.0458 × flank-to-flank, cm + 1.1838 (boar equation).
[d]Equation 3: $BW^{0.333}$, kg = 0.0511 × flank-to-flank, cm + 0.5687 (sow equation).

Table 2. Predicted Pig Body Weight (lb) by Using Flank-to-flank Measurement

Flank-to-flank Measurement		Predicted BW
in	cm	lb
24	61	110
25	64	122
26	66	135
27	69	149
28	71	164
29	74	179
30	76	196
31	79	214
32	81	232
33	84	252
34	86	273
35	89	294
36	91	317
37	94	342
38	97	367
39	99	394
40	102	421
41	104	451
42	107	481
43	109	513
44	112	546
45	114	580
46	117	616
47	119	654
48	122	693
49	124	733
50	127	775

INVESTIGATION INTO THE EFFECTS OF FEEDING SCHEDULE ON BODY CONDITION, AGGRESSIVENESS, AND REPRODUCTIVE FAILURE IN GROUP HOUSED SOWS[1]

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

Summary

A total of 208 sows and 288 gilts (PIC Line C29) were used to determine the influence of feeding frequency (2 versus 6 times per day) in gestation on performance and welfare measurements. The experiment was conducted on a commercial sow farm in northeast Kansas that typically housed gestating sows and gilts in pens. Treatments consisted of feeding similar amounts of feed to each sow or gilt over 2 (07:00 and 15:30) or 6 meals per day (07:00, 07:30, 08:00, 15:30, 16:00, and 16:30 hours). There were 8 sows or 12 gilts in each pen. Gilts and sows were moved to pens after breeding.

In gestating sows, there were no differences (P>0.10) between treatments in ADG, backfat change, or variation in body weight. There was a trend (P<0.08) for sows fed twice a day to farrow more total number born, but number born alive or other measures of reproductive performance were not different (P>0.10) among treatments. Sows fed 6 times a day had increased vocalization during the morning (P<0.07) and afternoon (P<0.01) feeding periods, compared with sows fed twice a day, but sows fed twice a day had more skin (P<0.01) and vulva (P<0.04) lesions, as well as a small, but significant, increase in feet/leg (P<0.01) and hoof (P<0.02) problems.

In this commercial facility, the standard management protocol required moving gilts to a different gestation facility. On d 42, two pens of gilts with similar breeding dates and treatment were combined and moved to another facility with larger pens until farrowing. From d 0 to 42, gilts fed 6 times a day had greater ADG (P<0.07) and d-42 backfat (P<0.09). After movement to the larger groups from d 42 to farrowing, ADG was similar (P > 0.10) for gilts fed 2 or 6 times per day. Gilts fed twice a day had less weight variation at both d 42 (P<0.04) and at farrowing (P<0.10). In gilts, there were no differences (P>0.10) for reproductive performance, skin and vulva lesions, and leg/feet and hoof scores.

In conclusion, there were few growth, farrowing, or aggression differences among gilts fed either 2 or 6 times per day. This suggests that either feeding method is suitable for group-housed gilts. Among sows, different feeding frequency resulted in few growth or farrowing-performance differences. Feeding 6 times per day did result in a small, but significant, reduction in skin and vulva lesions and structural-problem scores, while increasing vocalization. Increasing the feeding frequency

[1]The authors thank the National Pork Board for funding.

[2]Food Animal Health and Management Center, College of Veterinary Medicine.

from 2 to 6 times per day does not seem to have a dramatic negative or positive impact on performance or welfare of group-housed gilts and sows.

(Key Words: Feeding Frequency Gilts, Group Housing, Gestation, Sows.)

Introduction

In many commercial swine facilities, sows are individually housed in gestation stalls; animal welfare concerns and equipment replacement costs may lead to increased usage of group housing strategies during gestation. Because housing sows in groups allows for an increase in freedom of movement and social interaction, it is perceived to be more welfare-friendly than individually housing sows in stalls. This approach is also thought to decrease chronic stress experienced by sows, and speed the farrowing process. But the social interactions between animals also can lead to greater aggressive behavior among sows. The condition commonly known as "boss sow" syndrome occurs when dominant sows that are high on the social order consume more feed than desired at the expense of other sows in the group. Not only does this form of aggression lead to timid sows consuming less feed than desired as they fail to compete with dominant sows, but also it is likely to result in high fear and distress in the less-dominant sows.

The ability to properly feed gestating sows in group housing has been an ongoing challenge for swine producers, and is one of the biggest detriments of group housing systems. Several different approaches to feed group-housed sows have been attempted, including feeding sows every other day, using feeding stalls within a pen, using electronic sow feeders, trickle feeding, and *ad libitum* feeding of high-fiber diets. A recent approach used on some swine farms is multiple feedings per day, in which pens of sows are fed small amounts of feed spread throughout the day (over 5 or 6 meals). The theory behind multiple feedings is that offering feed more frequently may result in dominate sows eating their allowance early in the day and possibly giving timid sows more opportunity to eat later in the day, resulting in less variation. Although this procedure seems to be popular among some producers, we are unaware of any research that validates this concept. The objective of this study was to determine whether feeding group-housed gestating sows multiple times per day reduces variation in sow body weight, backfat thickness, aggressiveness, and feet and leg problems, compared with feeding twice per day.

Procedures

A total of 496 group-housed gilts and sows were used to determine the influence of feeding frequency (2 versus 6 times per day) on performance and welfare measurements. The experiment was conducted on a commercial sow farm in northeastern Kansas that typically housed gestating sows and gilts in pens. Sows and gilts were managed differently in the experiment, so procedures and data are presented separately for them.

A total of 208 sows were randomly allotted to treatments (13 pens/treatment) in a balanced incomplete-block design. After weaning sows were moved to a breeding facility. Sows (average of 3 parities) received boar exposure and were housed in crates until detection of estrus, then were inseminated twice. The next day, 24 to 40 sows were randomly allotted by parity and assigned to a pen (16 × 10 ft; 8 sows/pen). Sows were weighed, and backfat was measured at the P2 position, at the time of allotment and before introduction into the farrowing house. Standard farrowing records were recorded by farm personnel.

A total of 288 gilts were allotted to treatments at breeding, with 12 replicates per treatment in a balanced incomplete-block design. Replacement gilts were selected for

breeding and were transported to a breeding facility. Upon arrival, gilts were housed in groups, with boar exposure, until estrus detection. Gilts were inseminated twice and then were moved to pens (16 × 10 ft) over approximately 4 d until there were 12 gilts each pen. Gilts were housed in this facility until d 42 of gestation. At this time, gilts of similar breeding dates and treatment were combined and moved to another facility with larger pens until farrowing. Thus, the 12 replicates per treatment were combined to give 6 replications per treatment after d 42 of gestation. Gilts were weighed, and backfat was measured at the P2 position, at allotment, on d 42, and before farrowing. Standard farrowing records were recorded by farm personnel.

A grain sorghum-soybean meal gestation diet was fed to all sows and gilts, but with either 2 or 6 feedings per day. Feed drops were set to provide 5.5 lb of feed per sow per day and 4.5 lb of feed per gilt per day. All feed for sows and gilts was dropped onto the solid concrete floor. Feed drops were scheduled to drop twice (07:00 and 15:30) or 6 times per day (07:00, 07:30, 08:00, 15:30, 16:00, and 16:30 hours). Feed drops were set at the beginning of the trial, and were adjusted if a sow or gilt was removed from the trial. To accommodate the amount of feed needed per day, there were two feed drops per sow pen. For the gilts, there were 3 feed drops per pen from d 0 to 42, and 5 feed drops per pen from d 42 to farrowing. Feed drops in the current trial were the Accu-Drop Feed Dispenser provided by Automated Production Systems (Assumption, IL).

Sow and gilt aggressiveness during gestation period was determined by visually scoring lesions on the total body and vulva. Total body lesion scores were determined from a scale: 1 = no blemishes to some reddening or calluses, 2 = less than 10 scratches or 5 small cuts, 3 = more than 10 scratches or 5 small cuts, and 4 = most or whole area covered with scratches/wounds, with little or no untouched skin. Visual scoring of the vulva was determined from a scale: 1 = no obvious wounds, 2 = slight laceration, 3 = severe lacerations, and 4 = sow with severe lacerations and portions of the vulva absent. Structural integrity for sows and gilts was performed by visual scoring of the feet and legs. Visual scores for mobility were determined from a scale: 1 = no lameness observed in front or rear legs, 2 = animals with slight structural and/or movement problems, and 3 = sows/gilts with severe structural problems and unable to get up or walk. Hoof integrity scores were determined on a scale: 1 = no obvious lesions or cracks, 2 = animals with slight lesions on their foot pad and/or between toes, and 3 = sows with severe hoof cracking and lesions on the foot pad and/or between toes. Lesion scores were recorded on day 1 (before mixing) and every 14 days until farrowing.

Vocalization of sows was recorded by using an Extech Model 407764 (Waltham, MA) data-logging sound-level meter. The data logger was set to a frequency weighting 'A' mode, which responds like the human ear (boosting and cutting the noise amplitude over the frequency spectrum). The 'A' weighting mode is typically used for environmental measurements, OSHA regulatory testing, law enforcement, and workplace design. The meter was also set to slow mode (meter responds in 500 ms) to monitor a sound source that has a reasonably consistent noise level or to average quickly changing levels. Decibel readings at 1-min intervals are determined by using a sound-level meter. The sound meters were placed approximately 0.15 m from the feed drop and 1 m above the feeding area. A directional cone was attached to the microphone to decrease extraneous noise from adjacent pens. Vocalization was not measured in gilts due to the combining of pens and movement to another facility on d 42. Chi-square analysis was used to determine differences in the proportion of gilts and sows removed from the trial. All other data reported were analyzed by using the MIXED procedure of SAS (2001).

Results and Discussion

Feeding frequency did not influence (P>0.93; Table 1) total sow removal or the proportion of sows removed for reproductive failure. Although relatively few sows were removed for structural problems, they were all on the 2 times per day feeding frequency, leading to a higher (P<0.07) removal rate for structural problems for sows fed 2 times per day than for sows fed 6 times per day. In gilts, there was no influence (P>0.31) of feeding frequency on removal from the trial because of reproductive failure or structural problems.

In sows, increasing feeding frequency from 2 to 6 times a day had no effect (P>0.10) on overall gain, ADG, and backfat change (Table 2). Initial and final P2 backfat were not different (P>0.10) among sows fed 2 or 6 times a day. Backfat gain (3.3 mm) was similar (P>0.10) for sows on both feeding treatments. Sow weight variation increased from the beginning of gestation (CV of 10 and 12%, respectively) to the end of gestation (CV of 15 and 17%, respectively), but was not influenced (P>0.10) by treatment.

In gilts, increasing the feeding frequency from 2 to 6 times a day did not affect weight gain from d 0 to 42 of gestation, but there was a trend (P<0.12; Table 3) for gilts fed 6 times a day to have a greater ADG and, therefore, gain more weight from d 0 to 42 (33 vs. 25 lb), when compared with gilts fed twice a day. There were no differences in weight gain from d 42 of gestation until farrowing. Thus, final weight was similar for the two feeding frequencies.

There was no difference (P>0.10) in initial weight variation for gilts, but d-42 weight variation was greater (P<0.04) for gilts fed 6 times a day. The increased variation at d 42 was maintained until farrowing, with greater variation in final weight (P<0.10) for gilts fed 6 times per day.

From d 0 to 42, gilts fed 6 times a day gained P2 backfat (0.37 mm), whereas gilts fed 2 times per day lost backfat (0.28 mm), resulting in 1 mm difference (P<0.09) on d 42. From d 42 to the end of gestation, all gilts lost approximately 1 mm, but the difference observed on d 42 was maintained until the end of the gestation period.

Among sows or gilts, there were no difference (P>0.10; Table 4) in number born alive, stillbirths, or mummies when feeding either 2 or 6 times a day during gestation.

In sows, aggressiveness, as determined by visual scores of skin and vulva lesions, was more pronounced (P<0.01 and 0.04, respectively) when fed 2 times a day versus sows fed 6 times a day (Table 5). Gestating sows fed 6 times a day experienced fewer (P<0.01 and 0.02, respectively) structural problems with feet and legs and hoofs as measured by higher visual scores. It must be noted, however, that all scores were low, indicating relatively few structural problems for either treatment. In gilts, there were no differences (P>0.10) observed for skin or vulva lesions or leg and hoof scores during the d 0 to 42 period or from d 42 to farrowing. Vocalization was greater in the 2-h period around the morning (P<0.07) and afternoon (P<0.01) feeding periods for sows fed 6 times a day versus sows fed 2 times a day (Table 6). As demonstrated in Figures 1 and 2, vocalization increased with each feeding and returned to baseline values. Sows fed 6 times per day had three distinct vocalization peaks during each feeding period, indicating that they were more active over the feeding period.

Feeding frequency did not affect ADG, backfat change, or weight variation of group-housed gestating sows. In gilts, feeding 6 times per day tended to increase ADG and backfat from d 0 to 42. The increased backfat was maintained until farrowing, but final weight was similar at the end of gestation. The lack of differences in final weight was not

surprising because gilts and sows on both treatments were fed the same total quantity of feed each day. The greater feeding frequency (6 times per day) was hypothesized to reduce variation in weight gain; this did not occur. The more aggressive "boss" sows were expected to consume a greater portion of feed at the first morning and afternoon feedings and then allow more-submissive sows to consume more feed at the second and third feedings. After the initial morning and afternoon meal, sows that consumed feed should have had a spike in blood glucose and insulin, which should have induced a greater sense of satiety by the time the second and third feeding occurred. In reality, variation in final weight increased numerically in both sows and gilts when feeding frequency was increased, suggesting that more aggressive sows may have been able to consume more total feed, instead of less.

There were no differences in reproductive performance for sows or gilts fed either treatment, except for a trend for sows fed 2 times a day to farrow more total number of pigs. Feeding frequency was not expected to have a large impact on reproductive performance.

Sows fed 6 times per day had lower skin and vulva lesion scores and leg/feet and hoof scores than scores of sows fed 2 times per day; however, there were no differences in gilts. Fewer skin and vulva lesions are an indication that fewer fights and subsequent injuries occurred in the sows fed 6 times per day, but the differences between treatments were relatively small. Sows fed 6 times per day were expected to have fewer hoof lesions; there should have been less impacted feed in hooves of sows fed 6 times per day because of the smaller amount of feed on the concrete at any one time. Sows fed 6 times a day were more active during the feeding period, as measured by vocalization, versus sows fed 2 times a day. Thus, the welfare criteria demonstrate both positive (lower lesion and structural-problem scores in sows) and negative (increased vocalization) responses to increasing the feeding frequency.

Determining the welfare status of gestating sows can be challenging because of the complexities between different gestation housing environments and challenges quantifying measures of welfare. A common problem with group housing of gestating sows is a condition commonly known as "boss sow" syndrome. This occurs when dominant sows that are high on the social order consume more feed than desired, at the expense of other sows in the group. In this project, we increased the feeding frequency from 2 to 6 times per day and spaced the feedings at a designed interval in an attempt to induce the sense of satiety of the boss sows and reduce variation in sow weight gain within each pen. Increasing feeding frequency did not improve overall weight gain, weight variation, reproductive performance, or overall removal rate of group-housed gestating sows or gilts. There were small reductions in skin and vulva lesions and structural scores, but there was an increase in vocalization for sows fed 6 times per day. In summary, increasing the feeding frequency from 2 to 6 times per day does not have a dramatic negative or positive impact on performance or welfare of group-housed gilts and sows.

Table 1. Effect of Feeding Frequency on Removal of Gestating Gilts and Sows[a]

	Frequency of Feeding per Day		Chi-Square
Item	2	6	P-value (P <)
Reason for sow removal			
Open	11	17	0.93
Structural problems	4	0	0.07
Total	15	17	0.97
Reason for gilt removal			
Open	23	19	0.31
Structural problem	0	0	0.99
Total	23	19	0.31

[a]Data were analyzed as a chi-square.

Table 2. Effect of Feeding Frequency on Performance of Gestating Sows[a]

	Frequency of Feeding per Day[bcd]			
Item	2	6	SE	P-value (P <)
Gestation period				
Initial weight, lb	504	512	12.28	0.66
Final weight, lb	602	600	10.72	0.90
Gain, lb	98	88	6.96	0.32
ADG, lb	1.03	0.93	0.07	0.30
ADFI, lb	5.50	5.50	0.01	0.22
CV of initial weight, %	10.62	12.27	1.09	0.31
CV of final weight, %	14.85	17.22	1.52	0.20
Initial backfat, mm	16.04	15.96	0.32	0.85
Final backfat, mm	19.35	19.32	0.35	0.95
Backfat change, mm	3.30	3.32	0.38	0.96

[a]Each value is the mean of 13 replications with 8 sows per pen.
[b]Data were analyzed as a balanced incomplete-block design with days on trial as a covariate.
[c]Pens that were fed twice daily received feed at 07:00 and 15:30 hours; Pens that were fed 6 times a day received feed at 07:00, 07:30, 08:00, 15:30, 16:00, and 16:30 hours, respectively.
[d]Feed drops were adjusted if a sow was removed from trial.

Table 3. Effect of Feeding Frequency on Performance of Gestating Gilts[ab]

	Frequency of Feeding per Day[cde]			
Item	2	6	SE	P-value (P <)
Gestation d 0 to 42				
Initial weight, lb	382	389	4.70	0.31
Final weight, lb	409	421	5.48	0.17
Gain, lb	25	33	3.28	0.12
ADG, lb	0.60	0.79	0.07	0.07
ADFI, lb	4.50	4.50	0.01	0.23
CV of initial weight, %	10.35	10.66	0.63	0.72
CV of final weight, %	10.26	12.48	0.65	0.04
Initial backfat, mm	18.93	19.53	0.28	0.14
Final backfat, mm	18.75	19.72	0.45	0.09
Backfat change, mm	-0.28	0.37	0.40	0.22
Gestation d 42 until farrowing				
Initial weight, lb	415	427	5.91	0.12
Final weight, lb	473	473	10.09	0.95
Gain, lb	58	49	8.79	0.35
ADG, lb	1.01	0.85	0.16	0.39
ADFI, lb	4.50	4.50	0.01	0.23
CV of initial weight, %	10.21	13.47	0.85	0.02
CV of final weight, %	10.39	15.12	2.20	0.10
Initial backfat, mm	18.93	20.07	0.67	0.17
Final backfat, mm	18.02	19.07	0.54	0.13
Backfat change, mm	-0.93	-1.05	0.59	0.85

[a]Gestation d 0 to 42, each value is the mean of 12 replications with 12 gilts per pen.
[b]Gestation d 42 until farrowing, each value is the mean of 6 replications with 17 to 23 gilts per pen.
[c]Data were analyzed as a balanced incomplete-block design with days on trial as a covariate.
[d]Pens that were fed twice daily received feed at 07:00 and 15:00 hours; Pens that were fed 6 times a day received feed at 07:00, 07:30, 08:00, 15:30, 16:00, and 16:30 hours, respectively.
[e]Feed drops were adjusted if a gilt was removed from trial.

Table 4. Effect of Feeding Frequency on Reproductive Performance of Gestating Gilts and Sows

	Frequency of Feeding per Day			
Item	2	6	SE	P-value (P <)
Sow farrowing record				
Total number born	14.64	13.58	0.38	0.08
Number born alive	11.98	11.32	0.39	0.26
Stillbirths	1.78	1.64	0.18	0.58
Mummies	0.89	0.62	0.15	0.21
Gilt farrowing record				
Total number born	14.22	14.39	0.39	0.75
Number born alive	11.15	11.37	0.31	0.62
Stillbirths	1.80	1.46	0.16	0.17
Mummies	1.28	1.56	0.27	0.42

Table 5. Effect of Feeding Frequency on Aggressiveness and Soundness Scores of Gestation Gilts and Sows

	Frequency of Feeding per Day			
Item	2	6	SE	P-value (P <)
Sows				
Aggressiveness				
Skin	1.51	1.34	0.04	0.01
Vulva	1.08	1.03	0.02	0.04
Structure				
Feet/leg	1.21	1.12	0.03	0.01
Hoof	1.05	1.01	0.01	0.02
Gilts				
d 0 to 42				
Aggressiveness				
Skin	1.36	1.37	0.03	0.82
Vulva	1.06	1.06	0.01	0.94
Structure				
Feet/Leg	1.03	1.03	0.01	0.75
Hoof	1.01	1.00	0.01	0.24
d 42 to farrowing				
Aggressiveness				
Skin	1.22	1.27	0.04	0.22
Vulva	1.12	1.12	0.01	0.92
Structure				
Feet/leg	1.09	1.11	0.01	0.12
Hoof	1.04	1.04	0.01	0.86

Table 6. Effect of Feeding Frequency on Area Under the Curve[a]

	Frequency of Feeding per Day			
Item	2	6	SE	P-value (P <)
Feeding Time				
AM	8,458	8,540	41.4	0.07
PM	8,348	8,906	41.4	0.01

[a]Area under the curve is the sum of the decibel level measurements over a 2-h sampling period.

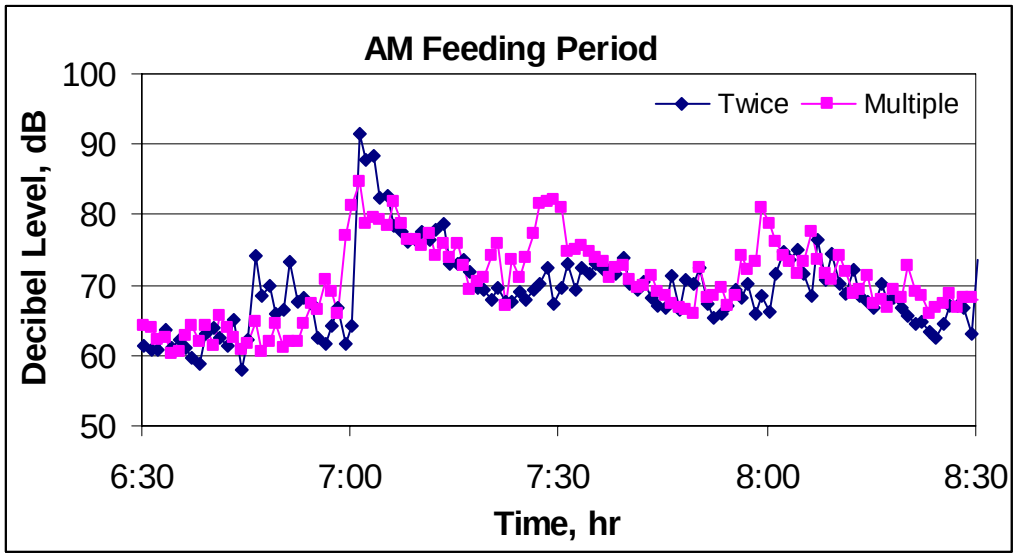

Figure 1. Area Under the Curve Measured in a Two-hour Period Over the Morning Feeding Period. Area under the curve is calculated as the sum of the measurements of peak decibel level.

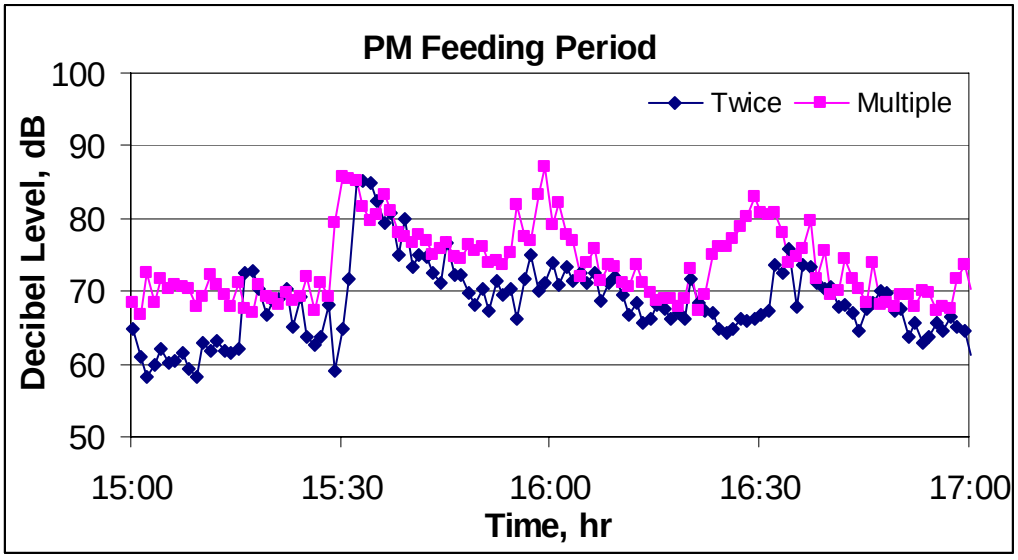

Figure 2. Area Under the Curve Measured in a Two-hour Period Over the Afternoon Feeding Period. Area under the curve is calculated as the sum of the measurements of peak decibel level.

DETERMINING THE EFFECT OF RESTRICTED FEED INTAKE ON DEVELOPING PIGS WEIGHING BETWEEN 150 AND 250 LB, FED TWO OR SIX TIMES DAILY

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Summary

Two 42-d studies were conducted to evaluate the effect of restricted feed intake and feeding frequency on the performance of pigs weighing from 150 to 250 lb (initially 148 lb in Exp. 1 and 155 lb in Exp. 2). Our objective was to use the limit-fed finishing pig as a model for gestating sows who are also limit fed. In both experiments, pigs were housed in a 6 ×10 ft pen with half solid cement and half slatted flooring, and with one nipple waterer. The diet consisted of a diet based on corn-soybean meal, formulated to 1.15% TID lysine (1.29% total lysine) and 1,494 kcal of ME/lb. Energy and lysine were supplied to pigs to target an average growth rate of 1.75 lb/d, based on NRC (1998) values. Pigs were fed by dropping similar amounts of feed, either 2 or 6 times per day, by an Accu-Drop Feed Dispenser (AP Systems, Assumption, IL) on the solid cement flooring with *ad libitum* access to water. In Exp. 1, there was an increase ($P<0.01$) in ADG and a decrease ($P<0.02$) in F/G for pigs fed similar amounts of feed 6 times per day, compared with pigs fed 2 times per day. In Exp. 2, increasing the feeding frequency of pigs fed a restricted diet from 2 to 6 times per day improved ADG ($P<0.02$) and F/G ($P<0.03$). These studies indicate that increasing the frequency of feeding may improve the metabolic efficiency of the growing pig fed a restricted diet. More research is needed to determine whether the greater gain is due to improved efficiency or whether there is another reason, such as a decrease in feed wastage.

(Key Words: Feeding Frequency, Restricted Intake, Pigs.)

Introduction

Sow longevity is the primary economic indicator of efficient piglet production. Most sow longevity research concentrates on feed intake and backfat loss during lactation, but little data is available on the effect of gilt performance on longevity. Current development recommendations are that gilts should reach their second estrus at a minimum body weight of 300 lb before they are eligible for breeding; some producers and breeding stock companies desire that gilts also reach a minimum age. In high-health situations, gilts may be past the 300 lb target weight before expressing their second estrus or reaching the minimum age set by the breeding stock supplier. Breeding gilts at too heavy a weight ultimately increases the lifetime feed maintenance requirement. Restricting feed intake in developing gilts would reverse this effect, but restricting feed is extremely difficult due to facility constraints.

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We recently tested whether increasing the frequency of feeding from 2 to 6 times per day for sows in group-housed pens would improve the welfare and/or reduce the variation in weight gain. The feeding regimen was spread out over a 2-h period, with 3 feedings in the morning and afternoon. Results from this trial produced a variable response to increasing feeding frequency in sows, but we decided to test the feeding regimen in developing gilts that were on a higher level of feeding, above maintenance. Furthermore, to our knowledge there are little data presently available that examine the effects of feeding gilts 2 versus 6 times per day.

The objective of this study was to determine if the frequency of feeding a restricted diet to pigs in a group-housed environment had any effect on pig performance or variation of weight gained.

Procedures

General. All experiments were conducted at the Kansas State University Swine Research and Teaching Center. Each pen was 6 × 10 ft and contained half solid and half slatted flooring with a deep pit and one curtain side. Each pen had one nipple waterer to allow *ad libitum* access to water.

Diet. The experimental diet was a corn-soybean meal diet formulated to 1.15% TID lysine (1.29% total lysine) and 1,494 kcal of ME/lb (Table 1). All pigs were fed a restricted diet that was calculated to allow a gain of 1.75 lb/d, based on NRC (1998) values. The amount of feed given to a pen was determined every 14 d, based on combined pen weight. If a pig was removed from the study for any reason, the pig weight and pen feed consumption to date was recorded, and feed drops were adjusted to accommodate changes in the feeding calculation. Feed was measured and delivered by using an Accu-Drop Feed Dispenser (Automated Production Systems, Assumption, IL). Feed was dropped onto the solid concrete portion of the floor.

Table 1. Composition of Diets (As-fed Basis)[a]

Item, %	Diet
Corn	63.14
Soybean meal (46.5%)	33.26
Monocalcium P (21% P, 18% C)	1.40
Limestone	1.25
Salt	0.35
Trace mineral premix	0.20
Vitamin premix	0.15
L-lysine HCl	0.15
L-threonine	0.05
DL-methionine	0.05
Total	100.00
Calculated Analysis	
ME, kcal/lb	1,494
Crude protein, %	21.0
Total lysine, %	1.29
TID amino acids, %	
Lysine, %	1.15
Threonine, %	0.74
Isoleucine, %	0.79
Leucine, %	1.66
Ca, %	0.87
P, %	0.70
Available P, %	0.37

[a]Energy and lysine were supplied to pigs to meet an average growth rate of 1.75 lb/day, based on NRC (1998) values.

Experiment 1. A total of 160 pigs with an initial weight of 148 lb were used in a 42-d growth assay to determine the effects of feeding a restricted diet either 2 or 6 times per day on growth performance. Pigs were separated by sex and blocked by body weight (BW) to 16 pens of 10 pigs each. There were 4 pens of barrows and 4 pens of gilts per treatment, for a total of 8 replications. Pigs were provided their daily feed allotment in 2 or 6 meals. Pigs fed 2 times per day were fed at 07:00 and 15:30 h. Pigs fed 6 times per day were fed at

07:00, 07:30, 08:00, 15:30, 16:00, and 16:30 h. Pigs were weighed individually on d 0, 14, 28, and 42 to determine ADG, F/G, and weight variation (CV).

Experiment 2. A total of 160 pigs (80 barrows and 80 gilts) initially weighing 155 lb were randomly allotted by BW to 16 pens of 10 pigs each. Pigs were separated by sex and given 2 or 6 feedings per day to measure growth performance. Pigs receiving 2 meals were fed at 07:00 and 15:00 h. Pigs fed 6 times per day had a greater interval between meals within the morning and afternoon feedings, with feedings at 07:00, 08:00, 09:00, 15:00, 16:00, and 17:00 h. Pigs were weighed individually every 14 d to determine ADG, F/G, and weight variation.

Statistical Analysis. Data from all experiments were analyzed as a randomized design. Analysis of variance was performed by using the MIXED procedure of SAS.

Results

Experiment 1. For the overall 42-d trial, pigs fed 6 times a day, versus 2 times a day, increased ($P<0.01$) ADG and decreased ($P<0.02$) F/G. The response was due to numeric improvements in all three feeding periods (d 0 to 14, 14 to 28, and 28 to 42). The coefficient of variation was not ($P = 0.82$) influenced by increasing the feeding frequency from 2 to 6 times per day. In addition, ADFI was not affected ($P = 0.91$) because similar amounts of feed were provided to both treatments.

Experiment 2. Over the entire 42-d trial, pigs fed 6 times a day, versus 2 times a day, had improved ADG ($P<0.02$) and F/G ($P<0.03$). Like Exp. 1, the growth performance response was directly related to the increased response seen in all three feeding periods (d 0 to 14, 14 to 28, and 28 to 42). The CV of gain was not influenced ($P = 0.45$) by treatments. Average daily feed intake was not influenced ($P = 0.91$) because the exact same amount of feed was given to both treatments.

Discussion

Increasing feeding frequency from 2 to 6 times per day resulted in a greater response in ADG than expected. The magnitude of the response was especially surprising after finding no benefits in weight gain to increased feeding frequency in gestating sows. The improvement in ADG may have been due to either altered efficiency of metabolism or to a reduction in feed wastage.

Previous research showed that frequent feeding increased the efficiency of utilization of metabolizable energy for production in growing pigs. The efficiency of ME for growth was increased approximately 6% in swine fed 5 times per day versus pigs fed 2 times a day. Other studies have demonstrated that many small meals trigger a greater output of enzymes from the pancreas. The repeated intake of small portions of feed also has been shown to positively influence the digestibility of the feed. Frequent small meals also have been observed to result in a greater lean tissue content of the carcass. Furthermore, it has been reported that growing sheep and cattle increased their utilization of metabolizable energy when fed more frequently, but this response was lost in mature ruminants. The response to more frequent feedings was reversed in the rat, which had a greater efficiency of energy utilization for meal feeding instead of nibbling.

It is also possible that the improvement in ADG was due to a reduction in feed wastage with feeding 6 times per day. When compared with predicted performance from the NRC (1998) model, all pigs gained less than the expected gain of 1.75 lb per day. This would signify that either the pigs were less efficient than the model would suggest, or that feeding larger amounts of feed 2 times a day resulted in more wastage during the 42-d trial than

feeding smaller increments of feed 6 times per day. Because we were not able to examine feed wastage in these trials, a follow-up study to examine changes in feed wastage with multiple feedings is under way.

Table 2. Effect of Feeding Frequency and Energy-restricted Diet on Performance of Finishing Pigs (Exp. 1)[a]

	Frequency of Feeding per Day[b,c]			
Item	2	6	SE	P-value (P <)
d 0 to 14				
ADG, lb	0.98	1.10	0.082	0.16
ADFI, lb	3.42	3.42	0.003	0.99
F/G	3.59	3.19	0.209	0.07
CV of gain, %	5.21	5.06	0.429	0.73
d 14 to 28				
ADG, lb	1.56	1.83	0.082	0.01
ADFI, lb	3.70	3.71	0.003	0.19
F/G	2.39	2.04	0.209	0.10
CV of gain, %	3.99	4.31	0.429	0.46
d 28 to 42				
ADG, lb	1.46	1.58	0.082	0.16
ADFI, lb	3.97	3.96	0.003	0.15
F/G	2.75	2.53	0.209	0.29
CV of gain, %	4.19	4.19	0.429	0.99
d 0 to 42				
ADG, lb	1.37	1.51	0.049	0.01
ADFI, lb	3.70	3.70	0.001	0.91
F/G	2.91	2.59	0.116	0.02
CV of gain, %	4.46	4.52	0.229	0.82

[a]Each value is the mean of 8 replications, with 10 pigs (initially 148 lb) per pen.
[b]Pens that were fed twice daily received feed at 07:00 and 15:30 hours; Pens that were fed 6 times a day received feed at 07:00, 07:30, 08:00, 15:30, 16:00, and 16:30 hours, respectively.
[c]Feed drops were adjusted every 14 d, based on the average weight of pigs.

Table 3. Effect of Feeding Frequency and Energy-restricted Diet on Performance of Finishing Pigs (Exp. 2)[a]

	Frequency of Feeding per Day[b,c]			
Item	2	6	SE	P-value (P <)
d 0 to 14				
ADG, lb	1.06	1.35	0.084	0.02
ADFI, lb	3.48	3.48	0.002	0.75
F/G	3.37	2.76	0.305	0.17
CV of gain, %	5.37	5.09	0.502	0.70
d 14 to 28				
ADG, lb	1.37	1.57	0.084	0.10
ADFI, lb	3.84	3.84	0.002	0.35
F/G	2.83	2.50	0.305	0.45
CV of gain, %	4.38	4.65	0.502	0.71
d 28 to 42				
ADG, lb	0.91	1.19	0.084	0.03
ADFI, lb	4.11	4.11	0.002	0.15
F/G	4.90	3.50	0.305	0.03
CV of gain, %	5.79	4.58	0.502	0.10
d 0 to 42				
ADG, lb	1.11	1.37	0.063	0.02
ADFI, lb	3.81	3.81	0.001	0.91
F/G	3.70	2.92	0.210	0.03
CV of gain, %	5.18	4.77	0.366	0.45

[a]Each value is the mean of 8 replications, with 10 pigs (initially 155 lb) per pen.
[b]Pens that were fed twice daily received feed at 07:00 and 15:00 hours; Pens that were fed 6 times a day received feed at 07:00, 08:00, 09:00, 15:00, 16:00, and 17:00 hours, respectively.
[c]Feed drops were adjusted every 14 d, based on the average weight of pigs.

DETERMINING THE ACCURACY OF GESTATION FEED DROPS

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

Summary

An experiment was conducted to determine the accuracy of three different gestation feed drops. Each drop was tested at three different angles (90, 75, 60°) from the feed line. Feed was collected and weighed at feeder settings of 2, 4, 6, 8, and 10 lb for the Econo-Drop and Accu-Drop feed dispensers. Samples were taken at 2, 4, 6, and 8 lb for the Ultra-Drop feed dispenser due to a smaller storage capacity for feed with this feed drop. There were five replications (five drops of each type) at each feed setting. There was a drop type by angle interaction ($P<0.01$) for the feed dispenser settings versus the actual pounds of feed dropped. At angles of 90 or 60 degrees, the Accu-Drop and the Ultra-Drop feed dispensers more ($P<0.10$) accurately dropped the correct amount of feed at the respective feeder settings. The amount of feed dropped at each dispenser setting was influenced more by angle to the feed line with the Econo-Drop than with the Accu-Drop or Ultra-Drop feed dispensers. This study demonstrated that the Accu-Drop and the Ultra-Drop feed dispensers are more accurate than the Econo-Drop feed dispenser. Therefore, producers should consider the additional feed cost over the lifetime of the feed drops and not rely solely on initial price.

Key Words: Feed Drops, Feed Cost, Slope-intercept.)

Introduction

The use of individual gestation stalls or crates in environmentally controlled barns has generally become the accepted standard method for sow management. Housing sows in stalls allows producers to have direct control over the intake of sows and, ultimately, the overall composition and growth of the animal. Individual feed drops are used to provide a set amount of feed to each individual sow. These feed drops are made by several manufacturers and come in several types, but information on the accuracy of individual feed drops has not been published. As a further complication to the question of accuracy of feed drops, the drops are installed and intended to be used when perpendicular (90° angle) to the feed line. Either during installation or after years of use, many drops are at angles of less than 90° from the feed line, which may influence their accuracy. Testing of different types of feed drops may help producers make equipment decisions for their facilities. Thus, the objective of this experiment was to determine the accuracy of different individual drop feeders when they are fitted at angles of 90, 75, or 60°.

Procedures

This experiment was conducted at the Kansas State University Swine Research and Teaching Center. The experimental diet was a

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corn-soybean meal diet that consisted of 1.15% TID lysine and a ME content of 1,494 kcal/lb (Table 1). All feed dispensers were purchased from Automated Production Systems (AP, Assumption, IL) and were attached to a 2-in diameter feed line. The feed drops used in this experiment were the Ultra-Drop feed dispenser, the Econo-Drop feed dispenser, and the Accu-Drop feed dispenser (Figure 1). The feed dispensers were adjusted to the specific test angles by using a Johnson Magnetic Angle Locator (Johnson Level and Tool, Mequon, WI). Feed was collected and weighed at feeder settings of 2, 4, 6, 8, and 10 lb for the Econo-Drop and Accu-Drop feed dispensers. Samples were taken at 2, 4, 6, and 8 lb for the Ultra-Drop feed dispenser due to a smaller storage capacity for feed with this feed drop. Samples were weighed on an Ohaus Champ II Bench Scale (Ohaus Balance and Scale, Pine Brook, NJ), which allowed for an accurate measurement to one hundredth of a pound.

Table 1. Composition of Diets (As-fed Basis)[a]

Item, %	Diet
Corn	63.14
Soybean meal (46.5%)	33.26
Monocalcium P (21% P, 18% C)	1.40
Limestone	1.25
Salt	0.35
Trace mineral premix	0.20
Vitamin premix	0.15
L-lysine HCl	0.15
L-threonine	0.05
DL-methionine	0.05
Total	100.00

[a]Diet was formulated to contain 1.15% TID lysine and 1,494 kcal/lb.

Data was analyzed as a split-plot design, with the feed dispenser as the whole plot and angle as the subplot. Feed dispensers were randomly blocked based on type, and analysis of variance was performed by using the PROC MIXED procedure of SAS (SAS Inst. Inc., Cary, NC).

Results and Discussion

There was a feed drop type by angle by lb interaction ($P<0.01$; Table 2) for all the selected feeder settings. The Econo-Drop feed dispenser (Figure 2) was affected the most by the treatment angles. At an angle of 90°, the Econo-Drop consistently dropped more feed than the target setting. When set at an angle of 60°, however, the Econo-Drop dropped considerably less than the targeted feed weight. Thus, producers using this drop would have difficulty targeting the correct feeding rate unless all drops in the barn were at the exact same angle to the feed line. On the other hand, the Accu-Drop (Figure 3) and the Ultra Drop feed dispensers (Figure 4) more accurately measured the exact amount of feed. Furthermore, moving the Econo-Drop from a 90 to 60° angle resulted in a larger change in the amount of feed dropped. For example, at the 8-lb setting, moving the dispensers from a 90 to 60° degree angle resulted in an approximately 50% (4.2 lb) change in the amount of feed dropped with the Econo-Drop. The same change in angle for the Accu-Drop and the Ultra-Drop only resulted in an approximately 10% change in the amounts of feed dropped (0.74 and 0.85 lb, respectively).

Pork producers planning to construct new sow barns or replace the feed delivery system in existing facilities should base their purchasing decisions on accuracy of the feed dispensers, not on initial cost. In this study, we determined that the Accu-Drop and the Ultra-Drop are more accurate than the Econo-Drop at a 90-degree angle. Furthermore, as the feed dispenser angle become more skewed on the line, the Accu-Drop and the Ultra-Drop feed dispensers will stay more accurate than the Econo-Drop feed dispensers.

The improvement in accuracy is potentially related to how the individual dispensers are attached to the feed line. As shown in Figure 1, the Accu-Drop and Ultra-Drop feed dispensers are attached to the feed line along the entire top of the drop, whereas the Econo-Drop is only attached in the center. The Econo-Drop and the Ultra-Drop feed dispensers are actually similar in shape and measuring system. Both feed dispensers are "box" shape and measure the amount of fill by use of a "ribbon" measuring system in which the feed enters the dispenser through a chute and fills until the feed level reaches an adjustable "ribbon." But the box, and ultimately the feed delivery chute, are turned 90° for the Ultra-Drop, compared with the Econo-Drop. Because of this, when the drop is rotated away from a perpendicular angle from the feed line, the feed flow is impacted more greatly with the Econo-Drop than with the Ultra-Drop.

For the Accu-Drop dispenser, feed volume is determined by the height setting for the plate within the cylinder. The volume that can enter the cylinder doesn't change greatly as the angle to the feed line changes. One potential concern with this design is that, if the plate doesn't remain on a consistent plane with the feed settings on the cylinder, the drop may become more difficult to set. The volume entering the cylinder wouldn't change if the plate was not flat, but determining the exact setting would be more difficult. A simple and economic solution to this problem would be for the manufacturers to print four equally spaced measuring labels on the sides of the cylinder.

Producers typically may examine the initial cost of equipment when building or retrofitting a gestation facility to make their decision on feed drops. This trial has shown that the accuracy of the drops should also be considered. Consistently over- or under-feeding in gestation has been demonstrated to reduce sow productivity. A small increase in initial investment may greatly reduce feed cost or increase sow productivity over the lifespan of the equipment.

Table 2. Weight Difference of Feed Dropped Versus Actual Feed Dispenser Setting[a]

	Feed Dispenser			
	Econo-Drop	Accu-Drop	Ultra-Drop[a]	SE
2 lb[b]				
90°	0.50^{x}	0.20^{y}	0.30^{y}	0.05
75°	0.12^{x}	0.30^{y}	0.16^{x}	0.05
60°	-0.47^{x}	-0.41^{x}	-0.22^{y}	0.05
Diff 90 to 60° [c]	0.96^{x}	0.61^{xy}	0.52^{y}	0.17
4 lb[b]				
90°	1.00^{x}	0.16^{y}	0.76^{z}	0.10
75°	-0.39^{x}	-0.03^{y}	0.59^{z}	0.10
60°	-1.60^{x}	-0.84^{y}	0.05^{z}	0.10
Diff 90 to 60°[c]	2.61^{x}	1.00^{y}	0.71^{y}	0.17
6 lb[b]				
90°	1.62^{x}	0.24^{y}	0.79^{z}	0.08
75°	-0.18^{x}	-0.03^{x}	0.52^{y}	0.08
60°	-2.30^{x}	-0.62^{y}	-0.08^{z}	0.08
Diff 90 to 60°[c]	3.92^{x}	0.86^{y}	0.87^{y}	0.17
8 lb[b]				
90°	1.34^{x}	0.19^{y}	0.35^{y}	0.11
75°	-0.28^{x}	0.09^{y}	0.22^{y}	0.11
60°	-2.84^{x}	-0.55^{y}	-0.50^{y}	0.11
Diff 90 to 60°[c]	4.19^{x}	0.74^{y}	0.86^{y}	0.17
10 lb[b]				
90°	1.38^{x}	0.28^{y}	---	0.12
75°	0.49^{x}	0.20^{y}	---	0.12
60°	-2.96^{x}	-0.66^{y}	---	0.12
Diff 90 to 60°[c]	4.34^{x}	0.94^{y}	---	0.17

[a]Ultra-Drop Feed Dispenser was not measured at 10 lbs due to limited storage capacity.
[b]Type by angle by lb interaction (P<0.01).
[c]Type by lb interaction (P<0.01).
[x,y,z]Means in the row with different superscripts differ (P<0.10).

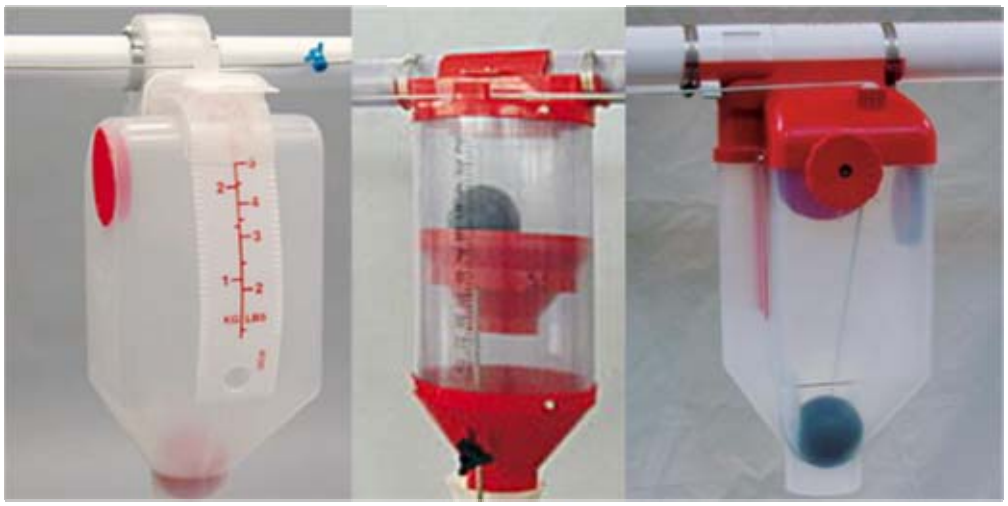

Figure 1. Example of the Types of Feed Dispensers Used in the Present Trial. Left to right: Econo-Drop, Accu-Drop, and the Ultra-Drop feed dispensers. Photos courtesy of Automated Production Systems, Assumption, IL (www.automatedproduction.com).

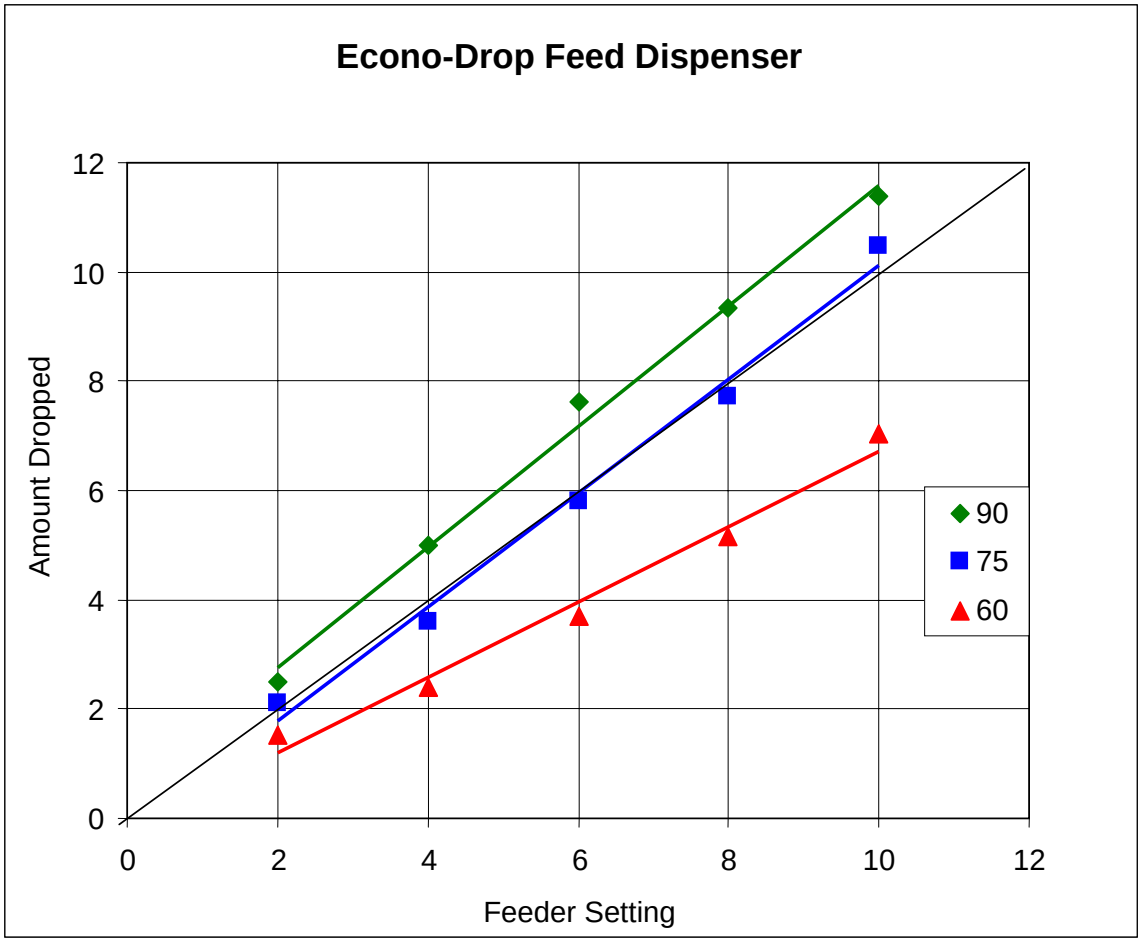

Figure 2. Example of the Actual Amount of Feed Dispensed for Each Feeder Setting Among the Respective Angles Tested for the Econo-Drop Feed Dispenser. Regression equations for the specific angles are listed as: 90°, y = 1.1056(x) + 0.5364; 75°, y = 1.0428(x) – 0.3052; 60°, y = 0.6890(x) – 0.1672. There was a type by angle interaction (P<0.01) for the slope and intercept of the line. The slope was not equal to one for the Econo-Drop feed dispenser at an angle of 90° (P<0.01), 75° (P<0.03), and 60° (P<0.01). The intercept was not equal to zero for the Econo-Drop feed dispenser at an angle of 90° (P<0.01), 75° (P<0.01), and 60° (P<0.07).

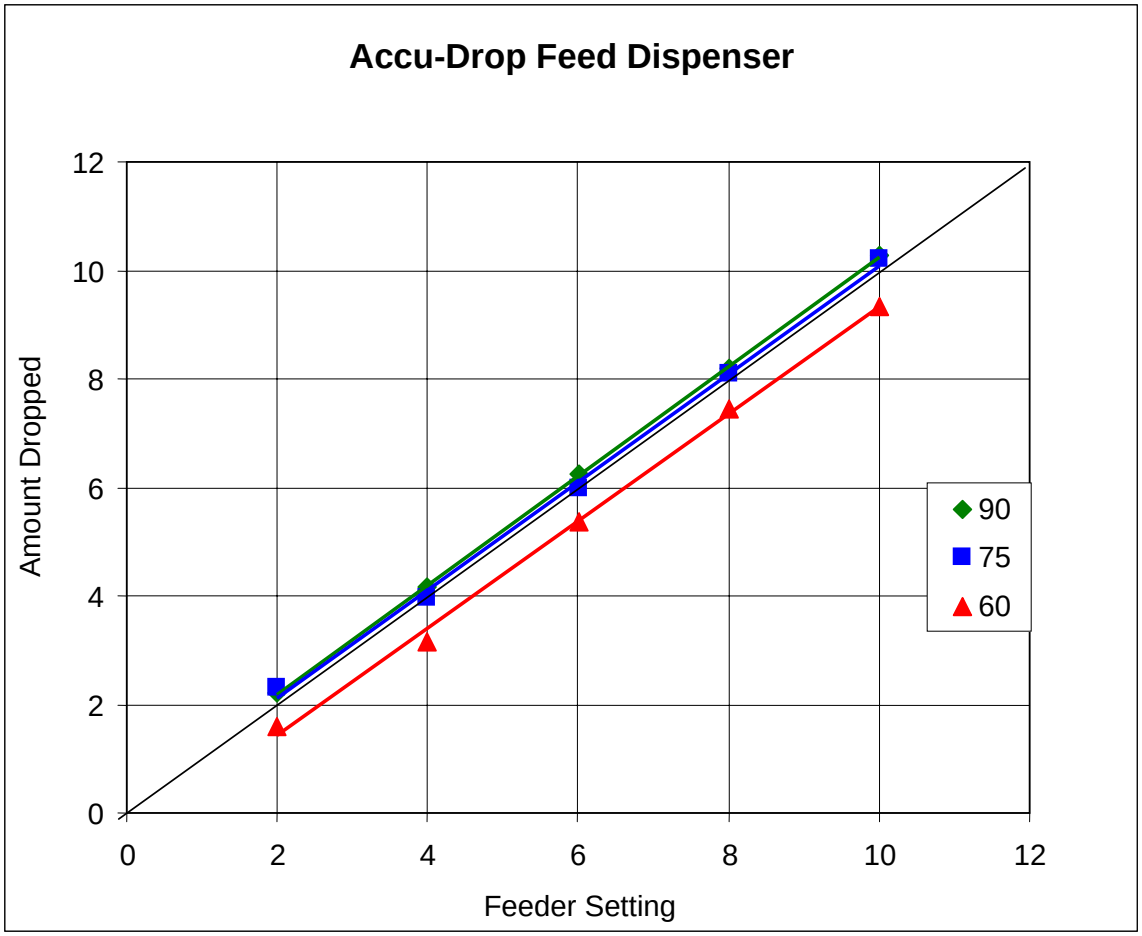

Figure 3. Example of the Actual Amount of Feed Dispensed for Each Feeder Setting Among the Respective Angles Tested for the Accu-Drop Feed Dispenser. Regression equations for the specific angles are listed as: 90°, y = 1.0096(x) + 0.1572; 75°, y = 0.9965(x) + 0.1268; 60°, y = 0.9890(x) – 0.5484. There was a type by angle interaction ($P<0.01$) for the slope and intercept of the line. The slope was equal to one for the Accu-Drop feed dispenser at an angle of 90° ($P>0.54$), 75° ($P>0.84$), and 60° ($P>0.60$). The intercept was not equal to zero for the Accu-Drop feed dispenser at an angle of 75° ($P<0.09$).

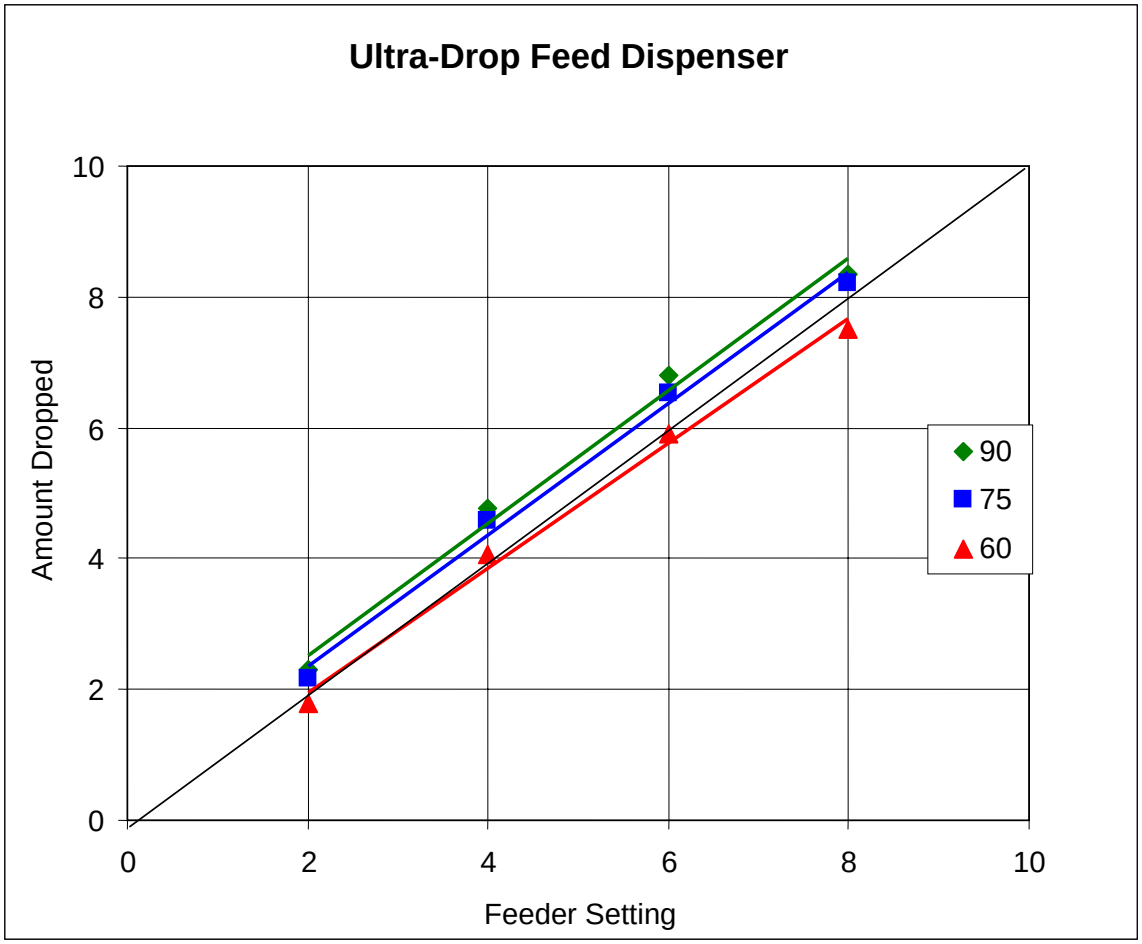

Figure 4. Example of the Actual Amount of Feed Dispensed for Each Feeder Setting Among the Respective Angles Tested for the Ultra-Drop Feed Dispenser. Regression equations for the specific angles are listed as: 90°, y = 1.0088(x) + 0.5080; 75°, y = 1.0054(x) + 0.3430; 60°, y = 0.9509(x) + 0.0560. There was a type by angle interaction ($P<0.01$) for the slope and intercept of the line. The slope was not equal to one for the Ultra-Drop feed dispenser at an angle of 60° ($P<0.02$). The intercept was not equal to zero for the Ultra-Drop feed dispenser at an angle of 90° ($P<0.01$) and 75° ($P<0.01$).

DETERMINING THE TOTAL SULFUR AMINO ACID TO LYSINE REQUIREMENT OF THE LACTATING SOW

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Summary

A total of 163 sows were used in a study to determine the requirement for total sulfur amino acids (TSAA), relative to lysine, during lactation. All experimental diets were corn-soybean meal-based and formulated to contain 0.88% true ileal digestible (TID) lysine (0.97% total lysine). The experimental diets contained 0.37% L-lysine HCl, with other crystalline amino acids added to ensure that TSAA was first limiting. The dietary TID TSAA rates were formulated to 0.44, 0.48, 0.53, 0.57, and 0.62%, corresponding to 50, 55, 60, 65, and 70% of lysine, respectively. Sows farrowed in six farrowing groups, and were randomly allotted to the dietary treatments on the basis of parity. Over the entire lactation period, there were no differences ($P>0.14$) in ADFI, weight loss, backfat loss, or plasma urea nitrogen among sows fed increasing TSAA:Lys ratios. Increasing TSAA, relative to lysine, had no effect ($P>0.25$) on litter weaning weight or preweaning mortality. In summary, there were no differences in litter performance with increasing TID TSAA:Lys ratio. These results suggest that the requirement for TID TSAA is no more than 50% of lysine. Additional research is needed to confirm this relatively low TSAA requirement, and that the relatively high feed (and amino acid) intake of sows, coupled with possible tissue breakdown as a source of TSAA, did not decrease the dietary requirement.

(Key Words: Total Sulfur Amino Acid, Lactation, Sows.)

Introduction

Due to increased litter size and milk production in modern sows, the requirements for amino acids have changed during the past 10 to 15 years. This has resulted in an increase in dietary lysine concentrations in diets for lactating sows. With the increase in dietary lysine concentration, however, other amino acid concentrations should be increased proportionally in a ratio relative to lysine. Methionine concentrations may become limiting as more soybean meal is added to the diet to increase the dietary lysine concentrations. Furthermore, if crystalline lysine is used in lactation diets, concentrations of methionine, which acts as a methylating substrate for synthesis of other metabolites, will decrease relative to lysine, also increasing the potential for a deficiency. There are little data available on TSAA requirements of lactating sows. Therefore, our objectives in this study were to determine the TID TSAA:Lys ratio requirement of the high-producing lactating sow.

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Procedures

One hundred and sixty-three sows (PIC, Line 1050) were blocked by parity and were allotted to one of five diets. The sows used in this study were farrowed in six groups, with approximately 29 sows per group, at the KSU Swine Teaching and Research Center. Sows were randomly assigned to treatments on the basis of parity when entering the farrowing house on day 110 of gestation. During lactation, sows were provided *ad libitum* access to feed and water, and feed disappearance was recorded. All sows were fed a diet based on corn-soybean meal, containing 1,534 kcal of ME per lb. The diets were formulated to 0.44, 0.48, 0.53, 0.57, or 0.62% TID TSAA, which corresponds to a TID TSAA:Lys ratio of 50, 55, 60, 65 and 70% of lysine, respectively. (Table 1). All diets were formulated to contain 0.88% TID lysine (0.97% total lysine) and contained other crystalline amino acids to ensure that TSAA was first limiting. We selected 0.88% TID lysine based on previous studies at this research farm so that we would be slightly below the sows requirement for lysine, and, thus, be able to accurately determine the TSAA ratio relative to lysine.

All sows were weighed after farrowing and again at weaning to calculate weight change during lactation. Backfat was measured with a Renco Leanmeter® at the last rib, upon entering the farrowing house on d 110 of gestation and on d 18 of lactation, to determine change in backfat during lactation. Blood samples were obtained by venipuncture on d 18 of lactation from each sow, after a 3-h period of feed withdrawal, and samples were analyzed for plasma urea N (PUN). Cross-fostering occurred before d 2 to standardize all litters with approximately 11 pigs. Pigs were weighed individually at birth, after fostering on d 2, and again at weaning. Any pigs removed from the trial were recorded, along with their date of removal and weight. Data were analyzed by using the Mixed procedure of SAS.

Table 1. Composition of Diets (As-fed Basis)[a]

Item	Percent
Corn	76.09
Soybean meal (46.5%)	16.00
Soybean oil	2.50
Monocalcium P (21% P, 18% C)	2.00
Limestone	1.00
L-lysine HCl	0.37
L-valine	0.31
L-isoleucine	0.04
L-tryptophan	0.05
L-threonine	0.20
DL-methionine	---
Salt	0.50
Vitamin premix	0.25
Trace mineral premix	0.15
Sow add pack	0.25
Sand[c]	0.30
Total	100.00
Calculated Analysis	
ME, kcal/lb	1,534
Crude protein, %	13.91
Total lysine, %	0.97
TID amino acids, %	
Lysine, %	0.88
Methionine, %	0.21
Met + Cys, %	0.44
Valine, %	0.88
Threonine, %	0.64
Tryptophan, %	0.18
Isoleucine, %	0.53
Leucine, %	1.21
Ca, %	0.83
P, %	0.74
Available P, %	0.48

[a]All diets are formulated to contain 0.88% TID lysine.

[c]Crystalline amino acid diets are formulated to contain increasing TID TSAA:Lys ratios of 50.0, 55.0, 60.0, 65.0, and 70.0%. DL-methionine was added to the crystalline amino acid diets at the expense of sand to achieve desired TID TSAA rates.

Results and Discussion

Increasing TID TSAA:Lys had no effect on ADFI over the lactation period (P>0.14; Table 2). Sow body weight and backfat loss during lactation were not affected (P>0.14) by dietary TID TSAA:Lys ratio. Increasing dietary TID TSAA:Lys did not affect (P>0.29) PUN when blood was sampled on day 18 of lactation. Total sulfur amino acid to lysine ratio did not affect total litter weight at weaning (P>0.25; Table 3). Sows nursed an average of 9.85 pigs during lactation, and preweaning mortality increased (linear, P<0.09) as the TID TSAA:Lys ratio increased, but this response was variable, in that sows fed TSAA at 65% of lysine had the best preweaning survival and those fed either 60 or 70% had greatest preweaning mortality.

One concern with expressing the TSAA rates on a ratio to lysine is that sows can not be above their lysine requirement for accurate determination. To support the 101 lbs of litter weight gain from d 2 to 21, sows would have had to consume more than 54 g of TID lysine per day. With ADFI of approximately 13 lb/day, sows on the diets with high concentrations of crystalline amino acids actually consumed approximately 53 g of TID lysine per day. Thus, sows were below their lysine requirement in our study, allowing for an accurate calculation of a TSAA:Lys ratio. There was no difference seen in litter performance from sows fed the experimental diets, but the litters suckling sows fed the diet containing 50% TID TSAA:Lys ratio had the most gain. This ratio is less than the ratio of approximately 61% calculated from estimates of the National Research Council (1998)

Amino acid requirements for lactating sows are generally difficult to calculate because a small sample size may produce variable results. To our knowledge, there has been only one published journal article that researched the sulfur amino acid requirements of lactating sows. The results of that trial suggest a requirement of 0.23 to 0.36% total dietary sulfur amino acid for a diet containing 0.52% lysine. This would calculate to a range in total TSAA:lys ratios of from 44 to 69%. In a preliminary trial that we conducted, the ratio of TID TSAA to lysine was greater than 50%. In this study, however, there was no significant difference in litter weight gain among the experimental treatments, with the greatest gain found at 50% TID TSAA:Lys ratio. The discrepancies between the previous study in our lab and the current research may be due to the large amount of sow body tissue that was mobilized. The breakdown in tissue would have allowed the lactating sow fed the low TSAA:Lys ratio diets to obtain essential amino acids necessary for milk production. Thus, the mobilization of body reserves of these sows buffered them from a dietary restriction of amino acid intake. Furthermore, other authors and the NRC (1998) have suggested that the ideal amino acid profile may change in relation to the rate of sow body tissue mobilization during lactation. The sows in this study lost amounts of weight similar to those in the NRC (1998) model that suggests a TID TSAA:Lys ratio of 61%, but maximal litter gain was achieved at a ratio of 50%. The difference in ratio may be explained by an increased loss of body protein in the modern sow versus sows used in the NRC (1998) model. Additional research is needed to determine the effects of a high amino acid intake, coupled with tissue breakdown, as a possible source of TSAA, thus decreasing the dietary requirement.

Table 2. Effects on Sow Performance of Increasing Dietary True Ileal Digestible Total Sulfur Amino Acids (TSAA) During Lactation[a]

	True Ileal Digestible TSAA:Lysine Ratio (%)[b]						Probability, P <	
Item	50	55	60	65	70	SE	Linear	Quad-ratic
Number of sows	32	35	32	32	32			
Lactation length, d	20.7	20.2	19.9	19.4	19.9			
ADFI, lb	13.4	12.7	13.2	12.9	13.6	0.46	0.14	0.21
Sow weight, lb								
Day 2	522.9	523.2	514.3	495.4	511.3	11.39	0.28	0.15
Weaning	493.2	494.5	492.9	474.9	491.9	11.38	0.40	0.07
Loss	29.5	29.0	21.6	20.3	19.2	4.63	0.53	0.47
Backfat, mm								
Day 2	16.8	17.6	17.4	16.8	16.5	0.65	0.51	0.30
Weaning	14.4	15.3	15.7	15.0	14.7	0.62	0.87	0.14
Loss	2.3	2.3	1.8	1.9	1.8	0.54	0.36	0.78
PUN, mM	3.51	3.86	3.58	3.84	3.83	0.18	0.29	0.79

[a]Lactation length was used as a covariate to analyze sow and litter performance.
[b]All diets are formulated to contain 0.88% TID lysine.

Table 3. Effects on Litter Performance of Increasing Dietary True Ileal Digestible Total Sulfur Amino Acids (TSAA) During Lactation[a]

	True Ileal Digestible TSAA:Lys Ratio (%)[b]						Probability, P <	
Item	50.0	55.0	60.0	65.0	70.0	SE	Linear	Quadratic
Number of sows	32	35	32	32	32			
Day 2 No. pigs	10.7	10.4	10.5	10.7	10.5	0.22	0.43	0.75
Day 2 litter wt, lb	34.7	32.9	33.1	32.6	33.8	1.05	0.33	0.31
No. of pigs weaned	10.1	9.8	9.6	10.2	9.5	0.21	0.11	0.61
Litter weaned wt, lb	143.4	134.5	131.5	128.8	134.1	4.26	0.25	0.70
Litter wt. gain, lb[c]	108.7	101.7	98.4	96.1	100.2	3.82	0.34	0.90
Preweaning mortality, %[c]	5.5	5.7	8.2	4.4	8.2	1.41	0.09	0.69

[a]Lactation length was used as a covariate to analyze sow and litter performance.
[b]All diets are formulated to contain 0.88% TID lysine.
[c]Calculated from d 2 to weaning.

EFFECTS OF A LIQUID (NEOLAC[1]) AND DRY FEED COMBINATION FED IN VARYING DURATIONS ON WEANLING PIG PERFORMANCE

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Summary

One hundred eighty pigs (initially 11.4 lb and 18 days of age) were used in a 28-d growth assay to determine the effects on nursery pig performance of combining a complete liquid feed (Neolac) with dry feed for various durations. Pigs were randomly allotted to experimental treatments consisting of: dry feed only (control) or Neolac provided for a period of 3 and 7 days in combination with dry feed. Overall, pigs fed the liquid-dry feed combination had a greater ADG ($P<0.01$) than did the dry-fed pigs until d 7 after weaning. Weight gains obtained during this period were not maintained until the end of the nursery period, regardless of the duration of liquid feeding. Both dry matter intake (DMI) and DM feed/gain increased ($P<0.01$) as a result of liquid feeding. Pigs provided liquid feed for 7 d also had a higher DM feed/gain ($P<0.06$) than that of the dry-fed controls in all periods. Feeding a liquid complete diet for various durations, in combination with dry feed, only had positive effects on growth rate immediately after weaning, but did not have lasting gains to influence overall nursery performance. Further experiments are needed to determine whether the improvement in initial feed intake with liquid feeding will reduce "starve-outs" and mortality.

(Key Words: Nursery Pig, Liquid Feed, Growth.)

Introduction

Liquid feeding has been explored in managing nutritional challenges that typically occur after weaning. A recent review of liquid feeding by Danish researchers found that ADG of newly weaned piglets was increased by 12.3 ± 9.4% by liquid feeding, compared with dry feeding, but a reduction in feed efficiency was normally observed in weaned pigs fed liquid diets, regardless of the type of liquid feed. The improvement in growth rate with liquid feeding is attributed mainly to an increase in ADFI. This positive ADFI response to liquid diets has a greater value immediately after weaning, which may potentially reduce "starve-outs" and improve survivability in the nursery. But most of the studies done on liquid feeding in newly weaned pigs were performed in direct replacement of dry feeding. Limited work has been done in combining the two diet forms. Therefore, this trial was conducted to determine the effects on post-weaning performance of combining dry feeding with a complete liquid diet (Neolac) for various durations.

[1]Neolac is a registered trademark of Inversiones Mira S.A., Peru.

[2]Food Animal Health and Management Center, College of Veterinary Medicine.
[3]TechMix Inc., 740 Bowman St., Stewart, MN 55385.

Procedures

A total of 180 weanling pigs (PIC L337 × C22), with an average initial weight of 11.4 lb and 18 days old, were used in a 28-d growth assay. Pigs were blocked by initial weight and were randomly allotted to 1 of 4 experimental treatments. Each treatment had 5 pigs per pen and 9 replications (pens). Experimental treatments were: dry feed only (control), or Neolac provided for a period of 3, 7, or 10 days in combination with dry feed. Liquid feeding was discontinued at d 7 of the trial because there were no more differences in body weight between treatments and because skin lesions were developing in liquid-fed pigs. Data for pigs from the 10-d Neolac treatment were added to the 7-d treatment as additional replications.

Liquid feed was provided by using translucent, 9-liter capacity, milk-replacement feeders (Kane Milk Feeders, Kane Mfg. Co. Inc., Des Moines, IA). Liquid feeders in each pen were weighed before the experiment and were positioned next to the waterer. Proper height of the liquid feeder was maintained, with the bottom of the feeder set on or close to the pen floor. Petroleum jelly was applied to the feeder cap gasket to help assure vacuum functioning in the feeder and to facilitate good flow of the liquid product. For the first 24 h, Neolac was mixed with water at a rate of 2 parts water to 1 part Neolac. After this initial mixture was consumed, all Neolac treatments were switched to full-strength Neolac, and provision of transition feed was initiated simultaneously. Neolac was added as necessary to provide *ad libitum* access. At the end of each allotted period for the liquid-dry feed combination, liquid feeders were removed, and pigs were fed only dry feed until the end of the study. Neolac treatments received a budget of 5 lb/pig of transition diet and a Phase 2 diet for the remainder of the experiment. For the control treatment, pigs were fed 1 lb/pig of pelleted SEW diet at the start of the experiment. After this was consumed, pigs received the same budget for transition and Phase 2 diets as the pigs in Neolac treatments. All diets were formulated according to K-State standard specifications (Table 1).

The trial was conducted in the environmentally controlled /Segregated Early Weaning (SEW) nursery facility at Kansas State University. Pigs were housed in a 5 × 5 ft pen containing one self-feeder and one nipple drinker to provide *ad libitum* access to feed and water. From d 1 to 10, both dry and liquid feeders were weighed daily. Average daily gain and F/G were determined by weighing pigs and feeders on d 3, 7, 10, 14, 21, and 28 after weaning. Average DMI was calculated on a DM basis. Data from this experiment were analyzed as a randomized complete-block design by the MIXED procedure of SAS, with pen as the experimental unit.

Results and Discussion

The effects on post-weaning pig performance of feeding a combination of a complete liquid (Neolac) and dry feed for various durations are presented in Tables 2 and 3. From d 0 to 3, physical form of the diet had a significant effect on growth performance. Pigs on liquid feed had 60% greater ADG ($P<0.01$; Table 2) than that of pigs fed the dry pellets. This can be attributed to the higher DMI ($P<0.01$) for liquid-fed pigs, compared with that of the dry-fed pigs. Dry matter intake of pigs on the liquid feed was three times greater ($P<0.01$) than the intake of the dry-fed controls 3 d after weaning (0.60 vs. 0.21 lb/d). But total DMI of pigs fed the liquid-dry feed combination decreased in the first 3 d (Figures 1 and 2), and the difference in DMI between treatments was mainly observed during the first 2 d after weaning (Figure 3). Moreover, liquid-fed pigs had higher DM F/G ($P<0.01$) than did dry-fed pigs (0.80 vs. 0.46).

From d 4 to 7, pigs on the liquid diet for 7 d had the same ADG as the dry-fed controls did, despite having a higher DMI (0.59 vs.

0.43 lb/d; P<0.03). Pigs on the liquid-dry feed combination for the first 3 d had a significantly lower ADG (P<0.01), growing by only 45% of the growth rate of the dry-fed controls (0.49 vs. 0.22 lb/d). This may be due to liquid-fed pigs having a lower DMI (P<0.03) than the dry-fed pigs did after removal of the liquid feed.

From d 8 to 10, ADG of pigs fed the liquid-dry feed combination for 7 d was 40% lower (P<0.01) than that of pigs fed only dry feed (0.57 vs. 0.34 lb/d). These reductions in daily gain can also be attributed to the significant reduction (P<0.01) in DMI after removal of the liquid feed. But pigs were able to regain normal feed intake 3 to 4 d after liquid feed removal. From d 14 to 28, no differences were observed in ADG and DM feed/gain among the treatments.

For pigs on the liquid diet, liquid feed intake contributed between 72 and 95% of the total DMI in the first week after weaning, but its contribution declined as the pigs aged (Figures 1 and 2). On the other hand, the contribution of dry feed to total DMI increased from 5% in d 2 to 28% in d 6 for pigs fed liquid feed for 7 d. For the dry-fed pigs, total DMI increased linearly in the first 10 d after weaning (Figure 3). In liquid-fed pigs, total DMI decreased in d 4 and 8 after liquid feeding was terminated at d 3 and 7, respectively. This reduction in DMI may indicate that pigs were adjusting to the removal of the liquid feed, which resulted in the loss of differences in weight gain. These pigs obtained similar DMI as the dry-fed controls by d 10 after weaning.

Overall, ADG of pigs fed the liquid-dry feed combination was only greater (P<0.01) until d 7 after weaning (Table 3). No differences in overall ADG were observed from d 0 to 10, 14, 21, or 28. Dry matter intake increased as a result of liquid feeding. For pigs provided with liquid feed for 3 d, DMI remained higher until d 10 (P<0.02) than the DMI of pigs fed only dry feed. Pigs given liquid feed for 7 days had consistently higher DMI (P<0.06) until d 14 than the DMI of pigs fed dry feed only. No differences in DMI were observed at d 21 and 28. Overall, DM F/G was higher in pigs fed liquid feed. In pigs given 3 d of liquid feed, DM F/G remained higher (P<0.03) than that of the dry-fed controls until d 21. Pigs provided liquid feed for 7 d consistently had a higher DM F/G (P<0.06) than that of the dry-fed controls in all periods.

Liquid feeding, in combination with dry feeding, can improve growth rates of pigs immediately after weaning. This can be attributed mainly to a large improvement in dry matter intake. But liquid feeding led to undesirable DM F/G, and its effect persisted 3 weeks after the removal of the liquid feed. Weight gains obtained during the first 3 d after weaning with the liquid feed did not persist until the end of the nursery period, regardless of the duration of liquid feeding. Further research is needed to determine whether the improvement in initial feed intake with liquid feeding will reduce “starve-outs” and mortality, or whether changes in composition of the liquid feed would allow the weight gain advantage to be maintained through the entire nursery period.

Table 1. Diet Composition (As-fed Basis)

Item	SEW	Transition	Phase 2
Corn	34.70	37.15	52.28
Soybean meal, 46.5%	12.55	20.06	26.65
Spray-dried porcine plasma	6.70	2.50	-
Select menhaden fish meal	6.00	5.00	4.50
Spray-dried blood cells	1.65	1.25	-
Spray-dried whey	2.50	25.00	10.00
Lactose	5.00	-	-
Choice white grease	5.00	5.00	3.00
Monocalcium phosphate, 21% P	0.30	0.70	0.55
Limestone	0.45	0.45	0.50
Salt	0.25	0.30	0.30
Zinc oxide	0.37	0.38	0.25
Vitamin premix with phytase	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15
L-lysine HCl	0.15	0.26	0.30
DL-methionine	0.15	0.18	0.15
L-threonine	0.08	0.13	0.13
Antibiotic	1.00	1.00	1.00
Acidifier	0.20	0.20	-
Vitamin E	0.05	0.05	-
Total	100.00	100.00	100.00
Calculated Analysis			
TID lysine, %	1.56	1.51	1.35
Total lysine, %	1.70	1.65	1.48
Total lysine:protein ratio, %	7.52	7.43	6.95
ME, kcal/lb	1,591	1,575	1,553
Protein, %	22.6	22.2	21.3
Ca, %	0.79	0.83	0.71
P, %	0.73	0.77	0.65
Available P, %	0.55	0.55	0.38
Lysine:calorie, g/Mcal	4.85	4.75	4.33
Na, %	0.58	0.47	0.25
Cl, %	0.71	0.70	0.45
K, %	0.94	1.09	0.97

Table 2. Effect on Post-weaning Performance of Feeding a Complete Liquid (Neolac) and Dry Feed Combination for Various Durations[a]

		Liquid Feeding Duration, d			
Treatment[b]	Dry Feed	3	7	SE	Probability, P <
DMI, lb/d[c]					
Day 0 to 3	0.209[d]	0.630[e]	0.590[e]	0.035	0.01
Day 4 to 7	0.429[d]	0.310[e]	0.595[f]	0.050	0.03
Day 8 to 10	0.673[d]	0.658[d]	0.531[e]	0.042	0.01
Day 11 to 14	0.936[d]	0.843[d]	0.771[e]	0.080	0.03
Day 15 to 21	1.299	1.293	1.294	0.059	0.99
Day 22 to 28	1.814	1.666	1.776	0.101	0.31
ADG, lb					
Day 0 to 3	0.497[d]	0.821[e]	0.772[e]	0.065	0.01
Day 4 to 7	0.490[d]	0.222[e]	0.460[d]	0.048	0.01
Day 8 to 10	0.567[d]	0.618[d]	0.337[e]	0.052	0.01
Day 11 to 14	0.745	0.744	0.706	0.047	0.57
Day 15 to 21	1.079	1.010	1.054	0.056	0.41
Day 22 to 28	1.236	1.200	1.264	0.053	0.40
F/G[g]					
Day 0 to 3	0.462[d]	0.784[e]	0.807[e]	0.104	0.01
Day 4 to 7	0.900[d]	2.231[e]	1.346[d]	0.635	0.05
Day 8 to 10	1.190	1.083	4.330	3.660	0.47
Day 11 to 14	1.262	1.165	1.104	0.115	0.30
Day 15 to 21	1.212	1.296	1.229	0.048	0.19
Day 22 to 28	1.467	1.391	1.401	0.055	0.32

[a]A total of 180 pigs, initial wt = 11.4 lb (PIC L337 × C22); values are means of 9 pens (for dry feed, 3 d liquid feeding) and 18 pens (7 d liquid feeding) of 5 pigs each, respectively.
[b]Liquid feed (Neolac) provided with the dry feed for 3 or 7 days after weaning.
[c]Average daily feed intake was calculated on a dry matter basis.
[d,e,f]Means in the same row with different superscript differ.
[g]F/G was calculated as DMI divided by ADG.

Table 3. Effect on Overall Post-weaning Performance of Feeding a Complete Liquid (Neolac) and Dry Feed Combination for Various Durations[a]

		Liquid Feeding Duration, d			
Treatment[b]	Dry Feed	3	7	SE	Probability, P <
DMI, lb/d[c]					
Day 0 to 7	0.335[d]	0.447[e]	0.593[f]	0.033	0.01
Day 0 to 10	0.412[d]	0.487[e]	0.556[f]	0.029	0.02
Day 0 to 14	0.530[d]	0.560[de]	0.591[e]	0.036	0.06
Day 0 to 21	0.734	0.752	0.774	0.028	0.28
Day 0 to 28	0.950	0.931	0.971	0.041	0.52
ADG, lb					
Day 0 to 7	0.493[d]	0.479[d]	0.593[e]	0.028	0.01
Day 0 to 10	0.515	0.521	0.517	0.028	0.98
Day 0 to 14	0.581	0.585	0.571	0.031	0.86
Day 0 to 21	0.747	0.726	0.732	0.032	0.80
Day 0 to 28	0.869	0.845	0.865	0.032	0.72
F/G[g]					
Day 0 to 7	0.679[d]	0.941[e]	1.003[e]	0.054	0.01
Day 0 to 10	0.799[d]	0.939[e]	1.082[f]	0.041	0.01
Day 0 to 14	0.911[d]	0.966[de]	1.040[e]	0.055	0.02
Day 0 to 21	0.984[d]	1.044[e]	1.058[e]	0.025	0.03
Day 0 to 28	1.091[d]	1.102[de]	1.121[e]	0.015	0.06

[a]A total of 180 pigs, initial wt = 11.4 lb (PIC L337 × C22); values are means of 9 pens (for dry feed, 3 d liquid feeding) and 18 pens (7 d liquid feeding) of 5 pigs each, respectively.
[b]Liquid feed (Neolac) provided with the dry feed for 3 or 7 days after weaning.
[c]Average daily feed intake was calculated on a dry matter basis.
[d,e,f]Means in the same row with different superscript differ.
[g]F/G was calculated as DMI divided by ADG.

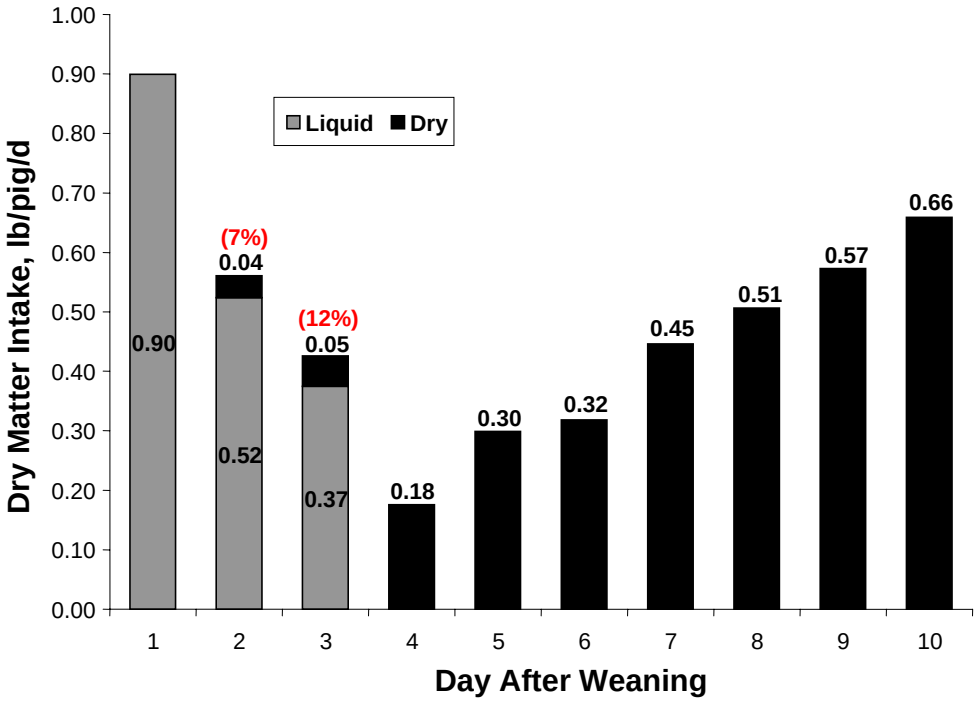

Figure 1. Dry and Liquid Feed Intake (lb DM/pig/d) in Nursery Pigs Fed a Complete Liquid and Dry Feed Combination for 3 d during the First 10 d After Weaning (% of total DMI in parentheses).

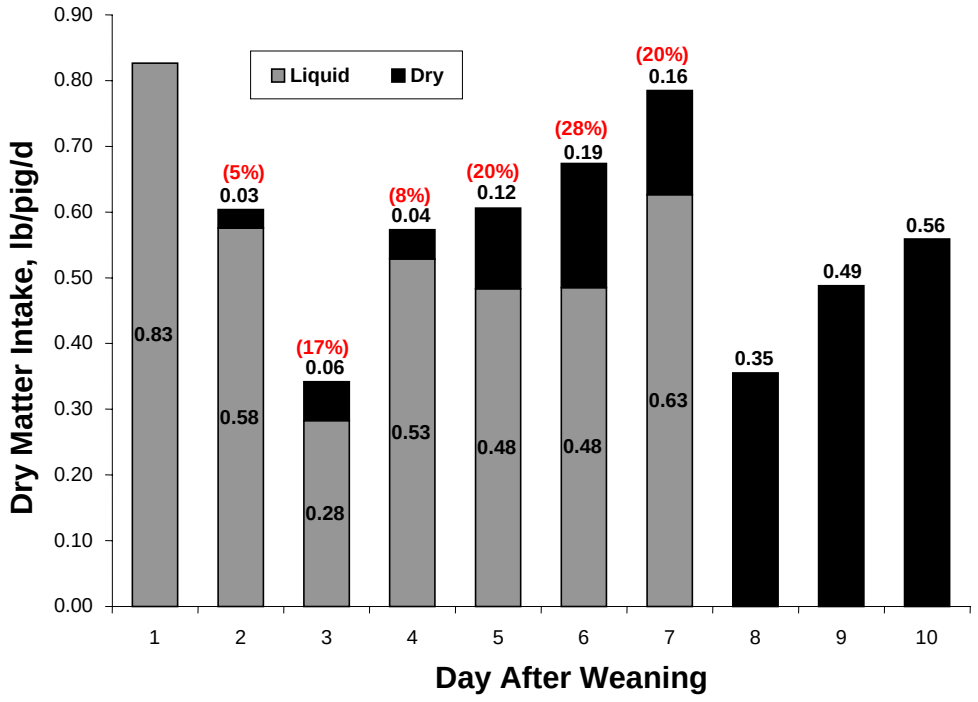

Figure 2. Dry and Liquid Feed Intake (lb DM/pig/d) in Nursery Pigs Fed a Complete Liquid and Dry Feed Combination for 7 d during the First 10 d After Weaning (% of total DMI in parentheses).

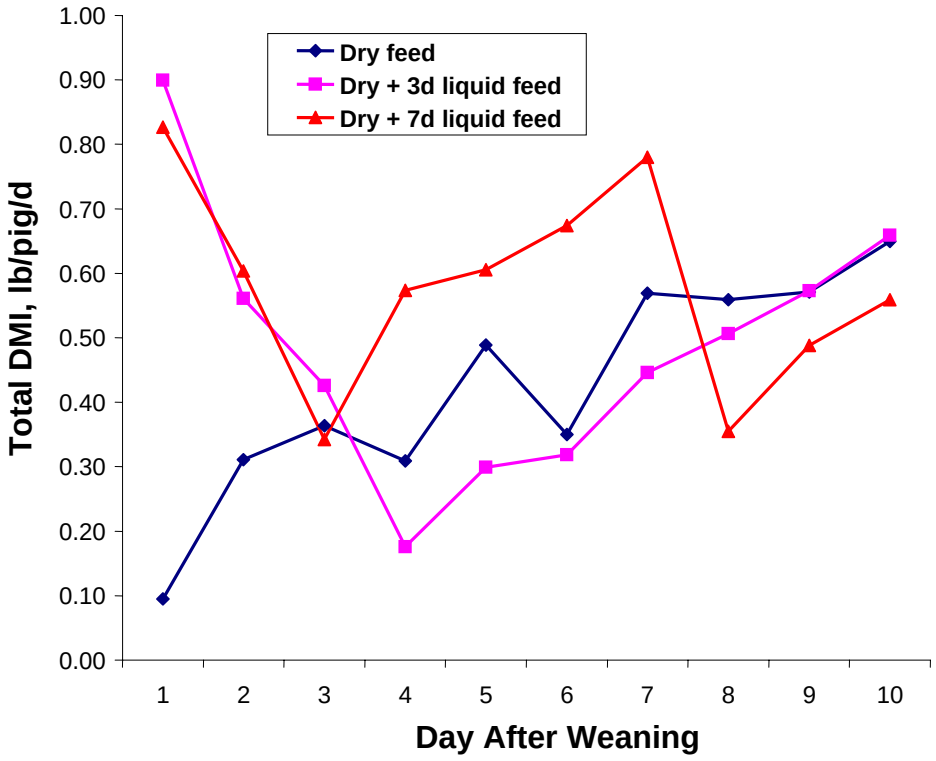

Figure 3. Dry Matter Intake (lb/pig/d) of Nursery Pigs Fed Dry Feed Only or a Complete Liquid and Dry Feed Combination for 3 or 7 d during the First 10 d After Weaning.

EFFECTS OF WATER-SOLUBLE AND IN-FEED ORGANIC ACIDS ON THE GROWTH PERFORMANCE OF WEANLING PIGS[1]

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Summary

A total of 360 weanling pigs (initially 11.5 lb and 18 ± 3 d of age, PIC) were used in a 42-d growth assay to determine the effects of water-soluble antimicrobials and organic acids in feed and/or water on nursery pig growth performance. Pigs were allotted to one of 9 experimental treatments: 1) control (no feed or water antimicrobials or acids); 2) water containing 38 mg/L neomycin sulfate; 3) water containing 0.06% Activate[3] WD; 4) water containing 0.12% Activate WD; 5) feed containing Neo-Terramycin[4] (140 g/ton neomycin sulfate, 140 g/ton oxytetracycline HCl; neo/oxy); 6) feed containing 0.50% Activate DA; 7) feed containing 0.45% Starter L; 8) feed containing 0.45% Multimax L; and 9) feed containing 0.50% Activate DA and 0.10% Mintrex[3] P. Overall (d 0 to 42 after weaning), pigs provided neo/oxy in the feed had greater (P<0.05) ADG, compared with pigs in all other treatments, except the pigs provided the combination of Activate DA and Mintrex P in the feed. Pigs provided neo/oxy in the feed had greater ADFI (P<0.02) than did pigs provided the control treatment. There were no differences in feed efficiency between any of the treatments. These data demonstrate that pigs provided in-feed antimicrobials had improved growth, whereas those provided organic acids in feed and water did not.

(Key Words: Nursery Pig, Antimicrobials, Organic Acids, Water, Growth.)

Introduction

Methionine hydroxyl analogs (MHA) are L-methionine precursors used in swine diets. In addition, MHA is chemically an organic acid, which may influence pig performance by modulating the growth of the microflora population in the gastrointestinal tract, and potentially improving nutrient utilization. Activate WD (water dispersible), DA (dry acid), Starter L (liquid), and Multimax L (liquid) organic acid blends are combinations of MHA and butyric, propionic, and/or lactic acids with methionine activity ranging from 29% to 31%. Mintrex P is a mixture of organic trace minerals, including zinc, copper, and manganese, with some residual methionine activity as a result of having MHA as the carrier. Although these Activate products are thought to improve growth performance in weanling pigs, antimicrobials such as neomycin sulfate, alone in the water, or in combination with oxytetracycline HCl in the feed, have been shown to improve growth performance and feed effi-

[1]The authors thank Novus Int. St. Louis, Missouri, for providing ingredients and partial funding for this study.

[2]Food Animal Health and Management Center, College of Veterinary Medicine.

[3]Activate and Mintrex are registered trademarks of Novus International, Inc.

[4]Neo-Terramycin is a registered trademark of Phibro Animal Health Ltd., Regina, Saskachewan, Canada.

ciency in weanling pigs through research at Kansas State University. Thus, the objective of this experiment was to evaluate the effectiveness of organic acid blends in the water and feed, in comparison with in-feed Neo-Terramycin and neomycin sulfate in the water, in improving the growth performance of weanling pigs.

Procedures

A total of 360 weanling pigs (initially 11.5 lb and 18 ± 3 d of age, PIC) were used to determine the effects of water-soluble organic acid blends in a water medication and in-feed antibiotic program on nursery pig growth performance. Individual pens were the experimental units, and water was supplied by an individual line and bowl drinker in each pen. There were 5 pigs per pen and 8 pens per treatment.

Pigs were given 1 of 9 experimental treatments: 1) negative control (no feed or water antimicrobials or acids); 2) water containing 38 mg/L neomycin sulfate; 3) water containing 0.06% Activate WD; 4) water containing 0.12% Activate WD; 5) feed containing Neo-Terramycin (140 g/ton neomycin sulfate, 140 g/ton oxytetracycline HCl); 6) feed containing 0.50% Activate DA; 7) feed containing 0.45% Starter L; 8) feed containing 0.45% Multimax L, and; 9) feed containing 0.50% Activate DA and 0.10% Mintrex P. Pigs were provided treatments in two phases: d 0 to 14 and d 14 to 28. All pigs were then fed a common diet from d 28 to 42. Pigs that received water-based treatments (Treatments 2, 3, and 4) were fed the negative control diet. Pigs that received feed-based treatments (Treatments 5, 6, 7, 8, and 9) were provided the control water. The trial was conducted in the environmentally controlled Segregated Early Weaning nursery facility at Kansas State University. Each pen (5 × 5 ft) contained one self-feeder and one bowl waterer to provide *ad libitum* access to feed and water.

Water-based treatments were administered through SelectDoser™ peristaltic pumps (Genesis Instruments; Elmwood, WI). This type of doser is powered by electricity, and siphons a concentrated, pre-mixed stock solution through a tube and doses the medication into the existing water supply. Concentrated stock solutions were made as needed throughout the experiment, and were dosed into the existing water line at a ratio of 1:100 to achieve the desired level of treatment.

Dietary treatments were fed in meal form (Tables 1, 2, and 3). Phase 1 (d 0 to 14 after weaning) diets were formulated to contain 1.41% true ileal digestible (TID) lysine, 0.90% Ca, and 0.50% available phosphorus. Phase 2 (d 14 to 28 after weaning) diets were formulated to contain 1.31% TID lysine, 0.80% Ca, and 0.40% available phosphorus. The Phase 3 (d 28 to 42 after weaning) common diet was formulated to contain 1.24% TID lysine, 0.77% Ca, and 0.37% available phosphorus. Average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G) were determined by weighing pigs and feeders on d 0, 14, 28, and 42 after weaning.

Data were analyzed as a randomized complete-block design, with pen as the experimental unit. Analysis of variance was performed by using the MIXED procedure of SAS. Contrasts were used to determine the effects of antibiotics, compared with the control and with the mean of pigs provided one of the organic acid treatments.

Results and Discussion

From d 0 to 14, pigs provided the water-based antimicrobial had greater ($P<0.05$) ADG and ADFI than those of pigs provided control feed and water and those of pigs provided water-soluble organic acids. Pigs provided the water-based antimicrobial also had greater ($P<0.05$) ADG than did pigs provided

feed containing Activate DA and Starter L, whereas in-feed Multimax L and DA plus Mintrex P treatments were intermediate. Pigs provided the water-based antimicrobial had greater (P<0.05) ADFI than that of pigs provided in-feed Activate DA, Starter L, or Multimax L, whereas DA plus Mintrex P and in-feed antimicrobial treatments were intermediate. Pigs provided feed containing Multimax L or DA plus Mintrex P had improved F/G, compared with that of pigs provided control feed and water, Activate WD, DA, or Starter L organic acids, whereas water-based and in-feed antimicrobial treatments were intermediate. Pigs provided antimicrobials had greater (P<0.01) ADG and ADFI than did pigs provided organic acids or pigs provided the control treatment. Pigs provided antimicrobials also had improved (P<0.01) F/G, compared with pigs provided the control.

From d 14 to 28, pigs provided in-feed antimicrobials had greater (P<0.05) ADG than that of all other pigs. In addition, pigs provided antimicrobials in the water or feed had greater ADG (P<0.01) and ADFI (P<0.05) than did pigs provided organic acids.

From d 28 to 42, pigs were provided a common diet, and there were no differences in growth performance and feed efficiency.

Overall (d 0 to 42), pigs provided in-feed antimicrobials had greater (P<0.05) ADG than that of all other pigs, except those provided diets containing Activate DA plus Mintrex P. Pigs provided antimicrobials had greater (P<0.03) ADG than did pigs provided organic acids or pigs provided control feed and water. Pigs provided antimicrobials also had improved (P<0.02) F/G, compared with that of pigs provided organic acids.

The use of organic acids in the feed or water in this experiment did not improve growth performance or feed efficiency over the control treatment during the 42-d nursery phase. In this experiment, antimicrobials provided in the feed or water yielded a significant improvement in average daily gain over all other treatments.

Table 1. Phase 1 Diet Composition (As-fed Basis)[a]

Ingredient, %	Control	Neo Terra	Activate DA	Activate Starter L	Activate Multimax L	Activate DA + Mintrex P
Corn	51.03	51.03	51.03	51.03	51.03	51.03
Soybean meal (46.5% CP)	30.16	30.16	30.16	30.16	30.16	30.16
Spray dried whey	10.00	10.00	10.00	10.00	10.00	10.00
Select menhaden fish meal	3.75	3.75	3.75	3.75	3.75	3.75
Soy oil	1.00	1.00	1.00	1.00	1.00	1.00
Monocalcium phosphate (21% P)	1.20	1.20	1.20	1.20	1.20	1.20
Limestone	0.75	0.75	0.75	0.75	0.75	0.75
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15
L-lysine HCl	0.30	0.30	0.30	0.30	0.30	0.30
L-threonine	0.15	0.15	0.15	0.15	0.15	0.15
Corn starch	0.73	0.21	0.41	0.43	0.43	0.31
Neo-Terramycin[b]	---	0.70	---	---	---	---
MHA-Ca[c]	0.18	---	---	0.03	0.03	---
Activate DA[d]	---	---	0.50	---	---	0.50
Activate Starter L[e]	---	---	---	0.45	---	---
Activate Multimax L[e]	---	---	---	---	0.45	---
Activate DA + Mintrex P[f]	---	---	---	---	---	0.10
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis						
Total lysine, %	1.55	1.55	1.55	1.55	1.55	1.55
True Digestible Amino Acids						
Lysine, %	1.41	1.41	1.41	1.41	1.41	1.41
Isoleucine:lysine ratio, %	60	60	60	60	60	60
Leucine:lysine ratio, %	118	118	118	118	118	118
Methionine:lysine ratio, %	35	35	35	35	35	35
Met & cys:lysine ratio, %	58	58	58	58	58	62
Threonine:lysine ratio, %	64	64	64	64	64	64
Tryptophan:lysine ratio, %	17	17	17	17	17	17
Valine:lysine ratio, %	66	66	66	66	66	66
ME, kcal/lb	1,502	1,502	1,502	1,502	1,502	1,502
CP, %	22.4	22.4	22.4	22.4	22.4	22.4
Ca, %	0.90	0.90	0.90	0.90	0.90	0.90
P, %	0.79	0.79	0.79	0.79	0.79	0.79
Available P, %	0.50	0.50	0.50	0.50	0.50	0.50

[a]Fed from d 0 to 14 after weaning.
[b]Neo-Terramycin (140 g/ton neomycin sulfate, 140 g/ton oxytetracycline HCl).
[c]Methionine hydroxy analog with calcium, 84% L-methionine activity.
[d]Activate dry organic acid blend, 31% L-methionine activity.
[e]Activate liquid acid blend, 29% L-methionine activity.
[f]Activate Mintrex P, 55% L-methionine activity.

Table 2. Phase 2 Diet Composition (As-fed Basis)[a]

Ingredient, %	Control	Neo Terra	Activate DA	Activate Starter L	Activate Multimax L	Activate DA + Mintrex P
Corn	59.00	59.00	59.00	59.00	59.00	59.00
Soybean meal (46.5% CP)	35.10	35.10	35.10	35.10	35.10	35.10
Soy oil	1.00	1.00	1.00	1.00	1.00	1.00
Monocalcium phosphate (21% P)	1.50	1.50	1.50	1.50	1.50	1.50
Limestone	1.10	1.10	1.10	1.10	1.10	1.10
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15
L-lysine HCl	0.30	0.30	0.30	0.30	0.30	0.30
L-threonine	0.15	0.15	0.15	0.15	0.15	0.15
Corn starch	0.92	0.92	0.60	0.62	0.62	0.52
Neo-Terramycin[b]	---	1.10	---	---	---	---
MHA-Ca (84%)[c]	0.18	---	---	0.03	0.03	---
Activate DA[d]	---	---	0.50	---	---	0.50
Activate Starter L[e]	---	---	---	0.45	---	---
Activate Multimax L[e]	---	---	---	---	0.45	---
Activate DA plus Mintrex P[f]	---	---	---	---	---	0.10
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis						
Total lysine, %	1.45	1.45	1.45	1.45	1.45	1.45
True Digestible Amino Acids						
Lysine, %	1.31	1.31	1.31	1.31	1.31	1.31
Isoleucine:lysine ratio, %	62	62	62	62	62	62
Leucine:lysine ratio, %	128	128	128	128	128`	128
Methionine:lysine ratio, %	35	35	35	35	35	39
Met & cys:lysine ratio, %	60	60	60	60	60	64
Threonine:lysine ratio, %	65	65	65	65	65	65
Tryptophan:lysine ratio, %	18	18	18	18	18	18
Valine:lysine ratio, %	69	69	69	69	69	69
ME, kcal/lb	1,500	1,500	1,500	1,500	1,500	1,500
CP, %	21.7	21.7	21.7	21.7	21.7	21.7
Ca, %	0.80	0.80	0.80	0.80	0.80	0.80
P, %	0.72	0.72	0.72	0.72	0.72	0.72
Available P, %	0.40	0.40	0.40	0.40	0.40	0.40

[a]Fed from d 14 to 28 after weaning.
[b]Neo-Terramycin (140 g/ton neomycin sulfate, 140 g/ton oxytetracycline HCl).
[c]Methionine hydroxy analog with calcium, 84% L-methionine activity.
[d]Activate dry organic acid blend, 31% L-methionine activity.
[e]Activate liquid acid blend, 29% L-methionine activity.
[f]Activate Mintrex P, 55% L-methionine activity.

Table 3. Phase 3 Diet Composition (As-fed Basis)[a]

Ingredient, %	Common
Corn	61.13
Soybean meal (46.5% CP)	33.00
Soy oil	2.00
Monocalcium phosphate (21% P)	1.40
Limestone	1.00
Salt	0.50
Vitamin premix	0.25
Trace mineral premix	0.15
L-lysine HCl	0.28
L-threonine	0.13
MHA-Ca (84%)[b]	0.16
Total	100.00
Calculated Analysis	
Total lysine, %	1.38
True Digestible Amino Acids	
Lysine, %	1.24
Isoleucine:lysine ratio, %	63
Leucine:lysine ratio, %	131
Methionine:lysine ratio, %	35
Met & cys:lysine ratio, %	60
Threonine:lysine ratio, %	65
Tryptophan:lysine ratio, %	18
Valine:lysine ratio, %	70
ME, kcal/lb	1,538
CP, %	20.9
Ca, %	0.77
P, %	0.69
Available P, %	0.37

[a]Fed from d 28 to 42 after weaning.
[b]Methionine hydroxy analog with calcium, 84% L-methionine activity.

Table 4. Growth Performance of Nursery Pigs Provided Organic Acid Blends[a]

				Activate Organic Acid Blended Products							Probability , P<		
				Activate WD, %[h]								Antimicrobial vs	
Item,	Control	Water Med[f]	Neo Terra[g]	0.06	0.12	DA[i]	Starter L[j]	Multimax L[j]	DA + Mintrex P[k]	SE	Trt	Control[m]	Organic Acids
d 0 to 14													
ADG, lb	0.42[b]	0.52[e]	0.50[de]	0.45[bcd]	0.46[cd]	0.42[bc]	0.41[bc]	0.48[cde]	0.50[de]	0.027	0.01	0.01	0.01
ADFI, lb	0.49[b]	0.57[d]	0.55[cd]	0.50[b]	0.52[bc]	0.48[b]	0.48[b]	0.51[bc]	0.53[cd]	0.027	0.02	0.01	0.01
F/G	1.19[d]	1.09[bc]	1.09[bc]	1.13[cd]	1.15[cd]	1.15[cd]	1.17[d]	1.08[b]	1.07[b]	0.030	0.01	0.01	0.11
d 14 to 28													
ADG, lb	1.06[b]	1.03[b]	1.18[c]	1.03[b]	1.07[b]	1.05[b]	1.04[b]	1.04[b]	1.04[b]	0.035	0.01	0.16	0.01
ADFI, lb	1.51	1.50	1.64	1.49	1.53	1.52	1.52	1.49	1.49	0.050	0.21	0.19	0.05
F/G	1.43	1.46	1.39	1.44	1.44	1.45	1.46	1.43	1.43	0.023	0.50	0.85	0.42
d 28 to 42													
ADG, lb	1.48	1.45	1.47	1.41	1.47	1.44	1.48	1.47	1.50	0.032	0.62	0.68	0.98
ADFI, lb	2.23	2.20	2.26	2.19	2.31	2.22	2.32	2.25	2.36	0.057	0.22	0.97	0.28
F/G	1.51	1.51	1.54	1.55	1.57	1.55	1.57	1.53	1.58	0.026	0.54	0.65	0.14
d 0 to 42													
ADG, lb	0.98[b]	1.00[b]	1.05[c]	0.96[b]	1.00[b]	0.96[b]	0.97[b]	1.00[b]	1.01[bc]	0.024	0.01	0.03	0.01
ADFI, lb	1.40	1.42	1.48	1.38	1.45	1.40	1.42	1.42	1.46	0.037	0.13	0.13	0.16
F/G	1.44	1.42	1.41	1.44	1.46	1.45	1.47	1.42	1.45	0.018	0.20	0.34	0.02

[a]A total of 360 weanling pigs (initially 11.5 lb, 18 ± 3d of age), with 5 pigs per pen and 8 pens per treatment.
[b,c,d,e]Means in the same row with different superscripts differ (P<0.05).
[f]Pigs provided water containing 38 mg/L neomycin sulfate.
[g]Neo-Terramycin® (140 g/ton neomycin sulfate, 140 g/ton oxytetracycline HCl).
[h]Water-dispersible organic acid blend, 29% L-methionine activity.
[i]Activate dry organic acid blend, 31% L-methionine activity.
[j]Activate liquid organic acid blend, 29% L-methionine activity.
[k]Activate Mintrex P, 55% L-methionine activity.
[m]Each P-value represents the contrast between the mean of all antimicrobial treatments and either the control or the mean of all organic acid treatments.

EFFECTS OF DIETARY CALCIUM FORMATE AND MALIC ACID ON NURSERY PIG GROWTH PERFORMANCE

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Summary

A total of 180 weanling pigs (initially 14.1 lb and 18 ± 3 d of age, PIC) were used to determine the effects of dietary calcium formate or malic acid on nursery pig growth performance. Treatments were arranged in a 2 × 3 factorial, with or without an antimicrobial, and with or without calcium formate or malic acid, for a total of six dietary treatments: 1) negative control (no organic acids or antimicrobials); 2) positive control (feed containing 140 g/ton neomycin sulfate, 140 g/ton oxytetracycline; neo/oxy); 3) negative control feed containing malic acid; 4) positive control feed containing malic acid; 5) negative control feed containing calcium formate; 6) positive control feed containing calcium formate. There were no interactions (P>0.10) between the antimicrobial and the organic acids. Overall, pigs fed diets containing neo/oxy had greater ADG and ADFI (P<0.04) than did pigs fed diets without an antimicrobial. There were no differences in growth performance between pigs fed the control diet and pigs fed diets containing organic acids. These data suggest that neo/oxy increases ADG and ADFI of weanling pigs. Neither malic acid nor calcium formate are suitable replacements for neo/oxy for growth performance in nursery pigs.

(Key Words: Nursery Pig, Antibiotics, Organic Acids, Water, Growth.)

Introduction

Recent concern over antimicrobial usage in livestock diets has prompted research for antimicrobial alternatives for nursery pig diets. One such alternative is the addition of organic acids to the feed. Research at Kansas State University in 1990 and 1996 evaluated organic acids in semi-complex nursery pig diets containing one or more antimicrobial additives. This research indicated that organic acids did not improve growth performance in nursery pigs when used in combination with an antimicrobial. Since this research was conducted, the general objective of diet acidification has taken secondary interest to antimicrobial replacement for growth performance enhancement. Many alternatives such as organic acids have received renewed interest as potential replacements for antimicrobials, but few have been proven effective. The two most commonly researched organic acids are citric and fumaric acid, neither of which have been shown to effectively replace antimicrobials in nursery pig diets. Two other organic acids that have shown potential for antimicrobial replacement are formic and malic acid. Although pure formic acid is not legal for use in animal feeds in the United States, salts of this acid are available. Salts of formic acid are typically used in food and feed preservation, and have limited availability for use in swine diets, but show the greatest potential for im-

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proving growth performance, according to European research. One such salt, potassium formate, has been effective in nursery pig diets in Europe and Canada, but is not yet available for use in the United States. Another salt, calcium formate, is available, but little research exists on its effectiveness. Another organic alternative, malic acid, is a naturally occurring substance in apples and other fruits, but is commercially produced as a fruit drink additive and food preserver. Malic acid has been briefly evaluated in beef cattle diets, with little or no effect on gastrointestinal pH, and in nursery pig diets, with a negative effect on feed intake. But little recent research exists for these organic acids as antimicrobial alternatives in nursery pig diets. Therefore, the objective of this experiment was to determine the effects of calcium formate and malic acid, and the interactive effects of these acids with an in-feed antimicrobial (neomycin/oxytetracycline), on the growth performance of weanling pigs.

Procedures

A total of 180 weanling pigs (initially 14.1 lb and 18 ± 3 d of age, PIC) were placed 5 pigs per pen in 36 pens, allowing 6 pens per treatment. Dietary treatments were arranged in a 2 × 3 factorial design for a total of 6 experimental diets: 1) negative control (no organic acids or antimicrobials); 2) positive control (feed containing 140 g/ton neomycin sulfate, 140 g/ton oxytetracycline; neo/oxy); 3) negative control feed containing malic acid; 4) positive control feed containing malic acid; 5) negative control feed containing calcium formate; 6) positive control feed containing calcium formate. Pigs remained on the same dietary treatments throughout the experiment.

Dietary treatments were fed in meal form (Table 1). Phase 1 (d 0 to 14 after weaning) diets were formulated to contain 1.41% true ileal digestible (TID) lysine, 0.92% Ca, and 0.55% available P. Phase 2 (d 14 to 28 after weaning) diets were formulated to contain 1.31% TID lysine, 0.80% Ca, and 0.38% available P. In diets containing calcium formate, this organic acid was used as the sole source of calcium, and no limestone was used. The trial was conducted at the Segregated Early Weaning nursery facility at Kansas State University. Each pen (5 × 5 ft) contained one self-feeder and one bowl waterer to provide *ad libitum* access to feed and water. Pigs and feeders were weighed on d 0, 14, and 28 after weaning to determine ADG, ADFI, and F/G.

Data were analyzed as a 2 × 3 factorial, with pen as the experimental unit. Analysis of variance was performed by using the MIXED procedure of SAS. Contrasts were used to determine treatment mean differences, main effects of antimicrobials or organic acids, and the antimicrobial × organic acid interaction. Data were also analyzed as two separate 2 × 2 factorial structures for each organic acid to further determine possible interactions between each organic acid and the antimicrobial.

Results

Interactions between organic acids and the antimicrobial were evaluated in the original 2 × 3 factorial arrangement and as two separate 2 × 2 factorials with each organic acid. In both analyses, there were no significant interactions during any phase of the experiment.

From d 0 to 14 after weaning, there were no differences ($P>0.17$) between pigs fed the control diets and those fed the neo/oxy for ADG or F/G, but pigs fed neo/oxy tended ($P = 0.10$) to have greater ADFI than those fed the control diet. Furthermore, addition of organic acid to the diet (with or without neo/oxy) had no effect on ADG, ADFI, or F/G.

From d 14 to 28 after weaning, pigs fed the diets containing neo/oxy had greater ($P<0.04$) ADG and ADFI than did pigs fed the diets with no antimicrobial; there was no change ($P>0.50$) in F/G. As observed from d 0 to 14, there were no improvements ($P>0.14$)

in growth performance when either malic acid or calcium formate was added to the diet.

Overall (d 0 to 28), pigs fed diets containing neo/oxy had greater ($P<0.04$) ADG and ADFI than did pigs fed non-medicated feed. No differences among pigs fed either organic acid were observed for the overall treatment period.

Discussion

In general, organic acids or their salts are thought to lower gastric pH, resulting in improved nutrient digestion and reduced bacteria concentration in the gut. Adding organic acids to the diet has been shown to be most effective during the first 2 weeks after weaning, with the benefit decreasing thereafter. Acidification of starter diets is also thought to be more effective in simple corn-soybean meal diets than in diets containing high amounts of dried whey and specialty protein sources. Perhaps the effect of organic acids in our experiment could have been improved if less complex diets were used. Pigs in this study also weighed more than 14 lb at weaning, which also may have reduced a response to acidification.

As observed in previous studies conducted at our research farm, pigs fed nursery diets containing neo/oxy had greater ADG and ADFI than did pigs fed the control diet with no medication during the first 28 days after weaning. Studies have shown that dietary organic acids can enhance the effects of antibiotics by improving their absorption, but this was not true in our study. These data suggest that neo/oxy increases ADG and ADFI of weanling pigs. Neither malic acid nor calcium formate are suitable replacements for neo/oxy for growth performance in nursery pigs.

Table 1. Diet Composition (As-fed Basis)

Ingredient, %	Phase 1[a]	Phase 2[b]
Corn[c]	43.06 to 44.68	55.63 to 57.25
Soybean meal, 46.5%	28.59 to 28.71	35.25 to 35.37
Spray dried whey	15.00	---
Select menhaden fish meal	5.00	---
Soy oil	3.00	3.00
Monocalcium phos, 21% P	1.15	1.45
Limestone[d]	0.00 to 0.60	0.00 to 1.05
Vitamins, minerals, & salt	0.75	0.75
Lysine HCl	0.25	0.30
DL -Methionine	0.15	0.13
L-Threonine	0.13	0.13
Test ingredient[e]	0.00 to 1.50	1.35 to 1.50
Total	100.00	100.00
Calculated Analysis		
True ileal digestible lysine,%	1.41	1.31
Total lysine, %	1.55	1.45
ME, kcal/lb	1,537 to 1,563	1,541 to 1,567
CP, %	22.4	21.6
Ca, %	0.92	0.80
P, %	0.82	0.71
Available P, %	0.55	0.38

[a]Phase 1 diets fed from d 0 to 14 after weaning.
[b]Phase 2 diets fed from d 14 to 28 after weaning.
[c]Corn and soybean meal contents fluctuated to accommodate various additions of organic acids, while maintaining amino acid values across treatments within phases.
[d]Diets containing calcium formate did not contain limestone; it was replaced as the source of calcium by this organic acid.
[e]Containing 0.70% cornstarch or antimicrobial (140 g neomycin sulfate and 140 g oxytetracycline HCl per ton of complete feed) and either 0% organic acids, 1.50% malic acid (Phases 1 and 2), 0.75% calcium formate (Phase 1) or 1.35% calcium formate (Phase 2).

Table 2. Effects of In-feed Antimicrobials and Organic Acids on Weanling Pig Growth Performance[a]

	Without Antimicrobial			Antimicrobial[b]				Probability, P<		
Item,	Negative Control	Malic Acid	Calcium Formate	Positive Control	Malic Acid	Calcium Formate	SE	Anti-microbial	Malic Acid	Calcium Formate
d 0 to 14										
ADG, lb	0.29	0.27	0.27	0.28	0.33	0.34	0.039	0.17	0.80	0.63
ADFI, lb	0.37	0.33	0.34	0.36	0.38	0.41	0.029	0.10	0.82	0.72
F/G	1.38	1.27	1.30	1.29	1.23	1.21	0.093	0.31	0.39	0.45
d 14 to 28										
ADG, lb	1.05	1.14	1.05	1.14	1.21	1.15	0.058	0.04	0.15	0.93
ADFI, lb	1.55	1.64	1.50	1.65	1.72	1.65	0.087	0.03	0.23	0.64
F/G	1.48	1.44	1.43	1.45	1.42	1.43	0.041	0.53	0.39	0.39
d 0 to 28										
ADG, lb	0.66	0.70	0.65	0.70	0.75	0.75	0.047	0.04	0.28	0.65
ADFI, lb	0.94	0.97	0.91	0.99	1.03	1.03	0.057	0.02	0.35	0.94
F/G	1.44	1.41	1.40	1.41	1.37	1.38	0.039	0.35	0.28	0.38

[a]A total of 180 pigs, initially 14.1 lb and 18 ± 3 d of age, with six replications per treatment. There were no interactions (P>0.10) between organic acids and the antimicrobial (2 × 3 factorial) or between the individual organic acids and the antimicrobial (2 × 2 factorial) during any phase of the experiment.
[b]Provided 140 g neomycin sulfate and 140 g oxytetracycline HCl (neo/oxy) per ton of complete feed.

GROWTH PERFORMANCE OF NURSERY PIGS FED BIOSAF[1] IN COMBINATION WITH IN-FEED ANTIMICROBIALS[2]

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Summary

Weaned pigs (n = 240; initial BW 13.5 lb) were used in a 28-d growth study. Pigs were blocked by sex and BW, and were assigned randomly to 1 of the 5 dietary treatments: control (no added antimicrobials or yeasts), Neo-Terramycin[4] (Neo-Terra; control diet plus Neo-Terra), Denagard[5] (control diet plus Denagard PLUS), Neo-Terra+BIOSAF (control diet plus Neo-Terra and 0.15% BIOSAF yeast), or Denagard+BIOSAF (control diet plus Denagard and 0.15% BIOSAF yeast). There were 8 pens per treatment and 6 pigs per pen. Treatments were applied in both Phase 1 (d 0 to 14) and Phase 2 (d 15 to 28) diets. Overall (d 0 to 28), pigs fed Denagard+BIOSAF had greater (P<0.05) ADG than all other treatments, and pigs fed Neo-Terra, Denagard, and Neo-Terra+BIOSAF had greater (P<0.05) ADG than did pigs fed the control diet. For the entire trial, pigs fed Denagard+BIOSAF also had greater (P<0.05) ADFI than did pigs fed the control diet or diet containing Neo-Terra, but had ADFI similar to that of pigs fed Denagard and Neo-Terra+BIOSAF. Over the entire 28-d experiment, pigs fed Denagard+BIOSAF maintained greater (P<0.05) F/G than did pigs fed the control diet and diet containing Denagard. But F/G was similar between pigs fed Denagard+BIOSAF, Neo-Terra+BIOSAF, and Neo-Terra. In summary, BIOSAF fed in combination with Denagard enhanced the growth response of nursery pigs beyond the growth advantage of Denagard alone. The interaction of BIOSAF with Denagard is generally consistent with other reports, although we anticipated that BIOSAF would also improve the response to Neo-Terra, as we had observed previously. Factors affecting the presence and magnitude of the interaction of BIOSAF and in-feed antibiotics to enhance the growth response in nursery pigs remain to be elucidated.

(Key Words: Yeast, Antimicrobials, Denagard, Neo-Terra, Nursery Pigs.)

Introduction

Results from previous studies indicate that yeast may interact with in-feed antibiotics to stimulate growth performance in nursery pigs

[1]BIOSAF is a registered trademark of SafAgri, Minneapolis, MN.

[2]The authors thank Saf Agri, a division of the Lesaffre Group, Minneapolis, MN, for partial funding of the experiment.

[3]Food Animal Health and Management Center, College of Veterinary Medicine.

[4]Neo-Teramycin is a registered trademark of Phibro Animal Health, Ltd., Regina, Saskachewan, Canada.

[5]Denagard is a registered trademark of Novartis Animal Health, Greensboro, NC.

to a greater extent than antibiotics alone. But these effects may be dependent on differences in yeast cultures, processing, and yeast activity, as well as the specific antimicrobial used.

BIOSAF is a heat-stable yeast product of *Saccharomyces cerevisiae.* Pigs fed BIOSAF at 0.15% in combination with Neo-Terra produced greater ADG and ADFI than that of pigs fed a diet without antibiotics, and showed numerically greater ADG than pigs fed Neo-Terra (2004 KSU Swine Day Report). The objective of the current experiment was to further evaluate the interactive effects of feeding antimicrobials in combination with BIOSAF yeast in nursery pig diets.

Table 1. Basal Diet Composition (As-fed Basis) %[a]

	Days of Experiment	
Ingredient	0 to 14	15 to 28
Corn	47.50	55.95
Soybean meal, 46.5%	27.00	37.40
Choice white grease	3.00	3.00
Monocalcium phosphate, 21% P	0.80	1.40
Limestone	0.50	1.00
Salt	0.20	0.30
Vitamin premix	0.25	0.25
Trace mineral premix	0.15	0.15
L-threonine	0.15	0.15
Lysine-HCl	0.30	0.30
DL-methionine	0.15	0.13
Select menhaden fish meal	5.00	0.00
Spray dried whey	15.00	0.00
Total	100.00	100.00

[a]Corn was removed from the basal diet and replaced with Neo-Terra (0.7%), Denagard (35 g Tiamulin, 400 g CTC/ton), and BIOSAF (0.15%) to achieve the appropriate experimental diets detailed in the Procedures.

Procedures

A total of 240 weaned pigs (initial BW 13.5 lb) were used in a 28-d study to determine the growth effects of BIOSAF yeast fed in combination with the anti-microbials Neo-Terra or Denagard. Pigs were blocked by weight and sex, and were assigned randomly within block to 1 of 5 dietary treatments: control (no added antimicrobials or yeasts), Neo-Terramycin (Neo-Terra; control diet plus Neo-Terra), Denagard (control diet plus Denagard PLUS), Neo-Terra+BIOSAF (control diet plus Neo-Terra and 0.15% BIOSAF yeast), or Denagard+BIOSAF (control diet plus Denagard and 0.15% BIOSAF yeast). There were 6 pigs per pen and 8 pens per diet. Phase 1 diets were fed from d 0 to 14, and Phase 2 diets were fed from d 15 to 28. All diets were formulated without growth-promoting concentrations of copper sulfate or zinc oxide.

During each week of the experiment, ADG, ADFI, and F/G were calculated by weighing pigs, feed added, and feeders.

Results and Discussion

Overall (d 0 to 28), pigs fed Denagard+BIOSAF had greater ($P<0.05$) ADG than did pigs fed the other four diets. In addition, pigs fed Neo-Terra, Denagard, and Neo-Terra+BIOSAF had greater ($P<0.05$) ADG than that of the pigs fed the control diet. But pigs fed Neo-Terra+BIOSAF and pigs fed Neo-Terra alone performed similarly. Overall, ADFI was similar for pigs fed Denagard+BIOSAF, compared with those fed Denagard and Neo-Terra, but was greater ($P<0.05$) than that of pigs fed the control or Neo-Terra. Pigs fed the Denagard+BIOSAF diet had improved ($P<0.05$) F/G, compared with pigs fed either the control diet or the Denagard diet during the 28-d experiment. The F/G for pigs fed the Denagard+BIOSAF diet was similar to the F/G of pigs fed Neo-Terra and Neo-Terra+BIOSAF.

The results of this trial indicate that the addition of BIOSAF to diets containing Denagard improved ADG of nursery pigs beyond the growth response achieved by feeding Denagard alone. Pigs also responded with increased growth performance to addition of Neo-Terra, but the addition of BIOSAF did not enhance this response as we had observed in a previous trial. Thus, the addition of BIOSAF has the potential to enhance the growth response to in-feed antibiotics, but the response has not been consistent across trials. The factors contributing to enhancement of the antibiotic-stimulated growth response remain unclear.

Table 2. Growth Performance of Nursery Pigs Fed Diets Containing In-feed Antibiotics With, and Without, Added BIOSAF Yeast[a]

	Treatments[b]						
	Control	Neo-Terra	Denagard	Neo Terra + BIOSAF	Denagard + BIOSAF	SEM	P Value
d 0 to 14							
ADG, lb	0.43[c]	0.51[d,e]	0.47[c,d]	0.48[c,d]	0.57[e]	0.01	0.01
ADFI, lb	0.55[c]	0.57[c]	0.62[d,e]	0.58[c,d]	0.64[e]	0.01	0.005
F/G	1.28[c]	1.12[d]	1.32[c]	1.21[c,d]	1.12[c]	0.03	0.02
d 15 to 28							
ADG, lb	1.20[c]	1.29[d]	1.31[d]	1.34[d]	1.37[d]	0.02	0.01
ADFI, lb	1.78[c]	1.85[c,d]	1.87[d]	1.92[d]	1.92[d]	0.02	0.03
F/G	1.48	1.43	1.43	1.43	1.40	0.01	0.3
d 0 to 28							
ADG, lb	0.82[c]	0.90[d]	0.89[d]	0.91[d]	0.97[e]	0.01	0.0005
ADFI, lb	1.16[c]	1.20[c,d]	1.25[d,e]	1.25[d,e]	1.28[e]	0.01	0.004
F/G	1.41[c]	1.33[d]	1.40[c]	1.37[c,d]	1.32[d]	0.01	0.005

[a]A total of 240 pigs (6 pigs per pen and 8 pens per diet).
[b]Control = diet containing no added antibiotic or yeast; Neo-Terra = diet with 140 g/ton neomycin sulfate and 140g/ton oxytetracycline HCl; Denagard = diet with 35 g Tiamulin, 400 g CTC/ton; Neo Terra + BIOSAF = Neo-Terra diet with BIOSAF at 0.15 %; Denagard + BIOSAF = diet with Denagard with BIOSAF at 0.15 %.
[c,d,e]Means in the same row without a common superscript differ (P<0.05).

COMPARISON OF CONCEPT PR 100 AND SPRAY-DRIED ANIMAL PLASMA ON NURSERY PIG PERFORMANCE[1]

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

Summary

One hundred eighty weanling pigs (initially 12.1 lb and 18 ± 2 d of age) were used in a 28-d growth assay to determine if Concept PR 100 (CNPR), a plant-based protein ingredient with added synthetic amino acids and nucleic acids, can replace spray-dried animal plasma (SDAP) in nursery pig diets. The five experimental treatments were: 1) control (no specialty protein source); 2) 2.5% SDAP; 3) 5.0% SDAP; 4) 2.5% CNPR; and 5) 5.0% CNPR. Treatment diets were fed from d 0 to 14 after weaning, with a common diet fed to all pigs from d 14 to 28 after weaning. From d 0 to 14, pigs fed increasing amounts of SDAP had improved (linear and quadratic, P<0.01) ADG and ADFI, which was primarily due to a large improvement from 0 to 2.5% SDAP, with a smaller increase when 5.0% was fed. In addition, pigs fed diets containing increasing amounts of CNPR had increased (linear and quadratic, P<0.003) ADG and ADFI, with the maximum response observed in pigs fed 2.5% CNPR. Furthermore, pigs fed increasing amounts of SDAP or CNPR had improved F/G (linear, P<0.001 and quadratic, P<0.07, respectively), compared with F/G of control pigs. When comparing the means of pigs fed diets containing SDAP versus those fed CNPR, pigs fed SDAP had greater (P<0.002) ADG, ADFI, and pig weight at d 14, compared with pigs fed CNPR.

Overall, (d 0 to 28), pigs fed increasing amounts of SDAP and CNPR had greater ADG, ADFI, and final weight (linear, P<0.01) than did pigs fed the control diet. The greatest improvement for pigs fed both protein sources was observed at 2.5% inclusion in the diet, with a smaller increase up to a 5.0% inclusion. Although either protein source improved growth performance, compared with the control diet, pigs fed SDAP tended to have greater overall ADG (P<0.12) and final body weight (P<0.11) than pigs fed CNPR.

(Key Words: Nursery Pig, Specialty Protein Sources, Spray-dried Animal Plasma, Growth.)

Introduction

Spray-dried animal plasma (SDAP) is commonly used in pelleted starter diets to increase daily gain and feed intake of newly weaned pigs. With increased consumer and regulatory pressure to potentially remove animal protein sources from swine diets, however, alternatives must be evaluated. A newly developed product, Concept PR 100 (CNPR), is a plant-based protein product that is rec-

[1]Appreciation is expressed to Charles Schel, Concept Nutrition Ltd., United Kingdom, for donation of Concept PR 100 for use in this trial. Concept is a trademark of Concept Nutrition Ltd., United Kingdom.

[2]Food Animal Health and Management Center, College of Veterinary Medicine.

ommended to replace spray-dried animal plasma (SDAP) on a 1:1 basis. Although past research evaluating plant-based protein replacements for SDAP in starter pig diets have shown limited success, evaluation of newly developed products, such as CNPR, is critical if substitutes are to be discovered for commercial use. Therefore, the objective of this study was to determine if CNPR, a plant-based protein ingredient, can be a substitute for SDAP in nursery pig diets.

Procedures

A total of 180 pigs (BW of 12.1 lb and 18 ± 2 d of age) were used in a 28-d growth assay. Pigs were blocked by weight and were allotted to 1 of 5 dietary treatments. There were 6 pigs/pen and 6 pens/treatment. Each pen contained one self-feeder and one nipple water to provide *ad libitum* access to feed and water. Pigs were housed in the Kansas State University Swine Teaching and Research Center.

The experimental treatments were: 1) control (no specialty protein source); 2) 2.5% SDAP; 3) 5.0% SDAP; 4) 2.5% CNPR; and 5) 5.0% CNPR. Treatment diets were fed from d 0 to 14 after weaning, with a common diet fed to all pigs from d 14 to 28 after weaning. All diets were fed in meal form. The CNPR (Concept Plasma Replacer 100; Concept Nutrition Ltd., UK) is a proprietary blend of plant protein ingredients, synthetic amino acids, and nucleic acids, which was substituted on a 1:1 basis for SDAP (APC 920; American Proteins Corp., Ankeny IA). Nutrient values from NRC (1998) were used for SDAP, and nutrient values for CNPR were provided by the manufacturer (Table 1). Experimental diets were formulated to contain 1.50% total lysine (Table 2). All pigs were fed a common Phase 2 diet (without SDAP or CNPR) from d 14 to 28. Average daily gain, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance on d 7, 14, 21, and 28 after weaning.

Data were analyzed as a randomized complete-block design, with pen as the experimental unit. Pigs were blocked based on weaning weight, and analysis of variance was performed by using the MIXED procedure of SAS. Linear and quadratic polynomial contrasts were used to determine the effects of increasing SDAP or CNPR in the diet. Also, a contrast comparing the means of pigs fed SDAP and fed CNPR was performed to determine differences between the two protein sources.

Table 1. Nutrient Composition of Specialty Ingredients (As-fed Basis)

Nutrient	SDAP[a]	CNPR[b]
CP, %	78.00	67.79
Ca, %	0.15	1.03
P, %	1.71	0.64
Amino Acids, %		
Arginine	4.55	4.70
Cysteine	2.63	0.92
Histidine	2.55	1.61
Isoleucine	2.71	2.89
Leucine	7.61	4.60
Lysine	6.84	6.85
Methionine	0.75	2.39
Threonine	4.72	4.64
Tryptophan	1.36	1.50
Valine	4.94	2.94

[a]Spray-dried animal plasma, nutrient values from NRC (1998).
[b]Concept Nutrition Plasma Replacer 100, nutrient values provided by the manufacturer.

Results and Discussion

From d 0 to 14, pigs fed diets with increasing amounts of SDAP had improved (linear and quadratic, P<0.01) ADG and ADFI, which was primarily due to a large improvement from 0 to 2.5% SDAP inclusions, with further increases when 5.0% was fed (Table 3). Pigs fed diets containing more CNPR also had increased (linear and quadratic, P<0.003) ADG and ADFI, with the maximum response observed in pigs fed 2.5%. Furthermore, pigs fed increasing amounts of SDAP (linear, P<0.001) or CNPR (quadratic, P<0.07) had improved F/G, compared with F/G of pigs fed the control diet. When comparing the means of pigs fed diets containing SDAP and fed CNPR, pigs fed SDAP had increased (P<0.002) ADG, ADFI, and pig weight at d 14, compared with pigs fed CNPR.

During the common feeding period (d 14 to 28), pigs previously fed increasing amounts of CNPR tended to have improved (linear, P<0.13) ADG and ADFI (linear, P<0.02), which was due to increased gain for pigs previously fed 5.0% CNPR. In addition, pigs previously fed increasing amounts of SDAP or CNPR tended to have increased (linear, P<0.13 and P<0.02, respectively) ADFI. During Phase 2, F/G was worse for pigs previously fed increasing amounts of SDAP (linear, P<0.04) or CNPR (linear and quadratic, P<0.03), with the poorest F/G observed at the 2.5% inclusion for either protein product. There were no differences in ADG, ADFI, or F/G (P>0.41) with pigs previously fed SDAP, compared with those previously fed CNPR.

Overall, (d 0 to 28), pigs had greater ADG and ADFI when fed diets with increasing amounts of SDAP (linear, P<0.001) or CNPR (linear, P<0.004), which was primarily due to large improvements for both protein sources when included at 2.5% of the diet, with further increases when fed at 5.0% of the diet. Also, pigs fed diets containing increasing amounts of either SDAP or CNPR had greater (linear, P<0.002) final body weight. The mean ADG and final body weight of pigs fed SDAP tended (P<0.12) to be greater than the BW for pigs fed CNPR.

Results from this study indicate that nursery pig performance improved, as expected, when a specialty protein source was used to partly replace soybean meal in the diet. At the end of the study, pigs fed diets containing SDAP or CNPR were approximately 3.7 lb and 2.7 lb heavier, respectively, than pigs fed the control diet.

These results indicated that SDAP and CNPR can effectively be used in nursery pig diets to improve growth performance, but it seems that SDAP increases ADG and final weight to a greater extent than CNPR does.

Table 2. Composition of Experimental Diets (As-fed Basis)[a]

		SDAP		CNPR		Phase 2
Ingredient, %	Control	2.5%	5.0%	2.5%	5.0%	Common
Corn	44.05	47.60	51.20	47.60	51.20	59.20
Soybean meal (46.5% CP)	37.50	31.50	25.50	31.50	25.50	34.75
Spray-dried animal plasma	-	2.50	5.00	-	-	-
Concept PR 100	-	-	-	2.50	5.00	-
Dried whey	15.00	15.00	15.00	15.00	15.00	-
Soy oil	-	-	-	-	-	2.00
Monocalcium P (21 % P)	1.40	1.25	1.13	1.25	1.13	1.60
Limestone	1.00	1.10	1.20	1.10	1.20	1.10
Salt	0.30	0.30	0.30	0.30	0.30	0.35
Vitamin premix	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.25	0.25	0.25	0.25	0.15
L-lysine HCl	0.15	0.15	0.15	0.15	0.15	0.30
DL-methionine	0.12	0.11	0.10	0.11	0.10	0.15
L-threonine	0.07	0.05	0.03	0.05	0.03	0.15
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis: [b]						
Total lysine, %	1.50	1.50	1.50	1.50	1.50	1.44
TID amino acids, %[c]						
Lysine	1.34	1.35	1.35	1.35	1.35	1.30
Methionine:lysine	32	31	29	31	29	35
Met & Cys:lysine	58	58	58	58	58	59
Threonine:lysine	64	64	64	64	64	65
Tryptophan:lysine	20	19	19	19	19	18
Isoleucine:lysine	67	64	60	64	60	62
Protein, %	23.3	22.7	22.2	22.5	21.6	21.7
Ca, %	0.89	0.89	0.89	0.91	0.93	0.85
P, %	0.78	0.76	0.75	0.74	0.70	0.74

[a]Experimental diets fed from d 0 to 14 after weaning, and all pigs were fed a common diet from d 14 to 28 after weaning.
[b]Nutrient values from NRC (1998) were used for SDAP, and nutrient values for CNPR were provided by the manufacturer.
[c]True ileal digestible amino acids.

Table 3. Effect of Specialty Protein Source on Nursery Pig Performance[a]

							Probability, P <				
		SDAP[b]		CNPR[c]			SDAP vs	SDAP		CNPR	
Item	Control	2.5%	5.0%	2.5%	5.0%	SEM	CNPR	Linear	Quadratic	Linear	Quadratic
d 0 to 14											
ADG, lb	0.26	0.45	0.52	0.42	0.41	0.03	0.001	0.001	0.01	0.001	0.002
ADFI, lb	0.37	0.59	0.62	0.52	0.50	0.03	0.001	0.001	0.002	0.001	0.003
F/G	1.46	1.31	1.22	1.25	1.23	0.04	0.55	0.001	0.48	0.001	0.07
d 14 to 28											
ADG, lb	1.08	1.12	1.12	1.08	1.16	0.05	0.92	0.47	0.67	0.13	0.39
ADFI, lb	1.33	1.44	1.43	1.42	1.49	0.07	0.62	0.13	0.31	0.02	0.86
F/G	1.23	1.29	1.28	1.31	1.29	0.02	0.41	0.04	0.21	0.03	0.03
d 0 to 28											
ADG, lb	0.67	0.78	0.82	0.75	0.78	0.04	0.12	0.001	0.12	0.001	0.34
ADFI, lb	0.85	1.01	1.03	0.97	0.99	0.05	0.24	0.001	0.06	0.004	0.21
F/G	1.27	1.29	1.26	1.29	1.27	0.02	0.67	0.76	0.26	0.88	0.29
Pig weight, lb											
d 0	12.1	12.3	12.1	12.1	12.1	0.7	0.30	0.79	0.06	0.90	0.63
d 14	15.7	18.6	19.3	18.0	17.8	1.0	0.002	0.001	0.009	0.001	0.004
d 28	30.9	34.2	35.0	33.2	34.0	1.6	0.11	0.001	0.09	0.002	0.34

[a]A total of 180 pigs (6 pigs per pen and 6 pens per treatment) with an initial BW of 12.1 lbs. Pigs were fed experimental diets from d 0 to 14 after weaning, and all pigs were fed a common diet from d 14 to 28 after weaning.
[b]Spray-dried animal plasma (APC 920; American Proteins Corp., Ankeny IA).
[c]Concept Plasma Replacer 100 (Concept Nutrition Ltd., UK).

THE EFFECTS OF ELECTRON BEAM AND GAMMA RAY IRRADIATION LEVELS IN SPRAY-DRIED ANIMAL PLASMA ON NURSERY PIG PERFORMANCE[1]

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Summary

A total of 385 pigs (initially 13.4 ± 2.2 lb and 21 ± 3 d of age) were used in a 28-d trial to determine the effects of electron beam and gamma ray irradiation dosage of spray-dried animal plasma (plasma) on nursery pig performance. Pigs were allotted to pen and blocked by weight by using an incomplete block design with either 7 or 8 replications per treatment. Dietary treatments were randomly allotted to pen within block. Ten dietary treatments were fed from d 0 to 14, including: a negative control diet with no added plasma, a positive control diet with added plasma, or one of 8 irradiated plasma diets. The 8 irradiated treatments included plasma irradiated with either electron beam or gamma radiation at increasing dosages of 2, 4, 6, or 10 kGy. All the pigs were fed a common diet from d 14 to 28. Irradiation of the plasma reduced the total bacterial and coliform counts at every dose, regardless of irradiation source. There were no interactions (P>0.05) between irradiation source and dosage for the entire trial. From d 0 to 14, pigs fed the diets containing plasma had increased (P<0.01) ADG and ADFI, compared with those of the pigs fed the negative control diet. Irradiating the plasma did not improve pig performance. There also were no differences (P>0.12) in growth performance between the pigs fed the plasma irradiated by electron beam or by gamma ray, which confirms previous research. But the majority of previous research has shown improvements in growth performance when pigs were fed diets with irradiated plasma, compared with performance of pigs fed diets containing regular plasma. Irradiation of plasma did not improve performance in this study.

Key Words: Nursery Pig, Spray-dried Animal Plasma, Irradiation.)

Introduction

Previous research conducted at Kansas State University has demonstrated an improvement in growth performance in weanling pigs when fed diets that contain irradiated spray-dried animal plasma (plasma) compared with non-irradiated plasma. The levels of irradiation dosage in those experiments have ranged from 2.5 to 20.0 kGy, with most of the studies using 10 kGy. Increasing the irradiation dosage level will result in a decrease in throughput at the irradiation facility and an increase in irradiation cost. Additional research evaluating levels of irradiation needs to be conducted. Commercial irradiation sources include electron beam and gamma ray. There is limited data comparing these two methods.

[1]Appreciation is expressed to Sadex, Sioux City, IA, for providing the electron beam irradiation of the spray-dried animal plasma for this research project.

[2]Food Animal Health and Management Center, College of Veterinary Medicine.

Therefore, the objective of our study was to evaluate the effects of electron beam and gamma ray irradiation dosage levels of plasma on diet bacterial reduction and nursery pig performance.

Procedures

A total of 385 pigs (initially 13.4 ± 2.2 lb and 21 ± 3 d of age) were used in a 25-d growth assay. Dietary treatments were randomly allotted to pen within block. Pigs were allotted to pen and blocked by weight by using an incomplete-block design. There were 7 replications for the negative control, the positive control, and the gamma ray irradiation at 2 kGy. All other treatments had 8 replications. The pigs were housed in the Kansas State University Segregated Early Weaning Facility. Each pen was 4 × 4 ft and contained one self-feeder and one cup waterer to provide *ad libitum* access to feed and water.

Dietary treatments were fed from d 0 to 14, and a common diet was fed to all pigs from d 14 to 28 (Table 1). The 10 dietary treatments consisted of a negative control diet with no added plasma, a positive control diet with plasma, or one of 8 diets with irradiated plasma, irradiated by electron beam or gamma ray radiation at increasing dosage levels of 2, 4, 6, or 10 kGy. A single lot of plasma was used and was divided into three groups, non-irradiated, or irradiated by either electron (Sadex; Sioux City, IA) or gamma ray (Sterigenics; Schaumburg, IL).

The negative control diet and a basal diet with all ingredients except plasma were manufactured at the Kansas State University Animal Science Feed Mill. The plasma treatment diets were manufactured by using the basal diet at the Kansas State University Poultry Unit in a 400-lb ribbon mixer. The basal diet, followed by the plasma, was weighed and added to the mixer and then mixed for 10 minutes. The mixer was cleaned, sprayed with alcohol, and allowed to dry between treatments to reduce carryover contamination. Samples of the negative control diet, the basal diet, all plasma bags, and all completed diets were collected and analyzed for total bacterial plate count and total coliform count. The ADG, ADFI, and F/G were determined by weighing pigs and feeders on d 4, 7, 14, 21, and 28.

Data were analyzed as an incomplete-block design by using Proc MIXED procedures in SAS 8.1. Linear and quadratic contrasts were used to determine the effects of increasing irradiation dosage level. Contrasts were also used to test for differences between irradiated and non-irradiated diets, electron beam and gamma irradiation, and between the negative control with no added plasma and diets with added plasma.

Results and Discussion

As expected, irradiation of the plasma effectively reduced total bacterial plate count and coliform concentrations, regardless of irradiation type or dosage (Table 2). The high counts in the diets indicate that ingredients besides plasma contribute a significant portion of total bacteria and coliforms in the experimental treatments.

From d 0 to 14, pigs fed the diets with plasma had increased ($P<0.01$) ADG and ADFI, compared with those of the pigs fed the negative control diet (Table 3). Pigs fed the diet containing regular plasma had a tendency ($P<0.09$) toward increased ADFI, compared with ADFI of the pigs fed the diets with irradiated plasma. There was no effect ($P>0.22$) of irradiation dose or source on growth performance.

From d 14 to 28, pigs fed diets containing electron beam irradiated plasma from d 0 to 14 had a tendency toward increased ($P<0.10$) ADG and ADFI, compared with performance of the pigs fed gamma ray irradiated plasma diets.

Overall (d 0 to 28), pigs fed the diets containing plasma had a tendency for increased (P<0.08) ADFI, compared with that of the pigs fed diets without added plasma. Although there was not a significant plasma response in ADG, the 2-lb advantage on d 14 for pigs fed plasma from d 0 to 14 was maintained through the end of the trial. There were no differences (P>0.12) in growth performance between the pigs fed diets containing plasma irradiated by electron beam or gamma ray. The irradiation dosage level and irradiation source had no effect (P>0.12) on growth performance.

These data indicated that irradiation of plasma will reduce total bacteria and coliforms in plasma, regardless of irradiation source or dosage. There were no differences in growth performance between pigs fed plasma irradiated by either the electron beam or gamma ray, which confirms previous research comparing these two sources. But data showed no improvements in performance for pigs fed the irradiated plasma, compared with performance of pigs fed regular plasma. This is in contradiction to previous research that has consistently shown improvements in growth performance when pigs were fed diets with irradiated plasma.

Results from this study indicated that irradiation of plasma at 2 kGy was sufficient to dramatically reduce the total bacteria and coliform counts, but growth performance was not improved by either irradiation source. Therefore, both electron beam and gamma ray may be used as an effective source of irradiation to reduce bacteria and coliform counts in plasma, but more research is needed to further understand the reason for a lack of growth response in this trial, compared with previous research at Kansas State University.

Table 1. Composition of Diets (As-fed Basis)

	D 0 to 14[a]		D 14 to 28[b]
Item	Neg Control	Plasma[c]	Phase 2
Corn	36.63	44.02	53.71
Soybean meal (46.5% CP)	31.78	19.4	31.54
Spray-dried whey	20.00	20.00	10.00
Spray-dried animal plasma	---	5.00	---
Menhaden fish meal	5.00	5.00	---
Soy oil	3.00	3.00	---
Monocalcium phosphate (21% P)	0.75	0.75	1.5
Limestone	0.65	0.65	0.95
Salt	0.25	0.25	0.35
Vitamin premix	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15
Antibiotic[d]	0.70	0.70	0.70
Zinc oxide	0.38	0.38	---
L-lysine HCl	0.23	0.23	0.33
DL-methionine	0.15	0.15	0.15
L-threonine	0.08	0.08	0.13
Total	100.00	100.00	100.00
Calculated Analysis			
Total lysine, %	1.50	1.50	1.30
ME, kcal/lb	1,539	1,552	1,474
Protein, %	23.8	22.6	20.9
Ca, %	0.92	0.88	0.84
P, %	0.78	0.80	0.76
Available P, %	0.50	0.57	0.46
Lysine:calorie ratio, g/Mcal	4.42	4.38	4.00

[a]The treatment diets were fed in meal form from d 0 to 14. The diets included a negative control with no added spray-dried animal plasma, a positive control with added spray-dried animal plasma, or irradiated spray-dried animal plasma at various levels of electron beam and gamma irradiation.
[b]Phase 2 (d 14 to 28) was a common diet fed to all pigs in meal form.
[c]Positive control diet and all irradiated spray-dried animal plasma (plasma) treatments.
[d]Neoterramycin® 144 g/ton.

Table 2. Aerobic Bacteria Concentration[a]

Item	Total Plate Count, CFU/g	Total Coliform Count, CFU/g
Spray-dried animal plasma		
Plasma, non-irradiated	4.2×10^5	3.0×10^1
Plasma, electron beam		
2 kGy	1.0×10^3	$< 1.0 \times 10^1$
4 kGy	4.0×10^1	$< 1.0 \times 10^1$
6 kGy	2.0×10^1	$< 1.0 \times 10^1$
10 kGy	6.0×10^1	$< 1.0 \times 10^1$
Plasma, gamma ray		
2 kGy	8.3×10^2	$< 1.0 \times 10^1$
4 kGy	7.0×10^1	$< 1.0 \times 10^1$
6 kGy	3.0×10^1	$< 1.0 \times 10^1$
10 kGy	3.0×10^1	$< 1.0 \times 10^1$
Complete diets		
Basal diet[b]	2.8×10^4	8.8×10^3
Negative control[c]	1.8×10^5	7.9×10^2
Positive control[d]	1.9×10^4	1.5×10^4
Electron beam diets		
2 kGy	3.7×10^4	1.3×10^3
4 kGy	4.9×10^3	3.8×10^3
6 kGy	1.1×10^4	1.0×10^4
10 kGy	5.8×10^4	1.1×10^4
Gamma ray diets		
2 kGy	1.5×10^4	7.8×10^3
4 kGy	6.7×10^3	4.9×10^3
6 kGy	7.9×10^3	4.7×10^3
10 kGy	4.3×10^4	4.9×10^3

[a]Spray-dried animal plasma was irradiated at an average dose of 2, 4, 6, or 10 kGy.
[b]Basal diet included all ingredients for the diets containing spray-dried animal plasma, except the spray-dried animal plasma.
[c]Negative control diet with no added spray-dried animal plasma.
[d]Positive control diet with regular spray-dried animal plasma.

Table 3. Effects of Electron Beam and Gamma Ray Irradiation of Spray-Dried Animal Plasma on Nursery Pig Performance[a]

			E-Beam Irradiation, kGy				Gamma Irradiation, kGy						Irradiation Effect, P<			
Item	Negative Control	Positive Control	2	4	6	10	2	4	6	10	SE	Source× Dose	Source	Dose	Linear	Quadratic
d 0 to 14																
ADG, lb[d]	0.45	0.60	0.63	0.53	0.51	0.56	0.54	0.56	0.54	0.53	0.03	0.16	0.43	0.66	0.72	0.59
ADFI, lb[df]	0.49	0.64	0.65	0.56	0.58	0.61	0.6	0.63	0.63	0.54	0.03	0.12	0.79	0.83	0.76	0.09
F/G	1.11	1.07	1.05	1.06	1.11	1.10	1.11	1.13	1.18	1.05	0.04	0.33	0.22	0.74	0.89	0.21
d 14 to 28																
ADG, lb	0.99	0.99	0.98	0.97	0.94	1.00	0.93	0.98	0.96	0.89	0.03	0.08	0.07	0.35	0.12	0.67
ADFI, lb	1.38	1.42	1.42	1.42	1.33	1.38	1.32	1.38	1.40	1.28	0.05	0.11	0.08	0.19	0.08	0.66
F/G	1.41	1.44	1.45	1.46	1.42	1.38	1.42	1.40	1.46	1.43	0.03	0.36	0.99	0.26	0.65	0.24
d 0 to 28																
ADG, lb	0.72	0.79	0.80	0.76	0.73	0.78	0.74	0.77	0.75	0.71	0.03	0.10	0.12	0.12	0.26	0.89
ADFI, lb[e]	0.93	1.03	1.04	0.99	0.95	0.99	0.96	1.00	1.03	0.91	0.03	0.26	0.23	0.19	0.22	0.12
F/G	1.31	1.30	1.29	1.31	1.31	1.28	1.31	1.3	1.36	1.29	0.03	0.71	0.37	0.41	0.68	0.13
Pig wt, lb																
d 0	13.5	13.4	13.3	13.4	13.4	13.5	13.5	13.4	13.4	13.4	0.8	0.14	0.41	0.74	0.65	0.14
d 14[d]	19.9	21.8	22.1	20.8	20.6	21.2	21.0	21.2	20.9	20.8	1.01	0.28	0.51	0.63	0.63	0.78
d 28	33.6	35.6	35.9	34.6	33.7	35.3	34.2	34.9	34.4	33.2	1.3	0.23	0.12	0.21	0.97	0.22

[a]A total of 385 pigs (5 pigs per pen) with an average initial weight of 13.4 ± 2.2 lb were used in the study. There were 7 replications for the negative control, the positive control, and the gamma ray irradiation at 2 kGy; all other treatments had 8 replications.
[b]Pigs were fed either a negative control diet with no added plasma, a positive control diet with plasma, or 1 of 8 irradiated plasma diets irradiated by electron beam or gamma ray irradiation at increasing dosage levels of 2, 4, 6, or 10 kGy.
[c]All pigs were fed a common diet in meal form from d 14 to 28.
[d]Plasma effects, (P<0.01).
[e]Plasma effects, (P<0.10).
[f]Irradiation vs. non-irradated effects, (P<0.10).

EFFECT OF IRRADIATED PROTEIN SOURCES, FED IN MEAL OR PELLETED DIETS, ON NURSERY PIG PERFORMANCE

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Summary

A total of 350 pigs (initially 10.8 ± 2.1 lb and 21 ± 3 d of age) were used in a 22-d trial to determine the effects of feeding irradiated protein sources (spray-dried animal plasma, soybean meal, fish meal, or all three), in meal and pelleted diets, on the growth performance of nursery pigs. Pigs were blocked by weight, with 5 pigs/pen and 7 pens/treatment. From d 0 to 11, pigs were fed 1 of 10 experimental treatments, which consisted of the same diet fed in either meal or pelleted form, containing either no irradiated protein sources or containing irradiated spray-dried animal plasma, soybean meal, fish meal, or all three irradiated protein sources; then all pigs were fed a common diet (meal form) from d 11 to 22. Irradiation of the protein sources, as well as pelleting, reduced total bacterial and coliform counts. There were no irradiation by diet form interactions (P>0.16) observed for growth performance. From d 0 to 11, there was no irradiation effect (P>0.16) of protein source on ADG, ADFI, or F/G. But pigs fed pelleted diets had improved (P<0.02) F/G, compared with pigs fed meal diets, with no difference in ADG and ADFI. From d 11 to 22, pigs previously fed meal diets had a tendency for improved (P<0.10) ADFI, compared with that of the pigs fed pelleted diets. Overall (d 0 to 22), pigs fed diets containing irradiated protein sources had a tendency for improved (P<0.13) F/G, compared with that of pigs fed control diets. Pigs fed meal diets had a tendency for improved (P<0.12) ADFI, compared with the ADFI of pigs fed pelleted diets. Pigs fed pelleted diets had improved (P<0.01) F/G, compared with that of pigs fed meal diets. These data confirm that irradiation of protein ingredients, as well as pelleting, will reduce total bacteria and coliform counts within individual feed ingredients or a complete diet. Although irradiation of protein source did not improve performance in this study, pelleting of diets improved feed efficiency.

(Key Words: Nursery Pig, Pellet, Protein Source, Irradiation.)

Introduction

Many studies suggest that weanling pigs fed pelleted diets have increased gain and feed intake, compared with performance of pigs fed meal diets. Because pelleting represents an increase in diet cost, feeding SEW and transition diets in meal form would reduce feed costs for producers. Furthermore, a recent study demonstrated that pigs fed a meal diet with irradiated spray-dried animal plasma had growth performance similar to that of pigs fed pelleted diets. Irradiation of spray-dried animal plasma has been shown to reduce bacteria concentrations, which may be responsible for the growth response. Also, limited data exist

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suggesting that irradiating other ingredients in the diet may improve growth performance. Therefore, the objective of our study was to further evaluate the effects of irradiated protein sources (spray-dried animal plasma, soybean meal, and fish meal) in the diet, and fed in either meal or pelleted form, on nursery pig performance.

Procedures

A total of 350 pigs (initially 10.8 ± 2.1 lb and 21 ± 3 d of age) were used in a 22-d growth assay. Pigs were randomly allotted to pens and blocked by weight and allotted to 1 of 10 dietary treatments. There were 5 pigs/pen and 7 pens/treatment. The pigs were housed in the Kansas State University Segregated Early Weaning Facility. Each pen was 4 × 4 ft, and contained one self-feeder and one cup waterer to provide *ad libitum* access to feed and water.

From d 0 to 11, pigs were fed 1 of 10 experimental treatments, which consisted of the same diet (Table 1), fed in either meal or pelleted form, containing either no irradiated protein sources or irradiated spray-dried animal plasma, soybean meal, fish meal, or all three irradiated protein sources; all pigs were then fed a common diet (meal form) from d 11 to 22. The spray-dried animal plasma, soybean meal, and fish meal were irradiated at Iowa State University Linear Accelerator Facility (Ames, IA), with an average irradiation dose of 10.20 kGy. The 5 meal diets were first manufactured at the Kansas State University Animal Science Feed Mill. One half of each of the meal diet was then pelleted at the KSU Grain Science and Industry Feed Mill, resulting in the 10 experimental dietary treatments.

Samples were collected from all of the regular and irradiated ingredients and from the complete diets, and were analyzed for total bacterial plate counts and total coliform counts. Pigs and feeders were weighed on d 7, 11, 14, and 22 for calculation of ADG, ADFI, and F/G.

Data was analyzed by using Proc MIXED procedures in SAS 8.1. Contrasts were used to test for differences between diets with regular and irradiated ingredients, and meal and pelleted diets.

Results and Discussion

Irradiation of the spray-dried animal plasma, soybean meal, and fish meal reduced total bacterial and coliform counts (Table 2). Pelleting of the diets also resulted in a reduction in the total bacterial counts, compared with counts for the meal diets.

There were no irradiation by diet form interactions ($P>0.16$) observed for growth performance parameters.

From d 0 to 11, there was no irradiation effect ($P>0.16$) of protein source on ADG, ADFI, or F/G. But pigs fed pelleted diets had improved ($P<0.02$) F/G, compared with that of pigs fed meal diets, with no difference in ADG and ADFI.

From d 11 to 22, pigs fed meal diets had a tendency for improved ($P<0.10$) ADFI, compared with ADFI of pigs fed pelleted diets.

Overall (d 0 to 22), pigs fed pelleted diets had improved ($P<0.01$) F/G, compared with that of pigs fed meal diets. Pigs fed diets containing irradiated protein sources had a tendency for improved ($P<0.13$) F/G, compared with that of pigs fed control diets, and pigs fed meal diets had a tendency for improved ($P<0.12$) ADFI, compared with ADFI of pigs fed pelleted diets.

These data confirm that irradiation of protein ingredients will reduce total bacteria and coliform counts within individual feed ingredients and complete diets. Unlike previous

studies, however, there were no differences in growth performance between pigs fed irradiated protein ingredients and pigs fed the control diets. The overall data indicated that weaning pigs onto pelleted diets results in an improved F/G, compared with that of pigs fed meal diets. These data also indicated that current feeding practices of feeding pelleted SEW and transition diets improves growth performance, compared with performance of pigs fed meal diets immediately after weaning. This study contradicts our previous research, in which pigs fed irradiated spray-dried animal plasma in a meal diet had growth performance equal to that of pigs fed a pelleted diet. Therefore, additional research to explain the variation in response is needed.

Table 1. Composition of Diets (As-fed Basis)

Item	Phase 1[a]	Phase 2[b]
Corn	44.02	53.71
Soybean meal (46.5% CP)	19.40	31.54
Spray-dried whey	20.00	10.00
Spray-dried animal plasma	5.00	---
Menhaden fish meal	5.00	---
Soy oil	3.00	---
Monocalcium phosphate (21% P)	0.75	1.50
Limestone	0.65	0.95
Salt	0.25	0.35
L-lysine HCl	0.23	0.33
DL-methionine	0.15	0.15
L-threonine	0.08	0.13
Vitamin premix	0.25	0.25
Trace mineral premix	0.15	0.15
Antibiotic[c]	0.70	0.70
Zinc oxide	0.38	---
	100.00	100.00
Calculated Analysis		
Total lysine, %	1.50	1.30
ME, kcal/lb	1,552	1,474
Protein, %	22.6	20.9
Ca, %	0.88	0.84
P, %	0.80	0.76
Available P, %	0.57	0.46
Lysine:calorie ratio, g/Mcal	4.38	4.00

[a]The Phase 1 (d 0 to 11) diet was feed, in either meal or pelleted form, with irradiated protein sources (plasma, soybean meal, fish meal, or a diet containing all three irradiated protein sources).
[b]The Phase 2 (d 11 to 22) diet was a common diet fed to all pigs in meal form.
[c]Provided 140 g of neomycin sulfate and 140 g oxytetracycline HCl per ton of complete feed.

Table 2. Aerobic Bacteria Concentration[a]

Item	Total Plate Count, CFU/g	Total Coliform Count, CFU/g
Protein Source		
Spray-dried animal plasma	4.8×10^4	2.9×10^2
Soybean meal	3.3×10^3	3.8×10^2
Fish meal	5.4×10^5	2.6×10^2
Irradiated Protein Source		
Spray-dried animal plasma	3.0×10^1	$< 1.0 \times 10^1$
Soybean meal	1.8×10^1	$< 1.0 \times 10^1$
Fish meal	4.1×10^1	$< 1.0 \times 10^1$
Complete Meal Diet		
Control	1.5×10^5	3.6×10^2
Irradiated plasma	2.0×10^3	$< 1.0 \times 10^1$
Irradiated soybean meal	2.1×10^3	$< 1.0 \times 10^1$
Irradiated fish meal	1.8×10^4	$< 1.0 \times 10^1$
All three sources	1.8×10^3	$< 1.0 \times 10^1$
Complete Pelleted Diet		
Control	1.7×10^2	$< 1.0 \times 10^1$
Irradiated plasma	1.4×10^2	$< 1.0 \times 10^1$
Irradiated soybean meal	1.8×10^2	$< 1.0 \times 10^1$
Irradiated fish meal	1.6×10^2	$< 1.0 \times 10^1$
All three sources	1.4×10^2	$< 1.0 \times 10^1$

[a]The plasma, fish meal, and soybean meal were irradiated at Iowa State University Linear Accelerator Facility (Ames, IA), with an average irradiation dose of 10.20 kGy.

Table 3. Effects of Irradiation of Protein Source, Fed in Meal or Pelleted Diets, on Nursery Pig Growth Performance[abc]

	Meal Diet					Pellet Diet							
		Irradiated Ingredient					Irradiated Ingredient						
Item	Control	Plasma	SBM	Fish Meal	All 3	Control	Plasma	SBM	Fish Meal	All 3	SE	Irr vs Non	Meal vs Pellet
d 0 to 11													
ADG, lb	0.52	0.53	0.57	0.51	0.57	0.50	0.55	0.56	0.56	0.52	0.05	0.28	0.95
ADFI, lb	0.61	0.60	0.61	0.57	0.59	0.54	0.55	0.57	0.58	0.56	0.04	0.99	0.17
F/G	1.20	1.16	1.08	1.12	1.06	1.11	1.02	1.02	1.05	1.10	0.04	0.16	0.02
d 11 to 22													
ADG, lb	1.30	1.27	1.30	1.29	1.23	1.29	1.22	1.28	1.26	1.26	0.07	0.37	0.57
ADFI, lb	1.69	1.60	1.66	1.59	1.59	1.58	1.54	1.59	1.60	1.53	0.08	0.33	0.10
F/G	1.29	1.26	1.29	1.24	1.30	1.22	1.27	1.23	1.28	1.22	0.04	0.91	0.23
d 0 to 22													
ADG, lb	0.80	0.79	0.83	0.78	0.80	0.78	0.79	0.83	0.80	0.78	0.05	0.71	0.90
ADFI, lb	1.00	0.95	0.99	0.93	0.95	0.91	0.91	0.94	0.94	0.90	0.05	0.59	0.12
F/G	1.25	1.22	1.20	1.18	1.19	1.17	1.15	1.14	1.17	1.16	0.02	0.13	0.01

[a]A total of 350 pigs (5 pigs/pen and 7 pens/treatment) with an average initial weight of 10.8 ± 2.1 lb were used in the study.
[b]The Phase 1 (d 0 to 11) diet was feed, in either meal or pelleted form, with irradiated protein sources (plasma, soybean meal, fish meal, or a diet containing all three irradiated protein sources). The Phase 2 (d 11 to 22) diet was a common diet fed to all pigs in meal form.
[c]No interactions between ($P>0.16$) irradiation of protein source and diet form were observed.

ISOLEUCINE IN SEGREGATED EARLY WEANING AND TRANSITION DIETS

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Summary

Two studies were conducted to test the effect of isoleucine amount and source on nursery pig performance. In Exp. 1, a total of 194 pigs were used in a 10-d study in a research facility to test the effects of isoleucine rate in high or low lysine diets. Dietary treatments included either high or low lysine and high or low isoleucine in a 2 × 2 factorial arrangement. High-lysine diets were formulated to 1.56% TID lysine, and low-lysine diets were formulated to 1.30% TID lysine. High-isoleucine diets contained approximately 60% TID isoleucine:lysine, whereas low-isoleucine diets contained approximately 49% isoleucine:lysine. Overall (d 0 to 10), there were no significant lysine by isoleucine interactions (P<0.23). From d 0 to 5, pigs fed diets containing high lysine had higher (P<0.02) ADG and tended to have higher (P<0.09) ADFI, compared with performance of pigs fed diets containing low lysine. Also, pigs fed diets containing high isoleucine had a weak tendency for higher (P<0.17) ADG and ADFI, compared with performance of pigs fed diets containing low isoleucine, because pigs fed high isoleucine and low lysine gained and ate more than pigs fed low isoleucine and low lysine. Overall (d 0 to 10), pigs fed diets containing high lysine had higher (P<0.01) ADG and improved (P<0.01) F/G, compared with performance of pigs fed diets containing low lysine. There was a weak tendency to have improved (P<0.18) ADFI for pigs fed diets containing either high lysine or high isoluecine. In Exp. 2, a total of 1,540 pigs were used in a 21-d growth assay in a commercial facility to test the effects of increased dietary L-isoleucine from different isoleucine sources on nursery pig performance. Treatments included: control (standard SEW and transition diets) or the control with increased isoleucine from added L-isoleucine, soybean meal, wheat gluten, or poultry meal. During the SEW period (d 0 to 5), pigs fed diets containing added L-isoleucine had better (P<0.05) ADG than did pigs fed the control or diets containing added soybean meal. Also, pigs fed the diet containing wheat gluten had better (P<0.05) ADG than did pigs fed added soybean meal. Pigs fed diets containing added L-isoleucine had better (P<0.05) F/G than did pigs fed the control or diets containing added soybean meal. Also, pigs fed diets containing wheat gluten had better (P<0.05) F/G than did pigs fed added soybean meal. During the transition period (d 5 to 10), pigs fed diets containing poultry meal had lower (P<0.05) ADG than did pigs fed the control diet or added soybean meal. Also, pigs fed diets containing added soybean meal had better (P<0.05) F/G than did pigs fed diets with added L-isoleucine or poultry meal. From d 0 to 10, there were no differences in ADG or ADFI between treatments; nonetheless, F/G

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was better (P<0.05) for pigs fed added soybean meal than for pigs fed the control diet. Overall (d 0 to 21), there were no differences in ADG or ADFI between treatments, but F/G was better (P<0.05) for pigs fed diets with added soybean meal or wheat gluten than for pigs fed diets containing added L-isoleucine.

For the economic analysis, pigs fed the diets containing wheat gluten had higher (P<0.05) cost per pound of gain from d 0 to 5, d 5 to 10, and d 0 to 10 than did pigs fed all other diets. From d 0 to 5, margin over feed was higher (P<0.05) for the diets with added L-isoleucine or poultry meal, compared with the diet containing wheat gluten. From d 5 to 10, margin over feed was higher (P<0.05) for diets containing added soybean meal than for diets containing wheat gluten, added L-isoleucine, or poultry meal. From d 0 to 10, margin over feed was lowest (P<0.05) for the diet containing wheat gluten, compared with all other diets. These studies indicate that maintaining an adequate amount of isoleucine is critical in diets immediately after weaning, and the addition of L-isoleucine is an economical means of increasing isoleucine in the SEW diet to improve performance.

(Key Words: Isoleucine, Amino Acid, Nursery Pig.)

Introduction

The Kansas State University SEW and transition diets are currently formulated to a lower TID isoleucine:lysine ration than recommended by the NRC (1998). The NRC (1998) recommends a TID isoleucine:lysine ratio of 54%, whereas KSU diets currently contain a ratio of approximately 49 and 52% for the SEW and transition diets, respectively. This is mainly due to use of blood products in these diets, which are a poor source of isoleucine. Isoleucine in a synthetic form is available, but has been cost-prohibitive to use. But other protein sources are available, such as wheat gluten or poultry meal, which contain relatively high concentrations of isoleucine. Using additional soybean meal would help to contribute additional isoleucine, but due to anti-nutritional factors, increasing soybean meal in the SEW and transition diets may decrease performance. Therefore, the objective of these trials was to evaluate low and high concentrations of isoleucine in nursery diets, to evaluate several practical diet formulation alternatives to increase isoleucine, and to characterize the cost of these alternatives in a commercial nursery.

Procedures

Experiment 1. A total of 194 weaned pigs (BW of 13.2 lb) were blocked by weight in a 10-d growth study in a research facility to test the effects of isoleucine in high- or low-lysine diets. Pigs were randomly allotted to 1 of 4 dietary treatments of either high or low lysine and high or low isoleucine in a 2 × 2 factorial arrangement. Each pen contained 7 pigs/pen and 7 pens/treatment. Pigs were housed at the Kansas State University Swine Teaching and Research Center. All pens (4 × 5 ft) contained one stainless steel self-feeder and one nipple waterer to allow *ad libitum* access to feed and water. Procedures used in these experiments were approved by the Kansas State University Animal Care and Use Committee.

Experimental diets (Table 1) were based on corn-soybean meal. Treatment diets included: 1) high lysine, low isoleucine; 2) high lysine, high isoleucine; 3) low lysine, low isoleucine; and 4) low lysine, high isoleucine. High-lysine diets were formulated to 1.56% TID lysine, whereas low-lysine diets were formulated to 1.30% TID lysine. High-isoleucine diets contained approximately 60% TID isoleucine:lysine, whereas low-isoleucine diets contained approximately 49% isoleucine:lysine. High and low lysine concentrations were achieved by altering the amount of soybean meal in the diet. L-isoleucine was used to increase the TID isoleucine:lysine ra-

tio within each lysine level. Pens and feeders were weighed on d 0, 5, and 10 to determine response criteria of ADG, ADFI, and F/G.

Data were analyzed as a randomized complete-block design, with pen as the experimental unit by using the PROC MIXED procedure of SAS. Least squares means were used to determine differences among treatments ($P<0.05$).

Experiment 2. A total of 1,540 pigs (BW of 12.3 lb) were used in a 21-d growth assay to determine the effect of increased dietary isoleucine from different sources on nursery pig performance. Pigs were randomly sorted into 1 of 70 pens (35 pens of barrows, 35 pens of gilts). All pigs were then weighed, and pens were allotted to 1 of 5 dietary treatments so that all pigs within block were the same average weight. One pen of barrows and one pen of gilts consumed feed from a single fenceline feeder; therefore, the experimental unit is the combined data from the 2 pens. Pigs were housed in a commercial research nursery in southern Minnesota.

Experimental diets (Table 2 and 3) were based on corn-soybean meal. Dietary treatments included: control (standard SEW and transition diets) or the control with increased isoleucine from added L-isoleucine, added soybean meal, wheat gluten, or poultry meal. All SEW diets were formulated to a 1.56% TID lysine, and transition diets were formulated to a 1.51% TID lysine. Treatments were fed in two phases: a SEW phase fed at 1 lb/pig and a transition phase fed until d 10 after weaning. All pigs were fed a common diet from d 10 to 21. Economic analysis of feed cost/lb of gain and margin over feed cost were determined by multiplying ADG by market price ($0.45/lb), then subtracting feed cost per pig. Calculations were made with ingredient pricing of: corn, $75/ton; soybean meal, $161/ton; L-isoleucine, $10.43/lb; poultry meal, $420/ton; wheat gluten, $2,700/ton; monocalcium phosphate, $376/ton; limestone, $82/ton; and $60/ton processing, pelleting, and delivery fee. The removal rate was calculated as the number of pigs left on trial during the period, divided by the number of pigs that started the trial. Pens and feeders were weighed at d 0, 5, 10, and 21 to determine the response criteria of ADG, ADFI, and F/G.

Data were analyzed as a complete-block design with initial weight as a covariate by using the PROC MIXED procedure of SAS. Pens (one barrow, one gilt) consuming feed from a single feeder were the experimental unit. Least squares means were used to determine differences between treatments ($P<0.05$).

Results and Discussion

Experiment 1. There were no significant lysine by isoleucine interactions ($P>0.23$) for the treatment period.

From d 0 to 5, pigs fed diets containing high lysine had higher ($P<0.02$) ADG and tended to have higher ($P<0.09$) ADFI than did pigs fed diets containing low lysine. Also, pigs fed diets containing high isoleucine had a weak tendency for higher ($P<0.17$) ADG and ADFI than those of pigs fed diets containing low isoleucine, because pigs fed high isoleucine and low lysine gained and ate more than pigs fed low isoleucine and low lysine.

From d 5 to 10, pigs fed diets containing high lysine had higher ($P<0.04$) ADG and tended to have better ($P<0.06$) F/G than did pigs fed diets containing low lysine.

Overall (d 0 to 10), pigs fed diets containing high lysine had higher ($P<0.01$) ADG and better ($P<0.01$) F/G than did pigs fed diets containing low lysine. There was a weak tendency to have improved ($P<0.18$) ADFI for pigs fed diets containing either high lysine or high isoluecine.

Experiment 2. During the SEW period (d 0 to 5), pigs fed diets containing added L-isoleucine had better (P<0.05) ADG than did pigs fed the control or diets containing added soybean meal. Also, pigs fed the diet containing wheat gluten had better (P<0.05) ADG than did pigs fed added soybean meal. Pigs fed diets containing added L-isoleucine had better (P<0.05) F/G than did to pigs fed the control or diets containing added soybean meal. Also, pigs fed diets containing wheat gluten had better (P<0.05) F/G than did pigs fed added soybean meal.

During the transition period (d 5 to 10), pigs fed diets containing poultry meal had lower (P<0.05) ADG than did pigs fed the control diet or added soybean meal. Also, pigs fed diets containing added soybean meal had better (P<0.05) F/G than did pigs fed diets with added L-isoleucine or poultry meal. From d 0 to 10, there were no differences in ADG or ADFI between treatments; nonetheless, F/G was improved (P<0.05) for pigs fed added soybean meal, compared with F/G of pigs fed the control diet.

Overall (d 0 to 21), there were no difference in ADG or ADFI between treatments, but F/G was better (P<0.05) for pigs fed diets with added soybean meal or wheat gluten than for pigs fed diets containing added L-isoleucine.

For the economic analysis, cost/lb gain and margin over feed were used to compare dietary treatments. Pigs fed the diets containing wheat gluten had higher (P<0.05) cost per pound of gain from d 0 to 5, d 5 to 10, and d 0 to 10 than did pigs fed all other diets. From d 0 to 5, margin over feed was higher (P<0.05) for the diets with added L-isoleucine or poultry meal than for the diet containing wheat gluten. From d 5 to 10, margin over feed was higher (P<0.05) for diets containing added soybean meal than for diets containing wheat gluten, added L-isoleucine, or poultry meal. From d 0 to 10, margin over feed was lowest (P<0.05) for the diet containing wheat gluten, compared with all other diets. Pigs fed the diet containing poultry meal had fewer (P<0.05) pigs remaining on test, compared with all treatments at both d 10 and 21. The primary reason for removal was unthrifty pigs or excess belly rubbing, of which 75% of those removed because of belly rubbing were fed the poultry meal dietary treatment.

When pigs were fed starter diets adequate in lysine in the first experiment, an isoleucine deficiency was not found. As the lysine content was reduced, performance decreased, demonstrating the importance of lysine for nursery diets. Although there were not interactions between lysine and isoleucine, increasing isoleucine in the diet marginally deficient in lysine increased weight gain by 0.5 lb for the first 5 days after weaning. The economic analysis demonstrates that isoleucine can be economically increased in the SEW diet or during the first 5 d after weaning by adding L-isoleucine.

Adding isoleucine to the diet after d 5 did not improve pig performance in either experiment, indicating that the amount of lysine fed may have been in excess of the pigs' requirement during this stage.

Because the SEW period, d 0 to 5, is critical for young pigs, the added isoleucine dietary treatment is beneficial during this period because it had the lowest cost/lb gain, and highest margin over feed, while having the highest ADG and best F/G. But these responses were not maintained during the transition phase, or from d 5 to 10 after weaning. The results of these trials warrant further research into the effects of isoleucine during the SEW period.

Table 1. Composition of Diets (Exp. 1; As-fed Basis)[a]

	High Lysine		Low Lysine	
Item Isoleucine:	Low	High	Low	High
Ingredient, %				
Corn	40.76	40.76	48.70	48.70
Soybean meal (46.5%)	11.80	11.80	4.04	4.04
Spray-dried plasma	6.70	6.70	6.70	6.70
Select menhaden fish meal	6.00	6.00	6.00	6.00
Spray-dried-blood cells	1.65	1.65	1.65	1.65
Spray-dried whey	25.00	25.00	25.00	25.00
Corn starch	0.18	-	0.15	-
Soybean oil	5.00	5.00	5.00	5.00
Monocalcium P (21% P)	0.30	0.30	0.30	0.30
Limestone	0.45	0.45	0.45	0.45
Salt	0.25	0.25	0.25	0.25
Zinc oxide	0.38	0.38	0.38	0.38
Vitamin premix	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15
L- lysine HCL	0.16	0.16	0.08	0.08
DL-methionine	0.15	0.15	0.13	0.13
L-threonine	0.08	0.08	0.04	0.04
L-isoleucine	-	0.18	-	0.15
Antibiotic[b]	0.70	0.70	0.70	0.70
Vitamin E, 20,000 IU	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00
Calculated Analysis				
Total lysine, %	1.70	1.70	1.42	1.42
True ileal digestible amino acids				
Lysine, %	1.56	1.56	1.30	1.30
Isoleucine:lysine ratio, %	49.1	60.2	49.0	60.4
Methionine:lysine ratio, %	31.0	31.0	32.0	32.0
Met & cys:lysine ratio, %	56.0	56.0	60.0	60.0
Threonine:lysine ratio, %	64.0	64.0	66.0	66.0
Tryptophan:lysine ratio, %	17.0	17.0	17.0	17.0
ME, kcal/lb	1,609	1,606	1,609	1,607
Lysine:ME ratio, g/Mcal	4.40	4.41	3.66	3.67
Calcium, %	0.79	0.79	0.77	0.77
Phosphorus, %	0.74	0.74	0.71	0.71
Available phosphorus, %	0.55	0.55	0.55	0.55
Avail P:calorie ratio, g/mcal	1.85	1.85	1.82	1.82

[a]Diets fed in meal form from d 0 to 10.
[b]Provided 140 g/ton neomycin sulfate and 140 g oxytetracycline HCI per ton of concentrate feed.

Table 2. Composition of SEW Diets (Exp. 2. As-fed Basis)[a]

Item	Control	L-isoleucine	Soybean Meal	Wheat Gluten	Poultry Meal
Ingredient, %					
Corn	34.86	34.75	31.40	31.40	31.20
Soybean meal (46.5 %)	12.50	12.50	17.60	12.50	12.50
Poultry meal	-	-	-	-	6.00
Spray-dried wheat gluten	-	-	-	5.00	-
Spray-dried porcine plasma	6.70	6.70	6.70	6.70	6.70
Select menhaden fishmeal	5.80	5.80	5.80	5.80	5.80
Spray-dried blood cells	1.65	1.65	-	-	-
Spray-dried whey	25.00	25.00	25.00	25.00	-
DairyLac 80	6.00	6.00	6.00	6.00	6.00
Choice white grease	5.00	5.00	5.00	5.00	5.00
Monocalcium P (21% P)	0.30	0.30	0.25	0.30	-
Limestone	0.31	0.31	0.36	0.45	-
Salt	0.25	0.25	0.25	0.25	0.25
Zinc oxide	0.38	0.38	0.38	0.38	0.38
MS vitamin premix	0.04	0.04	0.04	0.04	0.04
Trace mineral premix	0.11	0.11	0.11	0.11	0.11
L-lysine HCl	0.15	0.15	0.15	0.25	0.13
DL-methionine	0.15	0.15	0.15	0.04	0.14
L-threonine	0.08	0.08	0.06	0.04	0.03
L-isoleucine	-	0.10	-	-	-
Antibiotic[b]	0.43	0.43	0.43	0.43	0.43
Kemgest®	0.20	0.20	0.20	0.20	0.20
Selenium 0.06%	0.04	0.04	0.04	0.04	0.04
Choline chloride	0.04	0.04	0.04	0.04	0.04
Total	100.00	100.00	100.00	100.00	100.00
Calculated Analysis					
Total lysine, %	1.70	1.70	1.71	1.70	1.73
True ileal digestible amino acids[b]					
Lysine, %	1.56	1.56	1.56	1.56	1.56
Isoleucine:lysine ratio, %	49	54	57	54	55
Methionine:lysine ratio, %	30	30	31	28	32
Met & cys:lysine ratio, %	55	55	57	62	58
Threonine:lysine ratio, %	64	64	64	64	63
Tryptophan:lysine ratio, %	18	18	18	18	17
ME, kcal/lb	1,601	1,600	1,604	1,580	1,599
Calcium, %	0.76	0.76	0.78	0.82	0.85
Phosphorus, %	0.76	0.76	0.77	0.76	0.83
Available phosphorus, %	0.58	0.58	0.58	0.58	0.64
TID Lysine:calorie ratio, g/,cal	4.13	4.43	4.42	4.48	4.43

[a]SEW diet fed at 1 lb/pig.
[b]Provided 100 g of carbodox and 600 g of tetracycline per ton of complete feed.

Table 3. Composition of Transition Diets (Exp. 2. As-fed Basis)[a]

Item	Control	L-isoleucine	Soybean Meal	Wheat Gluten	Poultry Meal
Ingredient, %					
Corn	37.44	37.35	34.80	35.00	35.25
Soybean meal (46.5 %)	22.22	22.22	26.10	22.22	22.22
Poultry meal	-	-	-	-	4.25
Spray-dried wheat gluten	-	-	-	3.75	-
Spray-dried porcine plasma	2.50	2.50	2.50	2.50	2.50
Select menhaden fishmeal	5.50	5.50	5.50	5.50	5.50
Spray-dried blood cells	1.25	1.25	-	-	-
Spray-dried whey	12.50	12.50	12.50	12.50	-
DairyLac 80	11.25	11.25	11.25	11.25	11.25
Choice white grease	4.00	4.00	4.00	4.00	4.00
Monocalcium P (21% P)	0.70	0.70	0.70	0.70	0.25
Limestone	0.51	0.51	0.51	0.51	0.20
Salt	0.30	0.30	0.30	0.30	0.30
Zinc oxide	0.39	0.39	0.39	0.39	0.39
MS vitamin premix	0.04	0.04	0.04	0.04	0.04
Trace mineral premix	0.11	0.11	0.11	0.11	0.11
L-lysine HCl	0.26	0.26	0.26	0.34	0.25
DL-methionine	0.18	0.20	0.20	0.07	0.18
L-threonine	0.15	0.16	0.15	0.13	0.13
L-isoleucine	-	0.08	-	-	-
Antibiotic[b]	0.43	0.43	0.43	0.43	0.43
Kemgest®	0.20	0.20	0.20	0.20	0.20
Selenium 0.06%	0.04	0.04	0.04	0.04	0.04
Choline chloride	0.04	0.04	0.04	0.04	0.04
Total	100.00	100.00	100.00	100.00	100.00
Calculated Analysis					
Total lysine, %	1.65	1.65	1.65	1.65	1.67
True ileal digestible amino acids[b]					
Lysine, %	1.51	1.51	1.51	1.51	1.51
Isoleucine:lysine ratio, %	52	57	58	56	57
Methionine:lysine ratio, %	34	35	36	29	35
Met & cys:lysine ratio, %	56	57	58	58	58
Threonine:lysine ratio, %	63	64	64	63	63
Tryptophan:lysine ratio, %	17	17	17	17	17
ME, kcal/lb	1,572	1,571	1,574	1,557	1,575
Calcium, %	0.85	0.85	0.86	0.86	0.84
Phosphorus, %	0.78	0.78	0.80	0.78	0.78
Available phosphorus, %	0.55	0.55	0.55	0.55	0.55
TID Lysine:calorie ratio, g/,cal	4.37	4.37	4.36	4.41	4.36

[a]Diet fed after SEW until 10 d after weaning.
[b]Provided 100 g of carbodox and 600 g of tetracycline per ton of complete feed.

Table 4. Effects of High and Low Lysine and Isoleucine Levels on Nursery Pig Performance (Exp. 1)[a]

	Lysine × Isoleucine					Probability, P <			
	High Lysine[b]		Low Lysine[c]						
Item; Isoleucine	Low[d]	High[e]	Low	High	SED	Lysine × Isoleucine	Lysine	Isoleucine	SED
d 0 to 5									
ADG, lb	0.79	0.80	0.63	0.75	0.062	0.24	0.02	0.16	0.044
ADFI, lb	0.58	0.58	0.49	0.57	0.039	0.23	0.09	0.17	0.028
F/G	0.75	0.74	0.80	0.77	0.06	0.80	0.33	0.64	0.042
d 5 to 10									
ADG, lb	1.06	1.08	0.95	0.95	0.082	0.90	0.04	0.85	0.058
ADFI, lb	1.11	1.16	1.09	1.12	0.049	0.75	0.33	0.26	0.034
F/G	1.05	1.09	1.17	1.19	0.074	0.81	0.06	0.59	0.052
d 0 to 10									
ADG, lb	0.93	0.94	0.79	0.85	0.046	0.48	0.01	0.26	0.033
ADFI, lb	0.84	0.87	0.79	0.84	0.041	0.69	0.16	0.18	0.023
F/G	0.91	0.92	1.00	1.01	0.021	0.33	0.01	0.96	0.015

[a]A total of 194 pigs, initially 13.18 lb, were used in this study, with 7 replications per treatment.
[b]High-lysine diets formulated to 1.56% TID lysine.
[c]Low-lysine diets formulated to 1.30% TID lysine.
[d]High-isoleucine diets contained 0.60% isoleucine:lysine ratio.
[e]Low-isoleucine diets contained 0.49% isoleucine:lysine ratio.

Table 5. The Effect of Alternative Diet Formulation to Increase Isoleucine Concentration in SEW and Transition Diets (Exp. 2)[a]

Item:	Control	L-isoleucine	Poultry Meal	Soybean Meal	Wheat Gluten	SE
d 0 to 5						
ADG, lb	0.33[ef]	0.36[d]	0.35[def]	0.32[f]	0.36[de]	0.011
ADFI, lb	0.30	0.30	0.30	0.30	0.30	0.003
F/G	0.91[de]	0.83[f]	0.86[def]	0.92[d]	0.86[ef]	0.023
Cost/lb gain, $[b]	0.29[e]	0.27[e]	0.27[e]	0.29[e]	0.32[d]	0.008
Margin over feed, $[c]	0.27[de]	0.33[d]	0.31[d]	0.27[de]	0.24[e]	0.026
d 5 to 10						
ADG, lb	0.44[d]	0.40[de]	0.39[e]	0.44[d]	0.43[de]	0.017
ADFI, lb	0.43	0.42	0.40	0.40	0.43	0.015
F/G	0.98[de]	1.05[d]	1.02[d]	0.91[e]	0.99[de]	0.025
Cost/lb gain, $	0.22[fg]	0.25[e]	0.23[ef]	0.21[g]	0.27[d]	0.006
Margin over feed, $	0.50[de]	0.41[f]	0.43[ef]	0.54[d]	0.40[f]	0.027
d 0 to 10						
ADG, lb	0.39	0.38	0.37	0.38	0.40	0.001
ADFI, lb	0.37	0.36	0.35	0.35	0.37	0.008
F/G	0.95[d]	0.94[de]	0.95[de]	0.91[e]	0.92[de]	0.012
Cost/lb gain, $	0.25[ef]	0.26[e]	0.25[ef]	0.25[f]	0.29[d]	0.003
Margin over feed, $	0.77[d]	0.74[d]	0.74[d]	0.80[d]	0.63[e]	0.028
d 0 to 21						
ADG, lb	0.59	0.57	0.58	0.59	0.60	0.011
ADFI, lb	0.73	0.72	0.71	0.71	0.72	0.011
F/G	1.23[de]	1.25[d]	1.23[de]	1.20[e]	1.21[e]	0.011
Weight, lb						
d 0	12.3	12.3	12.3	12.3	12.3	0.000
d 5	14.0[ef]	14.2[d]	14.1[def]	13.9[f]	14.1[de]	0.056
d 10	16.2	16.2	16.2	16.2	16.3	0.104
d 21	24.8	24.5	24.9	25.0	25.0	0.182
Survival, %						
d 10	99.7%[d]	99.1%[d]	97.5%[e]	99.3%[d]	99.5%[d]	0.005
d 21	99.0%[d]	97.9%[d]	94.6%[e]	98.0%[d]	98.5%[d]	0.009

[a]A total of 1,540 gilts, initially 12.3 lb, were used in this study, with 7 replications per treatment. Pigs were budgeted 1 lb SEW diet and then fed the transition diet until d 10. Pigs were then fed a common Phase 2 diet until d 21.

[b]Ingredient pricing used in this analysis included: corn, $75/ton; soybean meal, $161/ton; L-isoleucine, $10.43/lb; poultry meal, $420/ton; wheat gluten, $2,700/ton; monocalcium phosphate, $376/ton; limestone, $82/ton; and $60/ton processing, pelleting, and delivery fee.

[c]Based on market price of $0.45/lb. Calculated as gain × $0.45/lb, minus feed cost per pig.

[defg]Means in the same row with different superscripts differ ($P<0.05$).

EFFECTS OF DRIED DISTILLERS GRAIN WITH SOLUBLES ON NURSERY PIG PERFORMANCE

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Summary

A total of 482 pigs (initial BW of 21.9 lb) were used in a 22-d study to determine the effects of dried distillers grains with solubles (DDGS) on growth performance of nursery pigs reared in a commercial environment. Pigs were allotted to one of two dietary treatments based on corn-soybean meal and containing either 0 or 10% DDGS. There was a tendency for pigs fed the diet containing 10% DDGS to have decreased (P<0.13) ADG, compared with pigs not fed DDGS (0.95 vs. 0.88 lb/d). Overall (d 0 to 22), there were no differences in ADFI, F/G, or final weight (P>0.21). For economic analysis, the DDGS price was compared at $109, $93, or $80/ton. There were no differences in feed cost per pound of gain in diets containing DDGS at the three price levels (P>0.29). Pigs fed the diets containing 10% DDGS had a tendency for reduced (P<0.12) margin over feed cost ($0.52, $0.54, and $0.56), regardless of DDGS price ($106, $93, or $80/ton, respectively). Although only a trend for decreased ADG was observed, feeding diets containing DDGS was less economical, as measured by margin over feed costs.

(Key Words: Dried Distillers Grain with Solubles, Nursery Pigs, Growth.)

Introduction

The availability of DDGS for use in swine diets has increased due to increases in the number of ethanol manufacturing plants. Research evaluating DDGS in university and commercial facilities has shown variable results, leading to a wide variety of recommended feeding levels. This has been partly attributed to variation in facilities (university vs. commercial) and between manufacturing processes at different plants. Potential sources of plant variation may include drying method, particle size, regional grain quality variation, and contents of residual sugars. To help overcome this variation, producers need to verify the quality of DDGS from individual plants. Therefore, the objective of this experiment was to determine the effects of DDGS on the growth performance of nursery pigs in a commercial research environment.

Procedures

A total of 482 pigs (initial BW of 21.9 lb) were used in a 22 d-growth assay evaluating the effects of DDGS on growth performance of nursery pigs in a commercial facility in Illinois. Pigs were randomly blocked and allotted to one of two experimental dietary treat-

[1]Appreciation is extended to Swine Nutrition Services, Inc. and M.U. Steidinger for providing data collection and facilities.

[2]Food Animal Health and Management Center, College of Veterinary Medicine.

ments. There were 12 pens per treatment and 18 to 21 pigs per pen.

Diets were based on corn-soybean meal and were fed in meal form (Table 1). The two dietary treatments were 0 or 10% DDGS. All pigs were fed commercial starter diets from d 0 to 10 after weaning and then switched to treatment diets. The DDGS was provided by Adkins Energy, LLC, in Lena, Illinois. Diets were formulated to an equal true ileal digestible (TID) lysine of 1.19% by using values from 1998 NRC. Economic analysis of feed cost per pound of gain and margin over feed cost were determined by multiplying ADG by market price ($0.45), then subtracting feed cost per pig. Calculations were made with DDGS priced at $106, $93, or $80/ton. Pigs and feeders were weighed on d 0 and 22 of the treatment period to determine the response criteria of ADG, ADFI, and F/G.

Data were analyzed by using the PROC MIXED procedure of SAS (SAS Institute Inc., Cary, NC), with pen as the experimental unit. Least squares means were used to determine differences between treatments.

Results and Discussion

There was a tendency for decreased ADG (0.95 vs. 0.88 lb/d, P = 0.13) for pigs fed 10% DDGS. There was no difference in ADFI, F/G, or final weight (P>0.21), but pigs fed the control diet without DDGS were 1.60 lb lighter at the end of the experiment.

For economic analysis, there was no difference in feed cost per pound of gain (P = 0.29) with DDGS at $106, $93, or $80/ton. Pigs fed the diets containing 10% DDGS had a tendency for reduced (P<0.12) margin over feed cost of $0.52, $0.54, and $0.56 when DDGS was priced at $106, $93, or $80/ton, respectively. Although not statistically significant, the numerical reduction in ADG, coupled with the lack of an advantage in feed cost per pound of gain, reduced profitability (margin over feed costs) by approximately $0.50 per pig in this study.

Table 1. Composition of Diets (As-fed Basis)[a]

	DDGS, %	
Ingredient, %	0	10
Corn	64.50	56.05
Soybean meal (46.5%)	30.40	29.05
DDGS	-	10.00
Choice white grease	2.00	2.00
Monocalcium P (21% P)	1.00	0.76
Limestone	0.95	1.05
Salt	0.35	0.35
Vitamin premix with phytase	0.25	0.25
Trace mineral		
Copper sulfate	0.08	0.08
L-lysine HCl	0.30	0.30
DL-methionine	0.09	0.07
L-threonine	0.08	0.05
Total	100.00	100.00
Calculated Values		
Total lysine, %	1.32	1.32
True ileal digestible amino acids[b]		
Lysine, %	1.19	1.19
Methionine:lysine ratio, %	31.0	31.0
Met & cys:lysine ratio, %	57	59
Threonine:lysine ratio, %	60	61
Tryptophan:lysine ratio, %	18	18
ME, kcal/lb	1,548	1,523
Calcium, %	0.67	0.68
Phosphorus, %	0.60	0.59
Available phosphorus equiv, %[c]	0.38	0.39
Lysine:calorie ratio, g/mcal	1.30	1.28

[a]Diets fed in meal form from d 0 to 32.
[b]DDGS nutrient values for formulation derived from 1998 NRC.
[c]Includes expected phytase phosphorus release from added phytase.

Table 2. Growth Performance of Nursery Pigs Fed DDGS[a]

	DDGS, %		Probability, P <	
Item	0	10	Treatment	SE
d 0 to 22				
ADG, lb	0.95	0.88	0.13	0.042
ADFI, lb	1.43	1.37	0.39	0.069
F/G	1.50	1.55	0.21	0.034
d 0 weight, lb	22.0	21.9	0.91	0.953
d 22 weight, lb	42.9	41.3	0.40	1.862
Feed cost/lb gain, $[b]				
DDGS at $106/ton	0.094	0.096	0.29	0.002
DDGS at $ 93/ton	0.094	0.095	0.55	0.001
DDGS at $80/ton	0.094	0.094	0.89	0.094
Margin over feed, $[c]				
DDGS at $106/ton	7.44	6.88	0.10	0.356
DDGS at $ 93/ton	7.44	6.90	0.11	0.355
DDGS at $80/ton	7.44	6.92	0.12	0.356

[a]Total of 482 pigs (17 to 21 per pen with 24 pens), initially 21.9 lb, were used in this study, with 12 replications per treatment.

[b]Diet cost of 0% DDGS = $124.97. Diet cost of 10% DDGS = $124.30. Ingredient pricing included: corn, $78.60/ton; soybean meal, $174.00/ton; DDGS, $106.00/ton; monocalcium phosphate, $340.00/ton; and limestone, $20.00/ton.

[c]Based on market price of $0.45/lb. Calculated as gain × $0.45/lb minus feed cost per pig.

EFFECTS OF DRIED DISTILLERS GRAIN WITH SOLUBLES ON GROWING-FINISHING PIG PERFORMANCE

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Summary

Three experiments were conducted to determine the effects of increasing dried distiller's grains with solubles (DDGS) on growth performance and palatability in growing-finishing pigs. In Exp. 1, a total of 1,050 pigs (initially 104.9 lb) were used in a 28-d study in May 2002. Pigs were fed diets with either 0 or 15% DDGS and 0, 3, or 6% added fat, for a 2 × 3 factorial arrangement. Overall, there were no DDGS × fat content interactions (P = 0.20). There was an improvement (linear, P<0.01) in ADG and F/G with increasing added fat and no difference in growth performance between pigs fed 0 or 15% DDGS. In Exp. 2, a total of 1,038 pigs (initially 102.1 lb) were used in a 56-d study in August 2005. Pigs were fed diets with either 0, 10, 20, or 30% DDGS from the same ethanol plant as in Exp. 1. Overall (d 0 to 56), there was a trend for decreased ADG (linear, P<0.10) and ADFI (linear, P<0.06) as DDGS increased. The greatest reduction occurred in pigs fed more than 10% DDGS. In Exp. 3, a total of 120 growing pigs (initially 48.7 lb) were used in a 21-d feed preference study in October 2005. Pigs were randomly allotted to a pen with 4 feeders, each containing a separate dietary treatment. Pigs were offered diets based on corn-soybean meal, with 0, 10, 20, or 30% DDGS from the same source as in Exp. 1 and 2. For all periods (d 0 to 7, 7 to 21, and 0 to 21), there was a decrease in ADFI (quadratic, P<0.01) as DDGS increased in the diet. The most dramatic decrease was observed between 0 and 10% DDGS. Experiment 1 showed no difference in growth performance in pigs fed 0 or 15% DDGS. In Exp 2, at DDGS contents higher than 10%, there were trends for decreased ADG and ADFI; in Exp. 3, ADFI decreased with increasing DDGS in the diet. In summary, DDGS from the ethanol plant tested can be used at 10 to 15% in finishing diets without reducing pig performance. Higher percentages of DDGS in the diet decreased ADFI in growing and finishing pigs.

(Key Words: Dried Distillers Grains, Growing-Finishing Pigs.)

Introduction

The use of DDGS in swine diets has increased because of increases in ethanol production. Research has shown variable results when pigs are fed various amounts of DDGS. This has been partly attributed to variation between manufacturing processes at different plants, and to batch variation at a single plant. Potential sources of variation that have been proposed to explain batch variation over time within a single plant include drying method, particle size, regional grain quality variation, and amounts of residual sugars. There is little information available about potential variation of DDGS from an individual ethanol production plant. Therefore, the objective of the ex-

[1]Food Animal Health and Management Center, College of Veterinary Medicine.

periments were: 1) To evaluate feeding DDGS over time from the same ethanol manufacturing plant to determine potential DDGS quality variation within plant: and 2) Determine the efficacy of a preference test to predict DDGS palatability in commercial settings.

Procedures

General. Procedures used in these experiments were approved by the Kansas State University Animal Care and Use Committee. Experiments 1 and 2 were conducted at a commercial research facility in southwestern Minnesota. The facility had totally slatted floors with approximately 10 × 18 ft pens that contained a five-hole feeder and one bowl drinker. The facility was a double curtain-sided, deep-pit barn that operated on minimal ventilation during the summer and on automatic ventilation during the winter. Experiment 1 was conducted in May 2002 and Exp. 2 was conducted in August 2005. Experiment 3 was performed at the Kansas State Swine Teaching and Research Center in October 2005. Dried distiller grains with solubles for all three experiments were from different batches from Agri-Energy, Luverne, Minnesota.

Experiment 1. A total of 1,050 pigs (initial BW of 104.9) were used in a 28-d growth assay evaluating the effects of DDGS and increasing added fat on growth performance. Pigs were randomly blocked by weight, and were allotted to one of 6 dietary treatments, with 7 pens per treatment. Each pen contained 24 to 26 pigs.

Experimental diets were based on corn-soybean meal and were fed in meal form (Table 1). Diets contained either 0 or 15% DDGS, in combination with 0, 3, or 6% added fat, and were formulated by using DDGS values from 1998 NRC. Pigs and feeders were weighed on d 0, 14, and 28 to determine the response criteria of ADG, ADFI, and F/G.

Data were analyzed as a 2 × 3 factorial, with pen as the experimental unit. Fixed model effects included with or without DDGS, fat content (0, 3, or 6%), and their interaction. Analysis of variance was performed by using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC). Linear and polynomial contrasts were used to determine the effects of increasing DDGS.

Experiment 2. A total of 1,038 gilts (initial BW of 102.1 lb) were used in a 56-d growth assay evaluating the effect of increasing DDGS (0, 10, 20, and 30%) in the diet on pig growth performance. Pigs were randomly blocked and were allotted to one of four dietary treatments, with 10 replications per treatment. Each pen contained 24 to 26 pigs.

The four experimental diets were based on corn-soybean meal and contained 0, 10, 20, or 30% DDGS. All diets contained 6% added fat and were fed in meal form. Dietary treatments were fed in two phases, with Phase 1 from d 0 to 28 (Table 2) and Phase 2 from d 28 to 56 (Table 3). The Phase 1 and Phase 2 diets were formulated to 0.95 and 0.78% true ileal digestible (TID) lysine with values from the 1998 NRC and to 0.55 and 0.54% calcium, respectively. Diets were formulated to maintain a minimum available phosphorus concentration of 0.29 and 0.26% in Phase 1 and Phase 2, respectively. The diet containing 30% DDGS did not need any supplemental phosphorus, and exceeded the minimum requirement. Pigs and feeders were weighed on d 0, 14, 28, 42, and 56 to determine the response criteria of ADG, ADFI, and F/G.

Analysis of variance was performed by using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC), with pen as the experimental unit. Linear and polynomial contrasts were used to determine the effects of increasing DDGS.

Experiment 3. A total of 120 growing pigs (initial BW of 48.7 lb) were used in a 21-

d study evaluating the effects on palatability of increasing DDGS from 0 to 30%. Pigs were randomly blocked by sex and allotted to a pen. There were 15 pigs/pen and 8 pens. Each pen used in this experiment was 10.5 × 10.2 ft. and contained one nipple waterer. Each pen contained 4 feeders and each feeder supplied one of the treatment diets. Feeders were randomly rotated within pens twice daily. *Ad libitum* access to feed and water was provided.

Diets were based on corn-soybean meal and contained 0, 10, 20, or 30% DDGS (Table 4). Experimental diets were formulated to 1.07% TID lysine and contained 0.29% available phosphorus. Diets were formulated by using an average of DDGS high and low values from Stein et al. (2005) and were fed in meal form. The only response criterion measured was ADFI, which was determined by weighing the feeders at d 0, 7, 14, and 21.

Data were analyzed by using the MIXED procedures of SAS as a completely randomized block design with feeder as the experimental unit. Linear and quadratic polynomial contrasts, as well as least squares means, were used to determine differences in treatment preference.

Results and Discussion

Experiment 1. Overall, there were no DDGS × added fat interactions (P = 0.20, Table 5). There was improvement (linear, P<0.01) in ADG and F/G as amount of added fat increased. There was no difference (P = 0.79) in pig growth performance between pigs fed 0 or 15% DDGS.

Experiment 2. For Phase 1 (d 0 to 28), pigs fed diets containing DDGS had decreased ADFI and improved (linear, P<0.01) F/G (Table 6). During this same period, there was no difference in ADG among treatments (P = 0.77). For Phase 2 (d 28 to 56), pigs fed diets with increasing DDGS tended to have decreased (linear, P<0.14) ADG and poorer F/G. Overall (d 0 to 56), pigs fed diets with increasing DDGS had a tendency for decreased ADG (linear, P<0.10) and ADFI (linear, P<0.06). This was due to reductions in intake and gain when DDGS was fed at 20 or 30% of the diet.

Experiment 3. For all periods (d 0 to 7, 7 to 21, and 0 to 21), pigs offered DDGS had decreased ADFI as the amount of DDGS in the diet increased (linear and quadratic, P<0.01, Table 7). The response was primarily due to a decrease in ADFI between 0 and 10% DDGS and a further reduction between 10 and 20% DDGS. Feed intake was similar for 20 and 30% DDGS.

Results from the commercial trials indicate that increasing the energy density of the diet by adding fat improved pig performance whether dietary DDGS was used or not. Also, feeding this DDGS source up to 15% in the growing and finishing diets did not affect pig performance (Exp. 1). But dietary DDGS at 20 or 30% of the diet reduced growth performance (Exp. 2). In contrast, a similar response was not seen in Exp. 3 when pigs were given a choice of diets consisting of the same dietary percentages of DDGS as in Exp. 2.

Pigs preferred to eat diets without DDGS, compared with diets that contained DDGS, even when only 10% was added to the diet. A research preference model provides valuable information in demonstrating that palatability is a concern when feeding high percentages of DDGS in the diet. Although the research model does not fully replicate responses observed in the commercial environment, Exp. 2 supports the concern with decreased palatability, especially at higher percentages of DDGS. In consequence, producers can use added fat to improve growth performance with confidence. If a producer or feed mill can obtain from a single ethanol plant DDGS demonstrated not to negatively affect feed intake, data from these trials indicate that 10 to 15% can be used in finishing diets.

Table 1. Composition of Diets (Exp. 1; As-fed Basis)[a]

	Without DDGS			With DDGS		
Item Added Fat, %:	0	3	6	0	3	6
Ingredient, %						
Corn	72.4	67.65	62.81	59.62	54.80	50.00
Soybean meal (46.5%)	25.2	26.98	28.80	23.30	25.10	27.00
DDGS	-	-	-	15.00	15.00	15.00
Choice white grease	-	3.00	6.00	-	3.00	6.00
Monocalcium P (21% P)	0.80	0.85	0.90	0.45	0.48	0.50
Limestone	0.90	0.85	0.85	0.95	0.95	0.95
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.08	0.08	0.08	0.08	0.08	0.08
Trace mineral premix	0.10	0.10	0.10	0.10	0.10	0.10
L-lysine HCl	0.15	0.15	0.15	0.15	0.15	0.15
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated values						
Total lysine, %	1.07	1.11	1.15	1.07	1.11	1.15
True ileal digestible amino acids[b]						
Lysine, %	0.95	0.99	1.03	0.93	0.97	1.00
Methionine:lysine ratio, %	0.27	0.27	0.26	0.31	0.30	0.30
Met & cys:lysine ratio, %	0.58	0.56	0.55	0.65	0.63	0.62
Threonine:lysine ratio, %	0.63	0.63	0.62	0.70	0.69	0.68
Tryptophan:lysine ratio, %	0.19	0.19	0.20	0.21	0.21	0.21
ME, kcal/lb	1,510	1,571	1,632	1,474	1,535	1,596
Calcium, %	0.60	0.59	0.61	0.57	0.58	0.59
Phosphorus, %	0.54	0.55	0.56	0.54	0.54	0.55
Available phosphorus, %	0.24	0.25	0.26	0.24	0.25	0.26
Lysine:calorie ratio, g/, mcal	3.21	3.21	3.21	3.21	3.21	3.21

[a]Diets fed in meal form from d 0 to 28.

[b]DDGS nutrient values for diet formulation derived from 1998 NRC.

Table 2. Composition of Diets (Exp. 2. Phase 1; As-fed Basis)[a]

	DDGS, %			
Item	0	10	20	30
Ingredient, %				
Corn	64.60	55.45	46.30	37.10
Soybean meal (46.5 %)	27.25	26.60	25.90	25.25
DDGS	-	10.00	20.00	30.00
Choice white grease	6.00	6.00	6.00	6.00
Monocalcium P (21% P)	0.70	0.40	0.15	-
Limestone	0.83	0.93	1.00	1.03
Salt	0.35	0.35	0.35	0.35
Vitamin premix with phytase	0.08	0.08	0.08	0.08
Trace mineral premix	0.10	0.10	0.10	0.10
L-lysine HCl	0.10	0.10	0.10	0.10
Total	100.00	100.00	100.00	100.00
Calculated values				
Total lysine, %	1.07	1.09	1.11	1.12
True ileal digestible amino acids[b]				
Lysine, %	0.95	0.95	0.95	0.95
Methionine:lysine ratio, %	0.28	0.30	0.32	0.34
Met & cys:lysine ratio, %	0.57	0.61	0.64	0.67
Threonine:lysine ratio, %	0.62	0.65	0.68	0.71
Tryptophan:lysine ratio, %	0.20	0.19	0.18	0.18
ME, kcal/lb	1,638	1,614	1,590	1,565
Calcium, %	0.55	0.55	0.55	0.55
Phosphorus, %	0.52	0.50	0.49	0.51
Available phosphorus equiv, %[c]	0.29	0.29	0.29	0.31
TID Lysine:calorie ratio, g/mcal	2.50	2.50	2.50	2.50

[a]Diets fed in meal form from d 0 to 28.

[b]DDGS nutrient values for diet formulation derived from 1998 NRC.

[c]Includes expected phytase phosphorus release from added phytase.

Table 3. Composition of Diets (Exp. 2. Phase 2; As-fed Basis)[a]

	DDGS, %			
Item	0	10	20	30
Ingredient, %				
Corn	70.70	61.50	52.35	43.10
Soybean meal (46.5%)	21.25	20.60	19.95	19.25
DDGS	-	10.00	20.00	30.00
Choice white grease	6.00	6.00	6.00	6.00
Monocalcium P (21% P)	0.60	0.35	0.10	-
Limestone	0.88	0.98	1.05	1.05
Salt	0.35	0.35	0.35	0.35
Vitamin premix with phytase	0.06	0.06	0.06	0.06
Trace mineral premix	0.08	0.08	0.08	0.08
L-lysine HCL	0.08	0.08	0.08	0.08
Total	100.00	100.00	100.00	100.00
Calculated values				
Total lysine, %	0.88	0.90	0.92	0.94
True ileal digestible amino acids[b]				
Lysine, %	0.78	0.78	0.78	0.78
Methionine:lysine ratio, %	0.30	0.33	0.35	0.38
Met & cys:lysine ratio, %	0.63	0.67	0.71	0.75
Threonine:lysine ratio, %	0.65	0.69	0.73	0.76
Tryptophan:lysine ratio, %	0.21	0.19	0.18	0.17
ME, kcal/lb	1,641	1,616	1,592	1,566
Calcium, %	0.54	0.54	0.54	0.54
Phosphorus, %	0.47	0.46	0.46	0.48
Available phosphorus equiv, %[c]	0.26	0.26	0.26	0.29
TID Lysine:calorie ratio, g/mcal	2.08	2.08	2.08	2.08

[a]Diets fed in meal form from d 28 to 56.

[b]DDGS nutrient values for diet formulation from 1998 NRC.

[c]Includes expected phytase phosphorus release from added phytase.

Table 4. Composition of Diets (Exp. 3; As-fed Basis)[a]

	DDGS, %			
Item	0	10	20	30
Ingredient, %				
Corn	67.05	59.00	50.85	42.75
Soybean meal (46.5%)	30.05	28.40	26.80	25.20
DDGS	-	10.00	20.00	30.00
Monocalcium P (21% P)	1.05	0.79	0.53	0.27
Limestone	1.00	1.00	1.00	1.00
Salt	0.35	0.35	0.35	0.35
Vitamin premix	0.15	0.15	0.15	0.15
Trace mineral premix	0.15	0.15	0.15	0.15
L-lysine HCl	0.15	0.15	0.15	0.15
DL-methoinine	0.05	0.02	-	-
L-threonine	0.02	-	-	-
Total	100.00	100.00	100.00	100.00
Calculated values				
Total lysine, %	1.20	1.22	1.24	1.26
True ileal digestible amino acids[b]				
Lysine, %	1.07	1.07	1.07	1.07
Methionine:lysine ratio, %	0.31	0.31	0.32	0.25
Met & cys:lysine ratio, %	0.60	0.63	0.67	0.74
Threonine:lysine ratio, %	0.62	0.62	0.65	0.67
Tryptophan:lysine ratio, %	0.20	0.20	0.20	0.20
ME, kcal/lb	1,505	1,522	1,538	1,555
Calcium, %	0.70	0.66	0.62	0.59
Phosphorus, %	0.62	0.60	0.59	0.58
Available phosphorus, %	0.29	0.29	0.29	0.29
TID Lysine:calorie ratio, g/mcal	3.02	3.02	3.02	3.02

[a]Diets fed in meal form from d 0 to 21.

[b]DDGS nutrient values for diet formulation from H.H. Stein, C. Pederson, and M.G. Boersma. 2005. Energy and nutrient digestibility in dried distillers grain with solubles by growing pigs. *Journal of Animal Science* 83 (Suppl. 2): p. 79 (Abstr. 199).

Table 5. Effects of DDGS with Added Fat on Finishing Pig Performance (Exp. 1)[a]

	Without DDGS			With DDGS				Probability, P<			
										Added Fat	
Item Added Fat, %:	0	3	6	0	3	6	SE	DDGS × Fat	DDGS	Level	Linear
D 0 to 28											
ADG, lb	1.98	2.12	2.12	2.02	2.03	2.17	0.041	0.20	0.99	0.01	0.01
ADFI, lb	4.68	4.76	4.68	4.79	4.66	4.72	0.081	0.43	0.79	0.92	0.68
F/G	2.37	2.25	2.21	2.38	2.30	2.18	0.038	0.57	0.92	0.01	0.01

[a]A total of 1,050 pigs initially 104.9 lb were used in this study, with 7 replications per treatment.

Table 6. Effects of Increasing Percentages of DDGS on Grower Pig Performance (Exp. 2)[a]

Item	DDGS, %				Probability, P <			SE
	0	10	20	30	Treatment	Linear	Quadratic	
D 0 to 28								
ADG, lb	1.75	1.76	1.74	1.72	0.77	0.40	0.59	0.040
ADFI, lb	3.66	3.68	3.52	3.47	0.03	0.01	0.49	0.076
F/G	2.10	2.09	2.03	2.02	0.02	0.01	0.99	0.028
D 28 to 56								
ADG, lb	1.99	2.02	1.93	1.96	0.14	0.14	0.96	0.036
ADFI, lb	4.91	5.02	4.91	4.90	0.40	0.62	0.31	0.084
F/G	2.47	2.49	2.54	2.50	0.21	0.14	0.22	0.032
D 0 to 56								
ADG, lb	1.87	1.89	1.83	1.84	0.17	0.10	0.68	0.026
ADFI, lb	4.28	4.35	4.21	4.18	0.10	0.06	0.35	0.069
F/G	2.29	2.30	2.29	2.28	0.71	0.42	0.40	0.023
Total Removals	3	10	9	8				

[a]A total of 1,038 growing pigs, initially 102.1 lb, were used in this study, with 10 replications per treatment.

Table 7. Effects of Increasing Dried Distiller Grains with Solubles on Feed Intake (Exp. 3)[a]

ADFI	Control	DDGS, %			Probability, P<			SED
		10	20	30	Trt	Linear	Quadratic	
D 0 to 7	1.01[b]	0.69[c]	0.49[d]	0.58[cd]	0.01	0.01	0.01	0.057
D 7 to 21	1.33[b]	0.86[c]	0.45[e]	0.53[d]	0.01	0.01	0.01	0.062
D 0 to 21	1.22[b]	0.80[c]	0.46[d]	0.55[d]	0.01	0.01	0.01	0.044

[a]A total of 120 pigs, initially 48.7 lb, were used in this study, with 8 replications per treatment. Pigs given the choice of one of four diets in the same pen; corn-soybean meal control or control with DDGS replacing corn.

[bcde]Means within a row with different subscripts differ (P<0.05).

INFLUENCE OF NUTRIDENSE LOW PHYTATE[1] CORN AND ADDED FAT ON GROWING-FINISHING PIG GROWTH PERFORMANCE

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Summary

Two studies were conducted to evaluate the effect of NutriDense Low Phytate corn in conjunction with increasing amounts of added fat on growing and finishing pig performance. NutriDense Low Phytate corn is similar to NutriDense corn, but with greater available phosphorus content because it has less phytate phosphorus. Both experiments were conducted at a commercial swine research facility in southwest Minnesota. In Exp. 1, 1,162 gilts (initially 98.3 lb) were used in a 28-d study. Pigs were blocked by weight, and were randomly allotted to one of six dietary treatments. Pigs were fed diets based on corn-soybean meal with yellow dent (YD) or NutriDense Low Phytate corn and 0, 3, or 6% added fat, in a 2 × 3 factorial arrangement. A constant true ileal digestible (TID) lysine:energy ratio of 2.80 g TID lysine:Mcal ME was maintained in all diets, as well a constant available P:energy ratio of 0.90 g/Mcal. Overall (d 0 to 28), there were no corn source × fat content interactions (P>0.79). Regardless of corn source, ADG and F/G improved linearly (P<0.03, and P<0.01, respectively) as the amount of fat increased in the diet. There were no differences in growth performance between pigs fed diets containing NutriDense Low Phytate and those fed YD corn.

In Exp. 2, a total of 1,128 gilts (initially 180.0 lb) were used in a 28-d growth assay. Pigs were blocked, and were randomly allotted to one of six dietary treatments. Pigs were fed similarly to those in Exp. 1, with diets based on corn-soybean meal, using either NutriDense Low Phytate or YD corn and 0, 3, or 6% added fat. A constant TID lysine:energy ratio of 2.15 g/Mcal ME was maintained in all diets, as well as a constant available P:energy ratio of 0.75 g/Mcal. Overall (d 0 to 28), there was a tendency for a corn source × fat content interaction for F/G (P<0.07), which was a result of pigs fed YD corn having improved F/G only at 6% added fat, whereas improvements were seen in pigs fed NutriDense Low Phytate at both 3 and 6% added fat. Also, there was an improvement in ADG (linear P<0.01) and F/G (linear, P<0.01) as the amount of fat increased in the diet, regardless of corn source. There was no difference in growth performance between pigs fed diets containing NutriDense Low Phytate and those fed YD corn.

These studies indicate that increasing amounts of added fat improved growth performance, regardless of corn source. Pig growth performance is similar for pigs fed NutriDense Low Phytate corn and fed YD corn, although NutriDense Low Phytate corn does

[1]Appreciation is expressed to ExSeed Genetics, a division of BASF Plant Science, for providing the NutriDense LP corn and sponsorship of the trial. NutriDense LP is a registered trademark of BASF Plant Science L.L.C.

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have the advantage of having higher amino acid concentrations and less phytate phosphorus.

(Key Words: Pigs, Yellow Dent Corn, NutriDense Low Phytate Corn.)

Introduction

NutriDense corn is a nutritionally enhanced product containing a stacked set of traits to provide greater nutrient density than conventional yellow dent corn. Although not higher in tryptophan, NutriDense Low Phytate corn does also have high amounts of amino acids, including 19% more lysine, 5% more sulfur amino acids, 6% more threonine, and 5% more energy than normal corn. Previous trials with nursery, growing and finishing pigs at Kansas State University indicated that the energy value of NutriDense corn was approximately 5% greater than the energy density of YD corn. In these trials, F/G was improved linearly through the highest energy content (6% fat added to a diet containing NutriDense corn). NutriDense Low Phytate corn is similar to NutriDense corn, but with greater available phosphorus content due to less phytate content (Table 1). Research from the University of Illinois suggested that the energy value of NutriDense Low Phytate corn was less than the energy of NutriDense corn, but higher than YD corn. Few growth trials have been conducted on the feeding value of NutriDense Low Phytate corn. Thus, the objective of these trials was to determine the value of NutriDense Low Phytate corn, compared with YD corn, in growing and finishing pigs.

Procedures

General. Procedures used in these experiments were approved by the Kansas State University Animal Care and Use Committee. Both trials were conducted at a commercial research facility in southwest Minnesota. The facility had a totally slatted floor, with approximately 7.2 ft^2 provided per pig. Each pen was equipped with a four-hole dry self feeder and one cup waterer. The facility was a double curtain-sided, deep-pit barn that operated on mechanical ventilation during the summer and on automatic ventilation during the winter. Experiments 1 and 2 were run in fall and winter, respectively. Pigs were randomly allotted and blocked to one of six dietary treatments with seven pens per treatment. Pigs and feeders were weighed on d 0, 14, and 28 to determine the response criteria of ADG, ADFI, and F/G.

Table 1. Nutrient Composition of Corn Sources (As-fed Basis)

		NutriDense Low Phytate Corn[b]	
Item	YD Corn[a]	Calculated	Analyzed
Lysine, %	0.26	0.32	0.32
Isoleucine, %	0.28	0.41	0.36
Leucine, %	0.99	1.35	1.25
Methionine, %	0.17	0.21	0.18
Met & Cys, %	0.36	0.43	0.38
Threonine, %	0.29	0.34	0.31
Tryptophan, %	0.06	0.08	0.06
Valine, %	0.39	0.55	0.49
ME, kcal/kg	3,420	3,591	3,591
CP, %	8.5	10.00	9.65
Ca, %	0.03	0.03	0.03
P, %	0.28	0.32	0.30
Available P, %	0.04	0.16[c]	0.15[c]

[a]Yellow dent corn values are from NRC (1998).

[b]Calculated and analyzed values of NutriDense Low Phytate corn courtesy of BASF. The calculated values were used in diet formulation.

[c]Availability of the P in NutriDense Low Phytate corn was assumed to be 50%.

Experiment 1. A total of 1,162 gilts (BW of 98.3 lb) were used in a 28-d growth assay. Each pen contained 25 to 28 pigs. Experimental diets (Table 2) were fed in meal form. The 6 dietary treatments were arranged in a 2 × 3 factorial, with diets based on YD or NutriDense Low Phytate corn containing 0, 3, or 6% added fat. A constant TID lysine:energy

ratio of 2.80 g/Mcal ME was maintained in all diets. The available P:energy ratio was 0.90 g/Mcal in all diets.

Experiment 2. A total of 1,128 gilts (BW of 180 lb) were used in a 28-d growth assay. There were also 6 experimental dietary treatments, with 7 pens/treatment and 25 to 29 pigs per pen. Similar to those in Exp. 1, dietary treatments included diets based on corn-soybean meal, with YD or NutriDense Low Phytate corn and 0, 3, or 6% added fat (Table 3). A constant TID lysine:energy ratio of 2.15 g/Mcal ME was maintained in all diets. The available P:energy ratio was 0.75 g/Mcal for all diets.

Statistical Analysis. Data were analyzed as a randomized complete-block design by using the PROC MIXED procedure of SAS, with pen as the experimental unit in both experiments. Tests for interactions between corn source and lysine concentrations were performed. Contrasts were used to determine the effect of corn source and fat addition, and linear and quadratic polynomial contrasts were used to determine the effects of increasing added fat.

Results and Discussion

The analyzed amino acid and mineral concentrations for NutriDense Low Phytate were similar to the calculated values used in diet formulation. The crude protein content and content of a few amino acids were slightly less in the analyzed values, but none of the differences were large enough to impact the experimental results.

Experiment 1. Overall (d 0 to 28), there were no corn source × fat content interactions (Table 4, $P>0.79$). Regardless of corn source, ADG increased (linear, $P<0.03$) and F/G improved (linear, $P<0.01$) as the content of fat increased in the diet (Table 5). There were no differences in pig growth performance between NutriDense Low Phytate and YD corn.

Experiment 2. Overall (d 0 to 28), there was a tendency for a corn source × fat content interaction ($P<0.07$, Table 6) for F/G. For pigs fed YD corn, F/G was only improved when 6% fat was added to the diet, whereas a linear improvement was found with increasing fat content for pigs fed NutriDense Low Phytate corn. Main effects indicated a linear improvement in ADG ($P<0.01$) and F/G ($P<0.01$) as the amount of fat increased in the diet (Table 7). There was no difference in growth performance between pigs fed NutriDense Low Phytate and those fed YD corn.

Results were similar to those in previous trials at Kansas State University; increasing the energy content of the diet by adding fat increased ADG and improved F/G in these experiments. These studies indicate that increasing amounts of added fat improved growth performance, regardless of corn source. Pig growth performance was similar for pigs fed NutriDense Low Phytate corn and those fed YD corn, although NutriDense Low Phytate does have added environmental advantages because of the low phytate phosphorus concentrations. This was evident because NutriDense Low Phytate corn diets required 37 to 63% less phosphorus supplementation, compared with the YD corn diets. The analyzed NutriDense Low Phytate corn had less methionine, cystine, threonine, tryptophan, and phosphorus than the calculated values of NutriDense Low Phytate corn. Because the higher amino acid and available P concentrations in NutriDense Low Phytate corn were accounted for in diet formulation, similar growth performance between pigs fed NutriDense Low Phytate and YD corn indicates that the formulation values for these nutrients in NutriDense Low Phytate corn are appropriate.

Table 2. Composition of Diets (Exp. 1; As-fed Basis)[a]

	Corn Source	Yellow Dent			NutriDense Low Phytate		
Item	Added Fat, %	0	3	6	0	3	6
Ingredient, %							
Corn		71.60	66.82	62.04	-	-	-
NutriDense Low Phytate		-	-	-	71.80	67.00	62.20
Soybean meal, (46.5%)		26.14	27.87	29.60	26.25	27.97	29.70
Choice white grease		-	3.00	6.00	-	3.00	6.00
Monocalcium phosphate, (21% P)		0.73	0.78	0.83	0.37	0.45	0.52
Limestone		0.90	0.90	0.90	0.95	0.95	0.95
Salt		0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix		0.08	0.08	0.08	0.08	0.08	0.08
Trace mineral premix		0.10	0.10	0.10	0.10	0.10	0.10
L- lysine HCL		0.10	0.10	0.10	0.10	0.10	0.10
Total		100	100	100	100	100	100
Calculated Values							
Total lysine, %		1.05	1.09	1.13	1.10	1.14	1.17
True ileal digestible amino acids							
Lysine, %		0.93	0.97	1.01	0.97	1.01	1.04
Lysine:ME ratio, g/Mcal		2.80	2.80	2.80	2.80	2.80	2.80
Methionine:lysine ratio, %		29	28	27	30	30	29
Met & cys:lysine ratio, %		59	58	56	62	60	58
Threonine:lysine ratio, %		63	63	62	64	63	63
Tryptophan:lysine ratio, %		20	20	20	21	21	21
ME, kcal/lb		1,514	1,574	1,635	1,574	1,630	1,687
Calcium, %		0.59	0.60	0.61	0.54	0.56	0.58
Phosphorus, %		0.53	0.54	0.55	0.49	0.50	0.51
Available phosphorus, %		0.22	0.23	0.25	0.23	0.25	0.26
Avail P:calorie ratio, g/mcal		0.90	0.90	0.90	0.90	0.90	0.90

[a]Diets fed in meal form from d 0 to 28.

Table 3. Composition of Diets (Exp. 2. as-fed Basis)[a]

	Corn Source	Yellow Dent			NutriDense Low Phytate		
Item	Added Fat, %	0	3	6	0	3	6
Ingredient, %							
Corn		80.34	75.89	71.46	-	-	-
NutriDense® Low Phytate		-	-	-	80.95	76.45	72.00
Soybean meal, (46.5%)		17.58	18.98	20.36	17.33	18.76	20.14
Choice white grease		-	3.00	6.00	-	3.00	6.00
Monocalcium phosphate, (21% P)		0.65	0.70	0.75	0.24	0.31	0.38
Limestone		0.85	0.85	0.85	0.90	0.90	0.90
Salt		0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix		0.05	0.05	0.05	0.05	0.05	0.05
Trace mineral premix		0.08	0.08	0.08	0.08	0.08	0.08
L- lysine HCL		0.10	0.10	0.10	0.10	0.10	0.10
Total		100	100	100	100	100	100
Calculated Values							
Total lysine, %		0.82	0.85	0.88	0.86	0.89	0.92
True ileal digestible amino acids							
Lysine, %		0.72	0.75	0.78	0.75	0.78	0.81
Lysine:ME ratio, g/Mcal		2.15	2.15	2.15	2.15	2.15	2.15
Methionine:lysine ratio, %		32	33	30	34	33	32
Met & cys:lysine ratio, %		66	66	62	70	67	65
Threonine:lysine ratio, %		66	64	64	67	66	65
Tryptophan:lysine ratio, %		20	19	20	21	21	21
ME, kcal/lb		1,518	1,579	1,639	1,586	1,643	1,700
Calcium, %		0.53	0.54	0.55	0.47	0.49	0.50
Phosphorus, %		0.48	0.49	0.50	0.43	0.44	0.45
Available phosphorus, %		0.20	0.21	0.22	0.21	0.22	0.23
Avail P:calorie ratio, g/mcal		0.75	0.75	0.75	0.75	0.75	0.75

[a]Diets fed in meal form from d 0 to 28.

Table 4. Means of Corn Source and Added Fat on Growth Performance (Exp. 1)[a]

Corn Source:	Yellow Dent			NutriDense Low Phytate				Probability, P <
Item; Added Fat, %	0	3	6	0	3	6	SE	Source × Fat %
D 0 to 28								
ADG, lb	1.87	1.92	1.98	1.89	1.93	2.00	0.047	0.97
ADFI, lb	4.14	4.12	4.08	4.30	4.13	4.15	0.108	0.79
F/G	2.23	2.14	2.06	2.27	2.14	2.08	0.033	0.86

[a]A total of 1,162 gilts (initially 98.3 lb), with 25 to 28 pigs per pen and 7 replications per treatment.

Table 5. Main Effects of Corn Source and Added Fat on Growth Performance (Exp. 1)[a]

								Probability, P <			
	Corn Source			Added Fat (%)						Fat %	
Item	YD[b]	NDLP[c]	SE	0	3	6	SE	Corn Source	Fat %	Linear	Quadratic
D 0 to 28											
ADG, lb	1.92	1.94	0.029	1.88	1.92	1.99	0.034	0.59	0.08	0.03	0.75
ADFI, lb	4.11	4.19	0.074	4.22	4.12	4.11	0.084	0.34	0.53	0.30	0.61
F/G	2.14	2.16	0.020	2.25	2.14	2.07	0.024	0.49	0.01	0.01	0.58

[a]A total of 1,162 gilts (initially 98.3 lb), with 25 to 28 pigs per pen and 7 replications per treatment.

[b]Yellow dent corn.

[c]NutriDense Low Phytate corn.

Table 6. Means of Corn Source and Added Fat on Growth Performance (Exp. 2)[a]

	Corn Source:	YD[b]			NutriDense Low Phytate				Probability, P <
Item;	Added Fat, %	0	3	6	0	3	6	SE	Source × Fat %
D 0 to 28									
ADG, lb		1.91	1.83	2.02	1.76	1.90	2.00	0.057	0.12
ADFI, lb		5.97	5.67	5.66	5.57	5.49	5.62	0.183	0.62
F/G		3.12	3.12	2.79	3.17	2.90	2.81	0.062	0.07

[a]A total of 1,128 gilts (initially 180.0), with 25 to 28 pigs per pen and 42 pens, provided 7 replications per treatment.

[b]Yellow dent corn.

Table 7. Main Effects of Corn Source and Added Fat on Growth Performance (Exp. 2)[a]

								Probability, P <			
	Corn Source			Added Fat (%)						Fat %	
Item	YD[b]	NDLP[c]	SE	0	3	6	SE	Corn Source	Fat %	Linear	Quadratic
D 0 to 28											
ADG, lb	1.92	1.89	0.033	1.83	1.86	2.01	0.040	0.50	0.01	0.01	0.22
ADFI, lb	5.77	5.56	0.106	5.77	5.58	5.64	0.130	0.18	0.58	0.49	0.44
F/G	3.01	2.96	0.036	3.15	3.01	2.80	0.043	0.33	0.01	0.01	0.49

[a]A total of 1,128 gilts (initially 180.0 lb), with 25 to 28 pigs per pen, and 42 pens provided 7 replications per treatment.

[b]Yellow dent corn.

[c]NutriDense Low Phytate corn.

EFFECTS OF REPLACING CORN WITH TRITICALE IN DIETS FOR NURSERY AND FINISHING PIGS

C. R. Monge, J. D. Hancock, T. L. Gugle, and C. Feoli

Summary

Two experiments were conducted to determine the effects of replacing corn (none, 1/3, 2/3, and all) with triticale on growth performance and nutrient digestibility in pigs. For the 34-d nursery experiment, 168 weanling pigs (avg initial weight of 14.8 lb and avg initial age of 21 d) were used. On d 24, fecal samples were collected to allow determination of nutrient digestibility. Overall, pigs consuming diets with 1/3 of the corn replaced with triticale improved ADG (cubic effect, $P<0.08$) and F/G (linear effect, $P<0.01$). Digestibility of DM, N, and GE were not affected ($P>0.18$). For the finishing experiment, 184 pigs (avg initial weight of 131 lb) were used, and fecal samples were collected on d 46. Overall, ADG (linear effect, $P<0.02$) and ADFI (linear effect, $P<0.06$) were decreased by 6% as replacement of corn with triticale was increased from none to 100%. But F/G and digestibility of nutrients were not affected ($P>0.16$), and the negative effects on ADG and ADFI were evident only at 2/3 replacement and replacement of all corn with triticale. In conclusion, replacing corn with triticale improved growth performance in nursery pigs, but reduced ADFI and, thus, ADG in finishing pigs, when more than 1/3 of the corn was replaced.

(Key Words: Triticale, Nursery Pigs, Finishing Pigs.)

Introduction

Triticale is a hybrid of wheat and rye that combines the protein and starch quality characteristics of wheat with the tolerance for harsh climates provided by rye. Resistance of triticale to drought is especially important because rainfall is limited in much of the world, and there is renewed interest in production of triticale in western Kansas. Thus, the objective of the experiments was to determine the effects of replacing corn with triticale on growth performance and nutrient digestibility in nursery and finishing pigs.

Procedures

Two experiments were conducted to determine the effects of replacing corn with triticale. In the first experiment, 168 weanling pigs (avg initial weight of 14.8 lb) were used in a 34-d growth assay. The pigs were sorted by sex and ancestry, blocked by weight, and allotted with 6 pigs per pen and 7 pens per treatment. The pigs were housed in an environmentally controlled nursery having 4 ft x 4 ft pens with woven-wire flooring. Each pen had a self feeder and nipple waterer so that feed and water could be consumed *ad libitum*. The control diet (Table 1) was based on corn-soybean meal and formulated to 1.8%, 1.6%, and 1.4% lysine for d 0 to 6, 6 to 20, and 20 to 34, respectively. Treatments were triticale added to the diet to replace none, 1/3, 2/3, and all of the corn.

For the last phase of the experiment (i.e., d 20 to 34), 0.25% chromic oxide was added to the diets as an indigestible marker. Feed and fecal samples were collected on d 24 of the growth assay and analyzed for DM, N, GE, and Cr to allow calculation of nutrient digestibility.

For the finishing experiment, 184 pigs (avg initial weight of 131 lb) were used in a 59-d growth assay. The pigs were sorted by sex and ancestry, blocked by weight, and allotted with 2 pens of 11 barrows and 2 pens of 12 gilts per treatment. The pigs were housed in a modified open-front facility having 6 ft x 16 ft pens with half slatted and half solid concrete floorings. Each pen had a self feeder and nipple waterer to allow *ad libitum* consumption of feed and water. The control diet (Table 2) was based on corn-soybean meal and formulated to 1.1% and 0.80% lysine for d 0 to 40 and 40 to 59, respectively. Treatments were triticale added to the diet to replace none, 1/3, 2/3, and all of the corn. Feed and fecal samples were collected on d 46 of the experiment and, as in the nursery experiment, analyzed for DM, N, GE, and Cr to allow calculation of nutrient digestibility.

All data were analyzed as randomized complete block designs by using the PROC MIXED procedure of SAS. Shape of the response to added triticale (linear, quadratic, and cubic) was determined with polynomial regression.

Results and Discussion

In nursery pigs, growth performance (ADG, ADFI, F/G) was not influenced ($P>0.28$) by replacing corn with triticale during d 0 to 6 (Table 3). For d 0 to 20 and d 0 to 34, however, pigs consuming diets with 1/3 of the corn replaced by triticale gained more weight (cubic effects, $P<0.02$ and $P<0.08$, respectively). Also, for d 0 to 34, there was a linear improvement ($P<0.01$) in F/G as triticale was used to replace corn.

From d 0 to 40 of the finishing experiment, triticale additions to the diets did not affect ($P>0.12$) ADG or ADFI (Table 4), but F/G was improved when triticale was used to replace 1/3 of the corn (quadratic effect, $P<0.05$). Overall (d 0 to 59), pigs tended to eat less (linear effect, $P<0.06$) and had reduced ADG (linear effect, $P<0.02$) as concentration of triticale was increased in the diet. But these effects were evident only when triticale was used to replace more than 1/3 of the corn.

In conclusion, our data suggested that replacing corn with triticale improved growth performance of nursery pigs, and had little effect on finishing pigs unless more than 1/3 of the corn was replaced. Thus, when the nursery and finishing are considered together, replacing a portion of the corn with triticale can be used to decrease diet costs and cost of gain when the price of triticale, relative to corn, warrants this type of substitution.

Table 1. Composition of Nursery Diets[a]

Ingredient, %	d 0 to 6	d 6 to 20	d 20 to 34
Corn [b]	26.50	40.42	61.18
Soybean meal (46.5% CP)	28.50	30.50	33.50
Dried whey	20.00	20.00	-
Lactose	10.00	-	-
Soy oil	2.00	1.00	1.00
Spray-dried plasma protein	6.00	-	-
Fish meal	3.00	5.00	-
Monocalcium phosphate	0.91	0.40	1.30
Limestone	0.91	0.56	1.20
Lysine-HCL	0.19	0.22	0.32
DL-methionine	0.23	0.17	0.15
Threonine	0.07	0.08	0.12
Salt	0.20	0.30	0.40
Vitamins	0.25	0.25	0.25
Minerals	0.15	0.15	0.15
Antibiotic [c]	0.70	0.70	0.10
Zinc oxide	0.39	0.25	-
Copper sulfate	-	-	0.08
Chromic oxide[d]	-	-	0.25

[a]Diets were formulated to 1.8% lysine, 0.9% Ca, and 0.8% P for d 0 to 6; 1.6% lysine, 0.8% Ca, and 0.7% P for d 6 to 20; and 1.4% lysine, 0.8% Ca, and 0.7% P for d 20 to 34.
[b]Triticale was use to replace none, 1/3, 2/3, and all of the corn on a lb/lb basis.
[c]To supply 140 g/ton oxytetracycline and 98 g/ton neomycin for d 0 to 6 and 6 to 20, and 40 g/ton of lincomycin for d 20 to 34.
[d]Indigestible marker top-dressed as 0.25% of the complete diet.

Table 2. Composition of Finishing Diets[a]

Ingredient, %	d 0 to 40	d 40 to 59
Corn[b]	70.07	81.28
Soybean meal (46.5% CP)	26.00	15.00
Soy oil	1.00	1.00
Monocalcium phosphate	0.82	0.82
Limestone	1.10	1.08
Lysine-HCL	0.19	0.18
DL-methionine	0.04	-
Threonine	0.08	0.03
Salt	0.35	0.30
Vitamins	0.15	0.13
Minerals	0.15	0.13
Antibiotic[c]	0.05	0.05
Chromic oxide[d]	-	0.25

[a]Diets were formulated to 1.1% lysine, 0.65% Ca, and 0.55% P for d 0 to 40, and 0.8% lysine, 0.6% Ca, and 0.5% P for d 40 to 59.
[b]Triticale was used to replace none, 1/3, 2/3, and all of the corn on a lb/lb basis.
[c]To supply 40 g/ton of tylosin.
[d]Indigestible marker top-dressed as 0.25% of the complete diet.

Table 3. Effects of Replacing Corn with Triticale on Growth Performance and Nutrient Digestibility in Nursery Pigs[a]

	Triticale					P Value		
Item	None	1/3	2/3	All	SE	Linear	Quadratic	Cubic
d 0 to 6								
ADG, lb	0.72	0.70	0.63	0.70	0.03	-	-	-
ADFI, lb	0.59	0.58	0.52	0.58	0.04	-	-	-
F/G	0.82	0.83	0.83	0.83	0.04	-	-	-
d 0 to 20								
ADG, lb	0.92	0.98	0.91	0.92	0.02	-	-	0.02
ADFI, lb	1.07	1.08	1.02	1.04	0.03	-	-	-
F/G	1.16	1.10	1.12	1.13	0.02	-	0. 10	-
d 0 to 34								
ADG, lb	1.16	1.22	1.18	1.21	0.02	-	-	0.08
ADFI, lb	1.56	1.60	1.53	1.56	0.03	-	-	0.15
F/G	1.34	1.31	1.30	1.29	0.01	0.01	-	-
Nutrient dig (d 24), %								
DM	82.2	82.5	83.3	82.9	0.9	-	-	-
GE	82.2	82.2	82.7	82.4	1.4	-	-	-
N	77.9	76.7	79.3	77.3	1.3	-	-	-

[a]A total of 168 pigs (initial weight of 14.8 lb), with 6 pigs per pen and 7 pens per treatment.

Table 4. Effects of Replacing Corn with Triticale on Growth Performance and Nutrient Digestibility in Finishing Pigs[a]

	Triticale					P Value		
Item	None	1/3	2/3	All	SE	Linear	Quadratic	Cubic
d 0 to 40								
ADG, lb	2.36	2.33	2.27	2.29	0.05	0.14	-	-
ADFI, lb	6.24	6.38	6.05	5.94	0.29	0.12	-	-
F/G	2.64	2.74	2.67	2.59	0.08	-	0.05	-
d 0 to 59								
ADG, lb	2.38	2.37	2.24	2.27	0.04	0.02	-	-
ADFI, lb	6.67	6.81	6.44	6.30	0.30	0.06	-	-
F/G	2.80	2.87	2.87	2.77	0.10	-	-	-
Nutrient dig (d 46), %								
DM	84.3	81.4	82.2	82.0	1.3	-	-	-
GE	84.3	82.1	82.0	82.2	1.2	-	-	-
N	79.4	76.0	77. 8	77.5	2.0	-	-	-

[a]A total of 184 pigs (initial weight of 131 lb), with 2 pens of 11 barrows and 2 pens of 12 gilts per treatment.

EFFECTS OF XYLANASE AND WHEAT MIDDLINGS IN DIETS FOR FINISHING PIGS

C. Feoli, J. D. Hancock, C. R. Monge, C. L. Jones, and C. W. Starkey

Summary

A total of 312 finishing pigs (average initial weight of 142 lb) were used in a 62-d experiment to determine the effects of xylanase and wheat middlings on growth performance, nutrient digestibility, and carcass characteristics. Treatments were a control diet based on corn-soybean meal, without and with 750 g/ton xylanase product (to supply none and 1,050 units of xylanase activity per lb of diet), and wheat middlings (none, 15%, and 30%) arranged as a 2 × 3 factorial. The pigs were sorted by sex and ancestry and blocked by weight, with 13 pigs/pen and 4 pens/treatment. Feed and water were provided on an *ad libitum* basis until the pigs were killed (average weight of 266 lb) at a commercial slaughter facility. Overall, there were no interactions among xylanase addition and concentration of wheat middlings in the diet for ADG, ADFI, F/G, dressing percentage, last-rib backfat thickness, or percentage carcass lean (P>0.26). For main effects, addition of xylanase did not change growth performance or carcass measurements (P>0.16), but, as concentration of wheat middlings was increased from none to 30%, there were linear decreases in overall ADG (P<0.003); efficiency of gain (P<0.002); hot carcass weight (P<0.001); dressing percentage (P<0.002); and digestibility of DM (P<0.001), N (P<0.04), and GE (P<0.001). Last-rib backfat thickness (P<0.06) decreased and percentage carcass lean increased (P<0.03) as wheat middlings concentration in the diet was increased from none to 30%. But these improvements in carcass leanness resulted from the light carcasses for pigs fed wheat middlings, and disappeared when hot carcass weight was used as a covariate (P>0.12). In conclusion, increasing the concentration of wheat middlings, in diets from none to 30% reduced growth performance and nutrient digestibility in finishing pigs. Addition of xylanase did not prevent these negative effects.

(Key Words: Finishing Pig, Wheat Middlings, Xylanase.)

Introduction

Worldwide, there is more land committed to production of wheat than to any other cereal crop. Kansas is the leading state in production and processing of wheat for human consumption, and co-products of the milling industry are easily available in the area. According to the American Association of Feed Control Officials, wheat middlings are “fine particles of wheat bran, wheat shorts, wheat germ, wheat flour, and some of the offal from the tail of the mill”. Wheat has arabinoxylans (complex and difficult to digest carbohydrates) in its bran and seed coat and, unfortunately, these compounds are concentrated in middlings. Thus, wheat middlings often can be used to reduce diet costs, but their high fiber and arabinoxylan content will reduce nutrient density, and possibly the digestibility of nutrients. Therefore, the objective of the experiment was to determine the effects of a xylanase enzyme (added to help digest the arabinoxylans in wheat middlings) on growth performance, nu-

trient digestibility, and carcass characteristics in finishing pigs.

Procedures

A total of 312 finishing pigs (initial weight of 142 lb) were used in a 62-d growth assay. The pigs were sorted by sex and ancestry, blocked by weight, and assigned to pens. There were 13 pigs/pen and 4 pens/treatment. The experimental diets were fed in two phases and formulated to 1.2% lysine, 0.65% Ca, and 0.25% available P for d 0 to 30, and 0.9% lysine, 0.60% Ca, and 0.22% available P for d 30 to 62 (Table 1). Treatments were a diet based on corn-soybean meal, without and with xylanase product (added as 750 g/ton of Safizym® XP 500 to supply 1,051 units of xylanase activity per lb of diet) and wheat middlings (none, 15%, and 30%).

Pigs and feeders were weighed on d 0, 30, and 62 to allow calculation of ADG, ADFI, and F/G. Approximately mid-experiment, 0.25% chromium oxide was added to the diets as an indigestibility marker, and fecal samples were collected (d 35). Concentrations of DM, N, GE, and Cr in the diets and feces were determined to allow calculation of apparent digestibilities. Feed and water were provided on an *ad libitum* basis until the pigs were killed on d 62 (average weight of 266 lb). The carcass data that were collected included hot carcass weight, last-rib backfat thickness, dressing percentage, and percentage carcass lean. All data were analyzed as a 2 × 3 factorial, with main effects of xylanase addition and amount of wheat middlings in the diet.

Results and Discussion

For d 0 to 30, there were no interactions ($P>0.28$) among xylanase addition and concentration of wheat middlings in the diet for ADG, ADFI, or F/G (Table 2). For main effects, addition of xylanase did not affect growth performance, but as wheat middlings concentration in the diet was increased from none to 30%, there were linear decreases in rate ($P<0.02$) and efficiency ($P<0.08$) of gain. Overall, pigs fed diets with increasing concentrations of wheat middlings had lower ADG and poorer F/G (linear effects at $P<0.003$ and 0.002, respectively). Apparent digestibility of DM, N, and GE decreased by 10% (linear effect, $P<0.001$), 6% (linear effect, $P<0.04$), and 10% (linear effect, $P<0.001$), respectively, as wheat middlings in the diet increased.

For carcass characteristics, as concentration of wheat middlings was increased in the diet, last-rib backfat thickness decreased ($P<0.06$) and percentage carcass lean increased ($P<0.03$). But hot carcass weight was 10 lb less (linear effect, $P<0.001$) for pigs fed 30% wheat middlings, compared with weight of pigs fed the control diet. When hot carcass weight was used as a covariate in statistical analyses, the advantages in carcass leanness with addition of wheat middlings disappeared ($P>0.12$).

In conclusion, increasing the concentration of wheat middlings in diets for finishing pigs reduced rate and efficiency of gain and apparent digestibility of DM, N, and GE. Addition of xylanase did not prevent these effects.

Table 1. Composition of Diets

	Day 0 to 30[b]			Day 30 to 62[b]		
Ingredient, %	0% Midds	15% Midds	30% Midds	0% Midds	15% Midds	30% Midds
Corn	67.17	55.87	44.60	76.36	65.09	53.75
Soybean meal	27.70	24.01	20.32	18.87	15.18	11.56
Wheat middlings	-	15.00	30.00	--	15.00	30.00
Soy oil	2.00	2.00	2.00	2.00	2.00	2.00
Limestone	1.10	1.20	1.30	1.08	1.17	1.27
Monocalcium phosphate	0.84	0.62	0.40	0.76	0.54	0.32
Salt	0.35	0.35	0.35	0.30	0.30	0.30
Lysine HCl	0.27	0.34	0.40	0.19	0.26	0.32
Threonine	0.08	0.11	0.13	0.06	0.08	0.10
Methionine	0.06	0.07	0.07	-	-	-
KSU vitamin premix	0.20	0.20	0.20	0.15	0.15	0.15
KSU mineral premix	0.10	0.10	0.10	0.10	0.10	0.10
Antibiotic [a]	0.13	0.13	0.13	0.13	0.13	0.13
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis						
Lysine, %	1.20	1.20	1.20	0.90	0.90	0.90
Met:lys ratio, %	30	30	30	28	27	27
Met & Cys:lys ratio, %	57	57	57	59	59	58
Threonine:lys ratio, %	64	64	64	68	68	68
Tryptophan:lys ratio, %	18	18	18	18	18	18
ME, Kcal/lb	3393	3340	3286	3412	3359	3306
Calcium, %	0.65	0.65	0.65	0.60	0.60	0.60
Phosphorus, %	0.55	0.59	0.62	0.50	0.54	0.57
Available phosphorus, %	0.25	0.25	0.25	0.22	0.22	0.22
Sodium, %	0.16	0.16	0.17	0.14	0.14	0.15
Chloride, %	0.25	0.25	0.25	0.22	0.22	0.22

[a]To provide 100 g/ton of tylosin.
[b]For the enzyme additions, Safizym® XP 500 was added (750 g/ton) to provide 1,051 units of xylanase activity per lb of diet.

Table 2. Effects of Xylanase and Wheat Middlings in Diets for Finishing Pigs[a]

Item	Without Xylanase			With Xylanase			SE	P value				
	0% Midds	15% Midds	30% Midds	0% Midds	15% Midds	30% Midds		Xylanase (1)	Midds Lin (2)	Midds Quad (3)	1 × 2	1 × 3
d 0 to 30												
ADG, lb	2.18	2.16	2.03	2.18	2.12	2.05	0.12	-	0.02	-	-	-
ADFI, lb	6.04	6.12	5.86	6.10	6.04	5.98	0.27	-	0.14	-	-	-
F/G	2.77	2.83	2.89	2.80	2.85	2.92	0.15	-	0.09	-	-	-
d 0 to 62												
ADG, lb	2.08	2.02	1.95	2.09	2.02	1.97	0.08	-	0.003	-	-	-
ADFI, lb	6.31	6.53	6.41	6.53	6.52	6.63	0.30	-	-	-	-	-
F/G	3.03	3.23	3.29	3.12	3.23	3.37	0.16	-	0.002	-	-	-
DM dig (d 35), %	83.6	80.1	75.9	83.9	81.1	74.5	1.3	-	0.001	-	-	-
N dig (d 35), %	78.8	79.3	74.6	80.5	79.8	74.8	2.3	-	0.04	-	-	-
GE dig (d 35), %	82.6	79.4	75.9	83.6	80.5	74.5	1.4	-	0.001	-	-	-
HCW, lb	201.5	198.0	191.5	201.5	197.2	194.0	3.6	-	0.001	-	-	-
Dress, %[b]	74.6	74.3	73.2	74.5	74.1	73.5	0.4	-	0.002	-	-	-
Last-rib backfat, in[b]	0.9	0.8	0.8	0.9	0.8	0.9	0.1	-	0.06	-	-	-
Carcass lean, %[b]	52.9	53.3	53.7	52.6	53.4	53.1	0.9	-	0.03	-	-	-

[a]A total of 312 finishing pigs (13 pigs per pen and 4 pens per treatment) with an average initial weight of 142 lb.
[b]Effects of wheat middlings on carcass traits disappeared (P>0.12) when the data were adjusted to the same hot carcass weight.
[c]Dashes indicate P>0.15.

EFFECTS OF INCREASING AMOUNTS OF TRUE ILEAL DIGESTIBLE LYSINE ON THE GROWTH PERFORMANCE OF GROWING-FINISHING PIGS REARED IN A COMMERCIAL FACILITY[1]

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

Summary

Two 28-d experiments using 2,259 gilts were conducted to determine the growth and economic effects of increasing dietary true ileal digestible (TID) lysine in commercially reared growing-finishing pigs. Both experiments included 6 dietary treatments of incrementally increasing TID lysine in diets containing 6% added fat. The dietary TID lysine ranged from below to above our current requirement estimates to determine if there were any changes in lysine requirements during the past five years. In Exp. 1, pigs were initially 132 lb and averaged 192 lb at the end of the 28-day study. The TID lysine rates were 0.65, 0.75, 0.85, 0.95, 1.05, and 1.15%, which corresponded to lysine:calorie ratios of 1.80, 2.08, 2.35, 2.63, 2.91, and 3.19 g/Mcal, respectively. Increasing TID lysine increased ADG (linear, P<0.01) and improved F/G (quadratic, P<0.06), with optimal performance at 1.05% TID lysine (TID lysine:ME ratio of 2.91 g/Mcal). Pigs fed this diet consumed approximately 22 g of TID lysine per day, and used 21.6 g of TID lysine/kg of gain. Although not significant, margin over feed cost (MOF) was numerically greatest for pigs fed 1.05% TID. In Exp. 2, pigs were initially 177 lb and averaged 241 lb at the end of the 28-d study. The TID lysine rates were 0.52, 0.62, 0.72, 0.82, 0.92, and 1.02%, which corresponded to lysine:calorie ratios of 1.44, 1.71, 1.99, 2.27, 2.55, and 2.83 g/Mcal, respectively. In Exp. 2, the optimal TID lysine rate changed over the course of the experiment. During the first 14 d, pigs fed 0.92% TID lysine had the greatest ADG and lowest F/G, whereas pigs fed 0.72% TID lysine had the numerically highest ADG and lowest F/G from d 14 to 28. Pigs fed these diets required approximately 19.5 g of TID lysine/kg gain. Margin over feed costs increased (quadratic, P<0.03) with increasing dietary TID lysine, with the greatest return at 0.72% TID lysine. In summary, results of the first experiment suggest an increase in dietary TID lysine recommendations, compared with our earlier studies. Even though the optimal lysine rate may be changing over time for this genetic line and production facility, it seems that using the estimate of approximately 20 g TID lysine per kg of gain will provide a good estimate of the pig's lysine requirement.

(Key Words: Finishing Pig, Energy, Lysine, Growth.)

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[1]Appreciation is expressed to New Horizon Farms and employees for use of pigs, facilities, and technical assistance.

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Introduction

Lysine requirements of growing-finishing pigs have been researched in depth, but as genetics, environment, and herd health in commercial production systems change over time, these requirements also may change. The most recent research on lysine requirement of finishing pigs by Kansas State University was reported in 2002, when Main et al. described the ideal lysine:calorie ratios for growing-finishing barrows and gilts. Continuous evaluation of requirements is time consuming, especially considering rapid changes in many of the factors affecting protein deposition. If there were a way to quickly assess amino acid requirements without periodically conducting titration studies, this would be a valuable procedure to determine lysine requirements within a production system. In previous studies, anecdotal observations have suggested that there might be a constant relationship between ADG and the lysine requirement. It seems that, for every 1 kg of gain, the pig needs to consume approximately 20 g of TID lysine. Therefore, the objectives of this study were to determine if lysine requirements in this production may have changed over the past three years and possibly to provide evidence that the estimate of 20 g TID lysine per kg might be an accurate requirement indicator in growing-finishing gilts reared in a commercial environment.

Procedures

Animals and Housing. A total of 1,130 growing and 1,129 finishing gilts (Exp. 1 and 2, respectively) were used in two 28-d studies. Pigs were randomly allotted to one of 42 pens into two different finishing barns on a commercial research site in southwestern Minnesota. The pigs in each experiment were weighed on d 0 of the experiment, and dietary treatments were assigned to pens blocked by initial weight. There were approximately 27 pigs per pen and 7 pens per treatment.

The trials were conducted in identical double curtain-sided, deep-pit commercial finishing barns that operated on natural ventilation during the summer and mechanical ventilation during the winter. Each barn had totally slatted flooring allowing 7.2 ft^2 per pig. Each pen was equipped with a five-hole dry self feeder and one cup waterer. The experiments were conducted from November 2005 to January 2006.

Dietary Treatments. Each experiment consisted of 6 corn/soybean meal dietary treatments that were formulated over a range of TID lysine values to be below, at, or above the current lysine estimates. In Exp. 1, gilts were initially 132 lb, and the trial was 28 d in duration. The TID lysine rates were 0.65, 0.75, 0.85, 0.95, 1.05, and 1.15%, and correspond to lysine:calorie ratios of 1.80, 2.08, 2.35, 2.63, 2.91, and 3.19 g/Mcal, respectively (Table 1). In this trial, DL-methionine was added in the 1.15% TID lysine diet to ensure that lysine was first limiting. In Exp. 2, initial weight of gilts was 177 lb, and the trial duration was 28-d. The TID lysine rates were 0.52, 0.62, 0.72, 0.82, 0.92, and 1.02, and corresponded to lysine:calorie ratios of 1.44, 1.71, 1.99, 2.27, 2.55, and 2.83 g/Mcal, respectively (Table 2). All diets contained 6% added choice white grease, and increasing TID lysine rates were achieved by changing the amount of corn and soybean meal; diets did not contain crystalline to ensure that all other amino acid ratios, relative to lysine, were above the pig's requirement. Dietary treatments were fed in meal form and were formulated to contain similar amounts of vitamins and minerals.

Response Criteria and Statistical Analysis. Pens of pigs and feeders were weighed on d 0, 14, and 28 to calculate ADG, ADFI, and F/G. Margin over feed cost (MOF) per pig was calculated by using a market hog value of $45/cwt and existing corn ($1.99/bu), soybean meal ($190/ton), and choice white grease ($0.19/lb) costs for southwestern Minnesota as

of January 2006. Data were analyzed as a randomized complete-block design, with pen as the experimental unit. Analysis of variance was performed by using the MIXED procedure of SAS. Linear and quadratic contrasts were used to evaluate the effects of increasing TID lysine on pig performance.

Results

Experiment 1. From d 0 to 14, increasing TID lysine improved ADG, ADFI, and F/G (linear, P<0.02; Table 3). Although the responses were linear, the greatest improvement was observed in pigs fed 1.05% TID lysine (2.91 g TID lysine/Mcal ME), with little improvement thereafter.

From d 14 to 28, increasing TID lysine had no effect on ADG, reduced ADFI (linear, P<0.01), and improved F/G (quadratic, P<0.07).

Overall (d 0 to 28), ADG was increased (linear, P<0.01) and ADFI was reduced (linear, P<0.01) with increasing TID lysine. Feed efficiency was also improved (quadratic, P<0.06). Again the optimal response was at 1.05% TID lysine. Pigs provided the diet formulated to contain 1.05% TID lysine consumed 21.8 g of TID lysine per day and used 21.6 g of TID lysine/kg of gain from d 0 to 28. Margin over feed cost per pig was not affected by increasing TID lysine.

Experiment 2. From d 0 to 14, increasing TID lysine improved ADG and F/G (quadratic, P<0.01), with the greatest growth performance for pigs fed diets containing 0.92% TID lysine (2.55 g TID lysine/Mcal ME; Table 4). Pigs consuming diets containing 0.92 of TID lysine used 22.3 g of TID lysine per day, or 19.5 g of TID lysine/kg of gain.

From d 14 to 28, there were no differences in ADG with increasing TID lysine, but ADFI decreased (linear, P<0.05) and F/G improved (linear, P<0.07). Despite the linear response, there were few improvements in performance in pigs fed more than 0.72% TID lysine. Pigs on this treatment consumed 19.3 g of TID lysine, and used 19.5 g of TID lysine/kg of gain.

Overall (d 0 to 28), ADG and F/G were improved (quadratic, P<0.02) with increasing TID lysine. Optimal performance occurred with pigs provided diets containing 0.72% TID lysine. This corresponded with 18.6 g TID lysine intake per day, and 17.9 g of TID lysine/kg of gain

Margin over feed cost per pig improved (quadratic, P<0.02) with increasing TID lysine, with the greatest MOF observed in pigs provided diets containing 0.72% TID lysine.

Discussion

Current Kansas State University lysine recommendations state that growing gilts (120-170 lb) require 0.85% TID lysine (2.35 g TID lysine/Mcal ME), whereas finishing gilts (180-240 lb) should receive diets containing 0.72% TID lysine (1.99 g TID lysine/Mcal ME). These recommended rates served as the basis for diet formulation for Exp. 1 and 2, respectively. In our study, grower diets formulated to contain 1.05% TID lysine (2.91 g TID lysine/Mcal ME) provided numerically improved growth performance and MOF. This lysine rate is much higher than previously observed in lysine titration studies in this production system.

Ideally, we would like a method to estimate a lysine requirement without the time and expense of conducting titration studies. Previous anecdotal observations suggested that pigs of modern genotypes require approximately 20 g/d of TID lysine per kg of gain. In Exp. 1, this estimate was slightly less than the actual g lysine/kg gain values observed for pigs with the best ADG and F/G. In Exp. 2, finishing pigs' lysine requirements seemed very similar to that in previous studies (0.72% TID lysine), and the 19.5 g of lysine

per kg of gain required in each two-week period for the optimal response was similar to the 20 g/kg suggested requirement. These findings may suggest that 20 g lysine per kg gain may be used as a potential estimate for lysine requirements in commercial facilities.

Table 1. Diet Composition (Exp. 1, As-fed Basis)

	True Ileal Digestible Lysine, %[a]					
Ingredient, %	0.65	0.75	0.85	0.95	1.05	1.15
Corn	73.49	69.57	65.60	61.67	57.70	53.59
Soybean meal, 46.5% CP	18.43	22.40	26.38	30.35	34.33	38.31
Choice white grease	6.00	6.00	6.00	6.00	6.00	6.00
Monocalcium phosphate, 21% P	0.65	0.60	0.60	0.55	0.55	0.65
Limestone	0.90	0.90	0.90	0.90	0.90	0.90
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.08	0.08	0.08	0.08	0.08	0.08
Trace mineral premix	0.10	0.10	0.10	0.10	0.10	0.10
DL-methionine	0.00	0.00	0.00	0.00	0.00	0.03
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis						
Total lysine, %	0.75	0.86	0.97	1.08	1.19	1.30
True ileal digestible amino acids						
Lysine, %	0.65	0.75	0.85	0.95	1.05	1.15
Isoleucine:lysine ratio, %	82	80	78	77	76	75
Leucine:lysine ratio, %	195	182	171	163	157	151
Methionine:lysine ratio, %	35	32	31	29	28	30
Met & cys:lysine ratio, %	71	67	63	61	58	59
Threonine:lysine ratio, %	73	70	68	67	66	65
Tryptophan:lysine ratio, %	22	22	22	22	22	22
Valine:lysine ratio, %	95	91	88	86	84	82
TID Lys:ME, g/Mcal	1.80	2.08	2.35	2.63	2.91	3.19
ME, kcal/lb	1,639	1,639	1,639	1,639	1,638	1,636
CP, %	14.8	16.3	17.8	19.4	20.9	22.4
Ca, %	0.55	0.55	0.56	0.57	0.58	0.61
P, %	0.47	0.48	0.49	0.50	0.51	0.55
Available P, %	0.19	0.19	0.19	0.19	0.19	0.22

[a]Nutrient values used in diet formulation from NRC, 1998.

Table 2. Diet Composition (Exp. 2, As-fed Basis)

Ingredient, %	True Ileal Digestible Lysine, %[a]					
	0.52	0.62	0.72	0.82	0.92	1.02
Corn	70.76	66.79	62.81	58.84	83.25	85.64
Soybean meal, 46.5% CP	21.21	25.19	29.16	33.14	14.85	12.46
Choice white grease	6.00	6.00	6.00	6.00	0.00	0.00
Monocalcium phosphate, 21% P	0.65	0.65	0.65	0.65	0.55	0.60
Limestone	0.85	0.85	0.85	0.85	0.80	0.80
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.08	0.08	0.08	0.08	0.10	0.08
Trace mineral premix	0.10	0.10	0.10	0.10	0.10	0.08
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis						
Total lysine, %	0.61	0.71	0.82	0.93	1.04	1.15
True ileal digestible amino acids						
Lysine, %	0.52	0.62	0.72	0.82	0.92	1.02
Isoleucine:lysine ratio, %	86	83	81	79	78	77
Leucine:lysine ratio, %	221	200	185	174	165	158
Methionine:lysine ratio, %	39	35	33	31	30	29
Met & cys:lysine ratio, %	80	73	68	64	61	59
Threonine:lysine ratio, %	77	73	71	69	67	66
Tryptophan:lysine ratio, %	23	22	22	22	22	22
Valine:lysine ratio, %	102	96	92	89	86	84
TID Lys:ME, g/Mcal	1.44	1.71	1.99	2.27	2.55	2.83
ME, kcal/lb	1,641	1,640	1,639	1,639	1,638	1,637
CP, %	12.9	14.4	15.9	17.4	18.9	20.4
Ca, %	0.51	0.52	0.54	0.55	0.56	0.57
P, %	0.45	0.46	0.48	0.50	0.51	0.53
Available P, %	0.19	0.19	0.20	0.20	0.21	0.21

[a]Nutrient values used in diet formulation from NRC, 1998.

Table 3. Influence of Increasing True Ileal Digestible Lysine Growth Performance of Pigs from 132 to 194 lb (Exp. 1)[a]

	True Ileal Digestible Lysine, %						Probability, P<			
Item	0.65	0.75	0.85	0.95	1.05	1.15	Trt	Linear	Quadratic	SE
d 0 to 14										
ADG, lb	2.05	2.01	2.10	2.13	2.24	2.21	0.01	0.01	0.79	0.066
ADFI, lb	4.61	4.51	4.36	4.43	4.47	4.31	0.08	0.02	0.49	0.100
F/G	2.25	2.25	2.08	2.08	2.00	1.95	0.01	0.01	0.73	0.058
TID lysine, g/d	13.6	15.3	16.8	19.1	21.3	22.5	0.01	0.01	0.97	0.390
TID lysine, g/kg gain	14.6	16.8	17.6	19.8	21.0	22.4	0.01	0.01	0.56	0.563
d 14 to 28										
ADG, lb	2.06	2.11	2.09	2.13	2.19	2.03	0.68	0.81	0.27	0.099
ADFI, lb	5.12	4.75	4.63	4.66	4.68	4.42	0.01	0.01	0.15	0.115
F/G	2.48	2.26	2.23	2.21	2.15	2.21	0.06	0.01	0.07	0.106
TID lysine, g/d	15.1	16.2	17.9	20.1	22.3	23.1	0.01	0.01	0.83	0.473
TID lysine, g/kg gain	16.2	16.9	18.8	20.8	22.4	25.0	0.01	0.01	0.22	1.071
d 0 to 28										
ADG, lb	2.05	2.06	2.10	2.13	2.22	2.12	0.11	0.01	0.46	0.061
ADFI, lb	4.86	4.63	4.50	4.54	4.57	4.36	0.01	0.01	0.24	0.102
F/G	2.37	2.25	2.15	2.14	2.06	2.06	0.01	0.01	0.06	0.053
TID lysine, g/d	14.3	15.8	17.4	19.6	21.8	22.7	0.01	0.01	0.88	0.403
TID lysine, g/kg gain	15.4	16.9	18.2	20.2	21.6	23.7	0.01	0.01	0.46	0.514
MOF/pig[b]	$17.31	$17.45	$17.93	$17.92	$18.66	$17.59	0.44	0.23	0.27	0.694
TID Lys:ME, g/Mcal	1.80	2.08	2.35	2.63	2.91	3.19				

[a]A total of 1,130 gilts (initially 132.6 lb, PIC).
[b]Margin over feed cost based on a market hog value of $45/cwt and current costs for corn, soybean meal, and choice white grease in southwestern Minnesota as of January 2006.

Table 4. Influence of Increasing True Ileal Digestible Lysine Growth Performance of Pigs from 177 to 241 lb (Exp. 2)[a]

	True Ileal Digestible Lysine, %						Probability, P<			
Item	0.52	0.62	0.72	0.82	0.92	1.02	Trt	Linear	Quadratic	SE
d 0 to 14										
ADG, lb	1.95	2.25	2.45	2.33	2.52	2.42	0.01	0.01	0.01	0.098
ADFI, lb	5.50	5.45	5.48	5.28	5.34	5.23	0.13	0.01	0.89	0.122
F/G	2.82	2.44	2.25	2.27	2.12	2.16	0.01	0.01	0.01	0.073
TID lysine, g/d	13.0	15.3	17.9	19.6	22.3	24.2	0.01	0.01	0.21	0.213
TID lysine, g/kg gain	14.7	15.0	16.1	18.6	19.5	22.0	0.01	0.01	0.01	0.322
d 14 to 28										
ADG, lb	2.05	2.10	2.18	2.14	2.12	2.14	0.90	0.48	0.43	0.104
ADFI, lb	5.81	5.85	5.91	5.82	5.70	5.59	0.21	0.05	0.12	0.137
F/G	2.83	2.80	2.72	2.77	2.69	2.62	0.51	0.07	0.81	0.120
TID lysine, g/d	13.7	16.5	19.3	21.7	23.8	25.9	0.01	0.01	0.07	0.525
TID lysine, g/kg gain	14.7	17.3	19.5	22.3	24.7	26.6	0.01	0.01	0.51	0.965
d 0 to 28										
ADG, lb	2.01	2.17	2.30	2.23	2.31	2.27	0.01	0.01	0.02	0.075
ADFI, lb	5.66	5.66	5.71	5.57	5.53	5.42	0.07	0.01	0.23	0.103
F/G	2.82	2.62	2.48	2.51	2.40	2.39	0.01	0.01	0.02	0.064
TID lysine, g/d	13.4	15.9	18.6	20.7	23.1	25.1	0.01	0.01	0.10	0.383
TID lysine, g/kg gain	14.6	16.2	17.9	20.5	22.0	24.4	0.01	0.01	0.35	0.533
MOF/pig[b]	$15.77	$17.43	$18.71	$17.65	$18.34	$17.73	0.02	0.03	0.02	0.805
TID Lys:ME, g/Mcal	1.44	1.71	1.99	2.27	2.55	2.83				

[a]A total of 1,129 gilts (initially 177.5 lb, PIC).
[b]Margin over feed cost based on a market hog value of $45/cwt and current costs for corn, soybean meal, and choice white grease in southwestern Minnesota as of January 2006.

THE EFFECT OF DIETARY NUTRIENTS ON OSTEOCHONDROSIS LESIONS AND CARTILAGE PROPERTIES IN PIGS[1]

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Summary

A total of 80 gilts (PIC 327 × 1050; 86 lb initial BW) were used in an 84-d study to determine the effect of different nutrients on the occurrence of osteochondrosis (OC) lesions, several cartilage criteria, growth performance, and carcass composition. Eight dietary treatments were formulated, consisting of 1) control (standard corn-soy diet, 3.5% choice white grease (CWG)) or the control diet plus 2) fish oil (3.5%) replaced CWG, 3) proline and glycine (Pro/Gly; 300 and 200% of lysine), 4) leucine, isoleucine, and valine (BCAA; 200, 100, and 100% of lysine, respectively), 5) silicon (1,000 ppm), 6) copper and manganese (Cu/Mn; 250 ppm and 100 ppm, respectively), 7) methionine and threonine (Met/Thr; 150 and 100% of lysine), and 8) combination of ingredients in diets 2 through 7. The diets were formulated slightly in excess of the pig's requirement for lysine and to meet minimum true ileal digestibility (TID) ratios for the other essential amino acids. The diets were also formulated to be isocaloric by slightly adjusting the fat (CWG) content, and were fed in three phases (1.07, 0.94, and 0.80% TID Lys). Upon completion of the feeding period, pigs were harvested, and the distal aspect of the left femur was evaluated by gross examination for OC lesions. The external surface was evaluated for abnormalities and given a severity score. Then each femur was sliced into 3-mm sections, and lesions were assigned a severity score for the underlying articular cartilage, and physeal growth plate. Overall (d 0 to 84), growth performance was unaffected by dietary treatment ($P>0.21$). Pigs fed diets containing fish oil or silicon tended ($P<0.07$) to have a higher severity score for external abnormalities (or defects in cartilage surface), compared with pigs fed the other dietary treatments, with pigs fed the control diet, Pro/Gly, or Cu/Mn intermediate. Pigs fed high Met/Thr, Cu/Mn, or silicon tended ($P<0.08$) to have lower articular cartilage severity scores than scores of pigs fed the control diet or BCAA, with the other dietary treatments intermediate. The occurrence of OC lesions at the growth plate, total faces with lesions, and total number of abnormalities were not affected by dietary treatment ($P>0.23$); there was a trend ($P<0.14$) for pigs fed diets containing high Met/Thr or fed the combination diet to have lower total severity scores than scores of pigs fed the control diet or fish oil, with the other treatments intermediate. Pigs fed additional Cu/Mn, Met/Thr, or the diet containing all additional ingredients had lower overall severity scores ($P<0.03$) than did pigs fed the control diet or fish oil. Cartilage compression or shear force were un-

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affected by dietary treatment (P>0.19), but pigs fed fish oil had a higher ratio for compression:shear energy (P<0.03), compared with the ratio for those fed the control diet, Cu/Mn, or silicon; the other treatments were intermediate. In summary, feeding pigs a diet containing additional silicon, Cu/Mn, Met/Thr, or a combination of these ingredients may offer the potential to reduce the incidence of osteochondrosis in gilts; more research will be required to verify these results.

(Key Words: Cartilage, Finishing Pigs, Osteochondrosis.)

Introduction

Osteochondrosis (OC) remains a common problem among growing swine; it occurs in approximately 85 to 90% of all pigs. Osteochondrosis is an irregularity in the underlying growth cartilage that has improperly calcified, leaving an area of cartilage protruding into the subchondral bone. It occurs primarily in the epiphyseal cartilage of the medial femoral condyle, humeral condyle, humeral head, the growth plate of the distal ulna, and the costochondral junction. It can cause reduced reproductive performance and increased culling rates in sows due to lameness, and can decrease performance and meat yield of finishing pigs. The direct cause of OC is relatively unknown, but several studies have tried to determine how handling, genetics, or nutrition may play a role in its development. It previously has been thought that rapid growth rate or an abnormality in bone growth that causes cartilage canal vessels supplying blood to the end of growing long bones to improperly fill with bone matrix were the major causes of OC in growing pigs. The reduced blood supply results in an area of cartilage that is weakened and susceptible to trauma. When trauma occurs, this underlying weakness can allow damage to occur to the articular cartilage surface or prevent the cartilage around it from properly maturing and growing at the appropriate rate. This damage to the articular cartilage surface results in pain and stiffness associated with the common lameness and decreased mobility seen in many pigs.

Therefore, the objective of these experiments was to screen dietary ingredients involved in cartilage and bone metabolism for their influence on OC lesion occurrence and severity, other cartilage criteria, growth performance, and carcass characteristics in growing-finishing pigs.

Procedures

Procedures used in these experiments were approved by the Kansas State University Animal Care and Use Committee. A total of 80 gilts (PIC line 327 × 1050; 86 lb initial BW) were blocked by weight in an 84-d growth assay. The experiment was conducted at the Kansas State University Swine Research and Teaching Center. Each pen contained one pig, for a total of 10 replicates (pigs) per treatment. The barn contains 80 pens with totally slatted concrete flooring (5 × 5 ft), providing approximately 25 sq ft/pig. Each pen was equipped with a one-hole dry self-feeder (Farmweld, Tuetopolis, IL) and nipple waterer to allow *ad libitum* access to feed and water.

Gilts were randomly allotted to one of 8 dietary treatments. Dietary treatments consisted of 1) control (standard corn-soy diet 3.5% choice white grease (CWG)) or the control diet plus 2) fish oil (3.5% replaced CWG), 3) proline and glycine (Pro/Gly; 300 and 200% of lysine, respectively), 4) leucine, isoleucine, and valine (BCAA; 200, 100, and 100% of lysine, respectively), 5) silicon (1,000 ppm), 6) copper and manganese (Cu/Mn; 250 ppm and 100 ppm, respectively), 7) methionine and threonine (Met/Thr; 150 and 100% of lysine, respectively), and 8) combination of ingredients in diets 2 through 7 (Tables 1 and 2). The control diet contained amino acidsPro (100% of lysine), Gly (65% of lysine), leucine (145% of lysine), isoleucine (69% of lysine), valine (76% of lysine), Met

(30% of lysine), and Thr (67% of lysine), with added amounts of Cu (16.5 and 14 mg/kg in Phase 1 and Phase 2 or 3, respectively), Mn (40 and 33 mg/kg in Phase 1 and Phase 2 or 3, respectively), and Si (0 mg/kg). Pigs were phase-fed over the 84-d period consisting of three 28-d phases. The values used in diet formulation and TID digestibilities were based on those published in the NRC (1998). Minimum true ileal digestible (TID) amino acid ratios, relative to lysine (Lys), were maintained in all diets, with minimum ratios set at 30% for methionine, 60% for methionine and cystine, 65% for threonine, and 16.5% for tryptophan. The Phase 1 diets were formulated to contain 1.07% TID Lys and 1,568 kcal of metabolizable energy (ME, Table 1), the Phase 2 diets contained 0.94% TID Lys and 1,573 kcal of ME, and Phase 3 diets contained 0.80% TID Lys and 1,570 kcal of ME. In each phase, all essential amino acids other than those used in dietary treatments were provided at approximately 10% above the requirement for pigs in these weight ranges, and added fat concentration differed slightly to maintain isocaloric diets. Other essential nutrients were supplied at, or above, NRC estimates. Diet samples were analyzed for amino acid concentration, and contained concentrations similar to formulated amounts.

Pigs and feeders were weighed every 14 d to determine ADG, ADFI, and F/G. At the start of the trial, all gilts were ultrasound scanned to determine initial backfat depth and to estimate fat-free lean. At the end of the trial, pigs were weighed before transport to the Kansas State University Meats Laboratory, where the left hind leg was collected for determination of OC lesions, as well as carcass data. Before transport, each pig was marked with a distinctive tattoo to allow the carcass data to be recorded for each pig. Carcass data were collected on each pig to evaluate 10th rib backfat depth, longissimus area, percentage lean, fat-free-lean gain, and hot carcass weight. Fat depth was measured with a ruler at the 10th rib, 2.3 in off of the midline, whereas longissimus muscle area was traced on translucent paper and calculated by using a grid. Percentage lean and fat-free-lean index were calculated according to NPPC (1994) procedures.

The left femur was collected and removed to visually determine the number of cartilage abnormalities (indentations or creasing of cartilage surface) and the occurrence of OC lesions by gross examination of the femoral condyle. The joints were cleaned of excess tissue and then stored in 10% formalin until evaluation. After external evaluation, the distal end of the femur was sliced into 3-mm sections by cutting perpendicular to the long axis of the bone with a bandsaw. This resulted in 12 faces (cut surfaces) for evaluation of lesions. Each joint was evaluated for the number of external abnormalities, OC lesions at the articular cartilage, and growth plate cartilage, and lesions were given a severity score (0 to 4) for all three locations, where 0 = normal, 1 = mild, 2 = moderate, 3 = severe, and 4 = OC dissecans, based on the extent of tissue involvement. Each joint was also categorized as “Yes” or “No” for the presence or absence of osteochondrosis lesions.

In addition, a cartilage sample was cut from the patella for cartilage property analysis. Cartilage samples were weighed, measured for thickness and length with a caliper, and then tested for the ability to absorb compression or to resist shearing by using an Instron machine (Model 4201 was used to determine cartilage properties). Each cartilage sample was placed between two flat surfaces of the Instron to perform texture profile analysis and compressed half of its thickness to measure the ability of the cartilage to resist compression force. A second measure was conducted in which the cartilage was cut by using a Warner-Bratzler shear blade, to determine the ability of the cartilage to withstand shearing force. Compression values and shear values were adjusted to cartilage weight/g to

equalize for differences in the actual cartilage weight.

Data were analyzed as a randomized complete-block design by using the PROC MIXED procedure of SAS, with pig as the experimental unit. The response criteria of growth performance, carcass composition, cartilage compression and shearing, and number of abnormalities were tested. Although scored categorically, severity of abnormalities scores for the external surface, articular cartilage, and growth plate cartilage were done via PROC MIXED because the small number of observations at some of the severity scores prevented categorical analysis. An overall score using the number of abnormalities at each location, multiplied by the severity at each location and then summed, was created to provide an overall severity score or indication of joint status. A 'Yes' or 'No' rating of the presence of OC lesions was compared by using the Cochran-Mantzel-Haenszel test statistic for row mean scores in PROC FREQ. To evaluate the effect of amino acids or added minerals, relative to the other dietary treatments, single-degree-of-freedom contrasts were constructed.

Results and Discussion

Overall (d 0 to 84), growth performance was unaffected by dietary treatment ($P>0.21$, Table 3), but pigs fed high Met/Thr tended ($P<0.10$) to have increased longissimus muscle area, compared with pigs in the other dietary treatments, whereas pigs fed fish oil were intermediate; no other carcass differences were observed ($P>0.84$). This response is similar to previous trials in which excess methionine has increased lean muscle deposition.

For the joint evaluation data, the number of animals with OC was not affected by dietary treatment ($P>0.52$). Pigs fed diets containing fish oil or silicon tended ($P<0.07$, Table 5) to have a higher severity score for external abnormalities, compared with pigs in the other dietary treatments; scores of pigs fed the control diet, Pro/Gly, or Cu/Mn were intermediate, but the prevalence of external abnormalities and severity scores were not different from controls. Pigs fed high Met/Thr, Cu/Mn, or silicon tended ($P<0.08$) to have lower articular cartilage lesion severity scores than those of pigs fed the control diet or BCAA, with the other dietary treatments intermediate. The distribution of severity scores are shown for the three treatments that tended to reduce articular cartilage lesion severity, compared with the control (Chart 1). The occurrence of OC lesions at the growth plate, total faces with lesions, or total number of abnormalities were not affected by dietary treatment ($P>0.23$); there was a numerical trend ($P<0.14$) for pigs fed diets containing high Met/Thr or the combination diet containing all ingredients to have lower total severity scores than those of pigs fed the control diet or fish oil, with the other treatments intermediate. Finally, pigs fed additional Cu/Mn, Met/Thr, or the diet containing all additional ingredients, had lower overall severity scores ($P<0.03$), compared with scores of pigs fed the control diet or fish oil. An intermediate response to additional Pro/Gly and silicon was also observed, compared with the control diet or fish oil. Pigs fed the diets containing additional amino acids had lower external and total severity scores ($P<0.05$) than did pigs fed the other dietary treatments, but pigs fed diets containing minerals (silicon or copper and manganese) tended ($P<0.08$) to have lower articular cartilage severity scores and had lower overall severity scores ($P<0.02$).

Cartilage compression or shear force were unaffected by dietary treatment ($P>0.19$, Table 6), but pigs fed fish oil had a higher ratio for compression:shear energy ($P<0.03$), compared with those fed the control diet, Cu/Mn, or silicon; the other treatments were intermediate. This suggests that fish oil stiffened the cartilage or has less ability to absorb impact force and less ability to resist shear forces. This may have been due to the ability of n-3

fatty acids to inhibit matrix metalloproteinases that degrade collagen. In doing so, the normal turnover of cartilage may have been inhibited, resulting in collagen with decreased ability to function in absorbing energy or resist breaking apart.

In summary, feeding pigs high Met/Thr not only increased loin eye area, but tended to reduce the total severity score, compared with the control diet. In addition, feeding pigs diets containing high Met/Thr, silicon, or Cu/Mn may reduce the severity of OC lesions at the articular cartilage (Chart 1). Although there is no requirement established for silicon in pigs, it may be essential for proper bone and cartilage strength due to its role in chondroitin sulfate metabolism and collagen formation. Copper also is required for the enzyme lysyl oxidase that helps form crosslinks in cartilage between collagen molecules, and may help stabilize the cartilage matrix from degradation or provide vascular stability to blood vessel walls. Finally, Met/Thr have indirect effects on cartilage metabolism. Methionine is thought to drive cartilage synthesis and also donate sulfur for the process of proteoglycan formation. Threonine can be converted to glycine, which is part of the collagen, and is also incorporated into collagen in small quantities itself. Feeding ingredients such as Met/Thr, Cu/Mn, silicon, or a combination of these ingredients that are involved in cartilage and bone metabolism may help reduce the incidence of OC by either positively influencing cartilage/bone metabolism or by preventing excess cartilage degradation, but this evidence only provides initial information and more research will be required to verify the results found in this study.

Table 1. Diet Composition (As-fed Basis)[ab]

Item	Phase 1	Phase 2	Phase 3
Ingredient			
Corn	62.65	68.60	74.05
Soybean meal (46.5% CP)	30.45	24.95	19.50
Choice white grease[c]	3.50	3.50	3.50
Monocalcium phosphate (21 % P)	1.50	1.25	1.25
Limestone	1.05	1.00	1.00
Salt	0.35	0.35	0.35
Vitamin premix	0.15	0.13	0.13
Trace mineral premix	0.15	0.13	0.13
L-lysine HCl	0.15	0.15	0.15
DL-methionine	0.06	0.03	-
L-threonine	0.06	0.05	0.05
Total	100.00	100.00	100.00
Calculated Analysis			
Total lysine, %	1.20	1.05	0.90
True ileal digestible amino acids			
Lysine, %	1.07	0.94	0.80
Isoleucine:lysine ratio, %	69	69	70
Leucine:lysine ratio, %	145	154	164
Methionine:lysine ratio, %	32	31	29
Met & Cys:lysine ratio, %	60	60	60
Threonine:lysine ratio, %	65	66	68
Tryptophan:lysine ratio, %	20	19	19
Valine:lysine ratio, %	76	78	80
ME, kcal/lb	1568	1573	1570
CP, %	19.5	17.4	15.4
Ca, %	0.80	0.72	0.72
P, %	0.70	0.62	0.62
Lysine:calorie ratio, g/mcal	3.47	3.03	2.60

[a]Diets fed in meal form in three 28-d phases.
[b]Dietary treatments were created by substituting ingredients for corn, except that fish oil replaced CWG.
[c]Amount of CWG varied slightly in the diet so that diets were isocaloric in each phase.

Table 2. Dietary Treatments[a]

Treatment	
Control[b]	Standard corn-soybean meal diet with 3.5% choice white grease.
Fish oil	3.5% fish oil replaced choice white grease, resulting in a n-6 to n-3 ratio of 2:1.
Pro/Gly	L-proline at 2.55% and L-glycine at 1.70% were added to create a ratio of proline:lysine of 300% and a glycine:lysine ratio of 200%.
BCAA	L-leucine was added at 0.60%, L-isoleucine at 0.35%, and L-valine at 0.29% to create a leucine:lysine ratio of 200%, isoleucine:lysine ratio of 100%, and valine:lysine ratio of 100%.
Silicon	Silicon was added at 0.80% (Zeolite A) to create the silicon diet (1,000 ppm).
Cu/Mn	Copper was added at 0.1% (250 ppm) and manganese was added at 0.02% (100 ppm).
Met/Thr	DL-methionine was added at 1.05% to create a methionine:lysine ratio of 150% and L-threonine was added at 0.45% to create a threonine:lysine ratio of 100%.
All ingredients	Contained all additional dietary ingredients at the expense of corn and choice white grease.

[a]All dietary treatments were fed in meal form and maintained throughout the three 28-d feeding phases.

[b]The control diet contained amino acid levels of Pro (100% of lysine), Gly (65% of lysine), leucine (145% of lysine), isoleucine (69% of lysine), valine (76% of lysine), Met (30% of lysine), and Thr (67% of lysine), with mineral levels of Cu (16.5 and 14 mg/kg in Phase 1 and Phase 2 or 3, respectively), Mn (40 and 33 mg/kg in Phase 1 and Phase 2 or 3, respectively), and Si (0 mg/kg).

Table 3. Effect of Different Nutrients on Growth Performance and Carcass Composition[a]

	Treatment									Probability, P <
Item	Control	Fish Oil	Pro/Gly	BCAA	Silicon	Cu/Mn	Met/Thr	All Ingredients[b]	SED	Treatment
Growth, d 0 to 84[c]										
ADG, lb	2.40	2.34	2.37	2.48	2.44	2.48	2.28	2.28	0.104	0.21
ADFI, lb	6.13	5.85	5.97	6.17	6.16	6.04	5.82	5.68	0.248	0.26
Feed/Gain	2.56	2.50	2.52	2.50	2.53	2.45	2.55	2.50	0.087	0.91
Carcass data										
Initial backfat, in	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.02	0.83
HCW, lb[d]	209.6	205.8	205.0	209.1	212.7	206.8	201.3	197.1	-	0.43
Final backfat, in	0.63	0.62	0.59	0.56	0.56	0.61	0.63	0.63	0.06	0.84
Final LEA, in	7.55[f]	7.92[fg]	7.46[f]	7.52[f]	7.49[f]	7.58[f]	8.27[g]	7.28[f]	0.327	0.10
Fat-free lean index	55.4	55.7	55.3	55.7	55.8	55.5	56.1	54.5	1.09	0.90
Fat-free lean gain, lbs/day[e]	0.936	0.953	0.949	0.955	0.957	0.948	0.960	0.926	0.025	0.88

[a]Each value is the mean of 9 or 10 replications, with pigs initially 86 lbs, and average final weight of 290 lbs.
[b]Diet contained all treatment ingredients combined into one diet.
[c]Pigs were fed diets in meal form in three 28-d phases.
[d]Hot carcass weight was used as a covariate in analysis, except for fat-free-lean gain.
[e]Calculated as the final fat-free lean minus initial fat-free lean, divided by days on feed.
[f,g]Treatments with different superscripts differ P<0.05.

Table 4. Effect of Different Nutrients on Cartilage Parameters[a]

	Treatment									Probability, P <
	Control	Fish Oil	Pro/Gly	BCAA	Silicon	Cu/Mn	Met/Thr	All[b]	SED	Treatment
Cartilage measures										
Cartilage weight, g[c]	1.07	1.26	1.08	1.22	1.24	1.10	1.16	1.26	0.138	0.65
Cartilage thickness, cm[d]	0.38	0.37	0.36	0.38	0.36	0.33	0.36	0.39	0.042	0.96
Cartilage length, cm[e]	3.19	3.37	3.22	3.25	3.28	3.21	3.30	3.32	0.109	0.71
Instron measures										
Compression energy, n/g[f]	85.4	126.9	144.7	102.5	86.0	59.8	116.4	110.7	39.22	0.59
Shear energy, n/g[g]	516.9	378.7	437.9	505.2	523.1	565.8	505.4	561.6	74.03	0.19
Total energy, n/g[2h]	1271.4	1226.8	976.5	1303.3	1342.3	1401.9	1326.9	1539.6	291.54	0.73
Ratio of CE/SE[i]	0.15[k]	0.41[j]	0.31[jk]	0.25[jk]	0.17[k]	0.15[k]	0.25[jk]	0.21	0.081	0.03

[a]Each value is the mean of 9 or 10 replications, with pigs initially 86 lb, and a final weight of 290 lbs.
[b]Diet contained all dietary ingredients added into one diet
[c]Weight of the cartilage sample taken from the patella.
[d]The thickness of the cartilage sample.
[e]The length of the cartilage sample.
[f]Amount of energy in newtons per gram of cartilage to compress the cartilage half its thickness.
[g]Amount of initial energy in newtons per gram of cartilage to shear the cartilage into two pieces.
[h]The total amount of energy required to shear the cartilage into two pieces.
[i]The ratio of compression force or energy to shear force or energy, in which smaller values would indicate more desirable characteristics.
[j,k]Treatments with different superscripts differ by P<0.05.

Table 5. Effect of Different Nutrients on the Occurrence of Osteochondrosis[a]

	Treatment									Probability, P <			
											Contrasts		
Item	Control	Fish Oil	Pro/ Gly	BCAA	Silicon	Cu/ Mn	Meth/ Thr	All[b]	SED	Treatment	Minerals vs AAs	Minerals vs others	AAs vs others
Total animals/trt[c]	10	10	10	10	10	9	10	10	-	-	-	-	-
Animals with lesions[d]	9	9	9	9	6	7	7	7	1.5	0.52	-	-	-
External													
Abnormalities[e]	1.9^{op}	2.6^{o}	2.0^{op}	1.4^{p}	2.5^{o}	1.8^{op}	1.3^{p}	1.4^{p}	0.56	0.13	0.31	0.86	0.02
Severity score[f]	2.1^{op}	2.5^{o}	1.9^{op}	1.4^{p}	2.4^{o}	1.8^{op}	1.3^{p}	1.4^{p}	0.48	0.07	0.24	0.94	0.01
Articular cartilage													
Number of faces[g]	5.0^{o}	4.5^{op}	2.4^{op}	5.0^{o}	2.2^{q}	2.3^{op}	2.6^{op}	4.1^{op}	1.44	0.16	0.57	0.19	0.87
Severity score[h]	2.0^{o}	1.3^{opq}	1.2^{opq}	1.6^{op}	0.7^{q}	0.8^{pq}	0.7^{q}	1.3^{opq}	0.48	0.08	0.38	0.08	0.98
Growth plate													
Number of faces[i]	0.9	1.7	1.2	0.6	1.2	1.6	1.8	0.2	0.68	0.23	0.58	0.47	0.25
Severity score[j]	0.6	1.1	0.9	0.6	0.8	0.8	1.0	0.1	0.43	0.38	0.27	0.21	0.43
Overall													
Total faces[k]	5.9	6.2	3.6	5.6	3.4	3.9	4.4	4.3	1.81	0.63	0.52	0.17	0.68
Total abnormalities[l]	8.7	8.8	5.6	7.0	5.9	5.7	5.7	5.7	1.89	0.54	0.75	0.21	0.27
Total severity[m]	4.7^{o}	4.9^{o}	4.0^{op}	3.6^{op}	3.9^{op}	3.3^{op}	3.0^{p}	2.8^{p}	0.85	0.14	0.70	0.12	0.05
Overall score[n]	17.1^{o}	15.0^{op}	8.8^{pq}	12.4^{opq}	8.4^{pq}	6.4^{q}	6.6^{q}	7.0^{q}	3.76	0.03	0.36	0.02	0.11
Final weight	294.6	282.3	291.4	293.4	298.8	287.3	284.2	285.4	10.23	0.70	0.89	0.81	0.68

[a]Each value is the mean of 9 or 10 replications, with one pig per pen, initially 86 lb. [b]Diet contained all dietary ingredients added into one diet. [c]Total animals evaluated per treatment. [d]The number of animals with OCD lesions (Cochran-Mantzel-Haenszel test). [e]Number of abnormalities noted upon visual evaluation of the intact joint. [f]Severity score (0-4 with 0 normal, 1 mild, 2 moderate, 3 severe, and 4 OC dissecans) of abnormalities by visual evaluation of the external joint. [g]The number of faces showing lesions from cutting the condyle into 3mm slices per animal. [h]Severity score (0-4 with 0 normal, 1 mild, 2 moderate, 3 severe, and 4 OC dissecans) for the articular cartilage faces. [i]The number of faces showing lesions in the growth plate per animal. [j]Severity score (0-4 with 0 normal, 1 mild, 2 moderate, 3 severe, and 4 OC dissecans) for the faces in the growth plate. [k]Total faces showing lesions at the articular cartilage and growth plate, evaluating 12 cut surfaces. [l]Sum of external abnormalities, articular faces, and growth plate faces. [m]Sum of severity scores for external abnormalities, articular cartilage, and growth plate faces. [n]Calculated as the number of abnormalities multiplied by the severity for each location, and then summed. [o,p,q]Treatments with different superscripts differ (P<0.05).

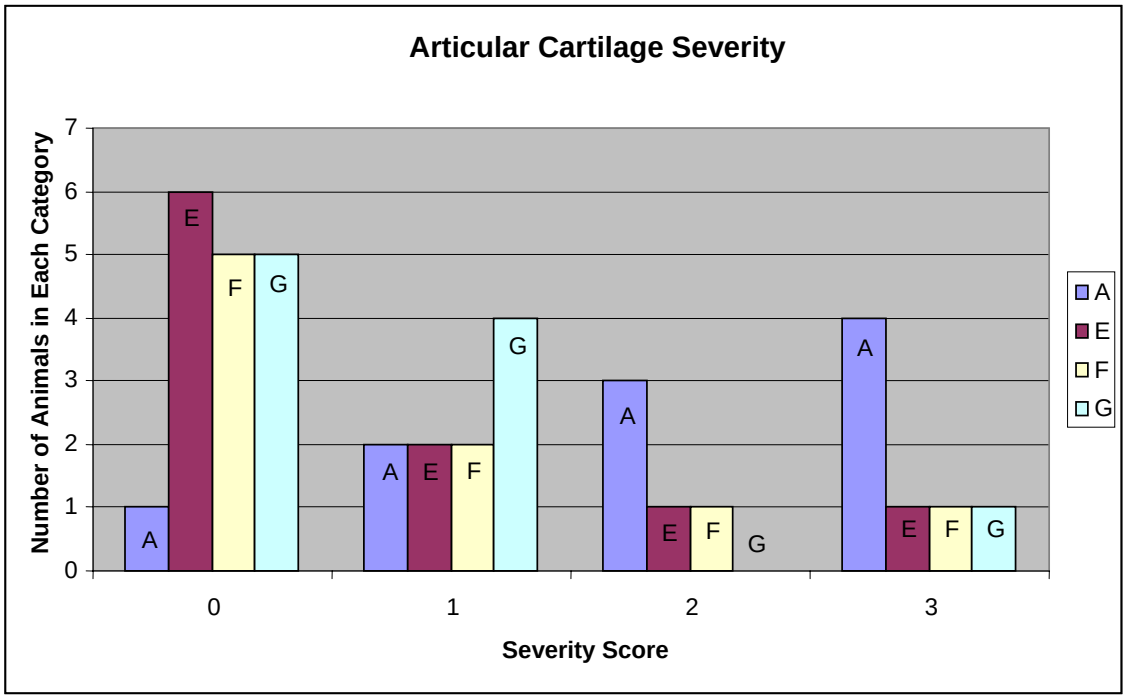

Chart 1. Distribution of Articular Cartilage Severity Scores for Treatments Silicon, Cu/Mn, and Methionine/threonine, Compared with Controls. A = control, E = silicon, F = Cu/Mn, and G = methionine/threonine (Only nine pigs fed Cu/Mn finished the experiment.)

EFFECT OF INCREASED DIETARY LYSINE ON GROWTH PERFORMANCE OF GILTS FED RACTOPAMINE HCL (PAYLEAN[1]) IN A COMMERCIAL FACILITY

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Summary

A total of 1,915 gilts (PIC L337 × C22) were used in two 21-d experiments in a commercial research barn to evaluate the effects of lysine rates on pig growth and carcass performance when fed ractopamine HCl. There were 7 replicates per treatment and 21 to 24 pigs per pen in both experiments. In both experiments, treatments included a control diet formulated to 0.65% TID lysine without ractopamine HCl, and diets containing 0.75, 0.85, 0.95, 1.05, and 1.15% TID lysine with 5 ppm ractopamine. There were 983 (initially 217.4 lb) and 932 (initially 226.2 lb) gilts in Exp. 1 and 2, respectively. All diets were based on corn-soybean meal and contained high concentrations of synthetic amino acids (0.325% of L-lysine HCl with added threonine, methionine, and tryptophan) in Exp. 1, but only 0.075% L-lysine HCl in Exp. 2. As lysine increased in the diet, ADG increased and F/G decreased (linear; $P<0.05$), with the greatest response through 1.05% TID lysine in Exp. 1 and through 0.95% TID lysine in Exp. 2. In both experiments, pigs fed ractopamine HCl had increased ($P<0.003$) ADG and F/G, compared with performance of pigs fed the control diet. For carcass data, average backfat and FFLI were improved (linear; $P<0.03$) in Exp. 2 with increasing rates of TID lysine, but were not changed in Exp. 1. These experiments suggest that pigs fed ractopamine HCl require at least 0.95% or 26 g/d of TID lysine and at least 25 g of TID lysine/kg of gain.

(Key Words: Finishing Pig, Lysine, Ractopamine HCl.)

Introduction

Feeding ractopamine HCl to finishing pigs is a common practice in the swine industry. Elanco Animal Health (Indianapolis, IN) sells ractopamine HCl under their trade name Paylean. Ractopamine HCl is a synthetic compound in a class of compounds called phenethanolamines, which are not hormones or antibiotics. Numerous research trials have been conducted and have shown that pigs fed ractopamine have improved daily gain and feed efficiency. In previous research at Kansas State University, ADG improved 17 to 22% and F/G 12 to 20% when ractopamine HCl was fed. The growth response to ractopamine HCl can be limited if amino acid concentrations are not sufficient to support the increased lean gain. The lysine requirement is the greatest during the first few weeks that ractopamine HCl is fed because the pigs are growing the most rapidly during this time. There is only limited published research evaluating the ly-

[1]Paylean is a registered trademark of Elanco Animal Health, Indianapolis, IN.
[2]Food Animal Health and Management Center, College of Veterinary Medicine.
[3]Anjinomoto Heartland Lysine LLC, Chicago, IL.

sine requirement of pigs fed ractopamine HCl in a commercial facility. In the 2005 Swine Day report, we reported that pigs responded linearly to increasing TID lysine, indicating that more research is needed. Therefore, the objectives of these experiments were to determine the lysine requirement for gilts fed ractopamine HCl in a commercial barn for growth performance and carcass characteristics.

Procedures

General. All experimental procedures used in these studies were approved by the Kansas State University Animal Care and Use Committee.

A total of 983 (initially 217.4 lb) and 932 (initially 226.2 lb) gilts were used in Exp. 1 and 2, respectively. There were 7 replicates per treatment, and 21 to 24 pigs per pen in both experiments, which were conducted in a commercial research finishing barn in southwestern Minnesota and used similar genetics (PIC L337 × C22). Pens were 18 × 10 feet. The barns were double curtain sided, with completely slatted flooring and a deep pit for manure storage. Each pen contained one self-feeder and one cup waterer.

All diets were based on corn-soybean meal and contained high concentrations of synthetic amino acids (0.325% of L-lysine HCl, with added threonine, methionine, and tryptophan) in Exp. 1, but only 0.075% L-lysine HCl in Exp. 2. For both experiments, there were 6 dietary treatments, with 1 control diet formulated to 0.65%TID lysine without ractopamine HCl and 5 treatments formulated to contain 0.75, 0.85, 0.95, 1.05, and 1.15% TID lysine with 5 ppm of ractopamine. For all experiments, the lowest and highest concentration TID lysine dietary treatments were made and then were blended to produce the other dietary treatments.

Pigs from both experiments were weighed on d 0, 7, 14, and 21 to determine ADG, ADFI, and F/G. On d 21, pigs were individually tattooed by pen number and transported to Swift and Co. (Worthington, MN) for carcass data. Pens of pigs were kept together and weighed at the slaughter plant to figure shrink.

Statistical Analyses. In both experiments, treatments were arranged in a completely random design. Analysis of variance was conducted on all data by using the MIXED procedure of SAS v. 8.1. Pen of pigs was the experimental unit. Linear and quadratic polynomial contrasts were used to determine the effects of increasing TID lysine for the treatments fed ractopamine HCl. Polynomial contrasts were used to compare pigs fed ractopamine HCl with pigs fed the control diet. Percentage shrink was calculated on all pigs by subtracting the farm weight from the plant weight, divided by the farm weight.

Results and Discussion

Experiment 1. Overall (d 0 to 21), pigs fed diets with increasing TID lysine had improved ADG (linear, ($P<0.02$) and F/G (linear; $P<0.01$), but there was no further improvement feeding more than 1.05% TID lysine. Pigs fed ractopamine HCl had improved ($P<0.01$) ADG and F/G compared with performance of pigs fed the control diet. In this experiment, the optimum rate of TID lysine in the diet was shown to be 1.05% when 4.5 g/ton of ractopamine HCl is added to the diet, or 27.8 g of TID lysine per d, which is 26.6 g of TID lysine per kg of gain (12 g per lb of gain).

Pigs fed ractopamine HCl had improved ($P<0.03$) carcass weight, backfat, loin depth, FFLI, and income per pig, compared with those measures in pigs fed the control diet. Pigs fed increasing rates of TID lysine had improved (linear; $P<0.02$) FFLI. Pigs fed diets with increasing rates of TID lysine had a trend

(linear; P<0.10) for decreased amounts of backfat and increased income per pig.

Experiment 2. Overall (d 0 to 21), increased rates of TID lysine in the diet improved (linear; P<0.01) ADG and F/G. Also, pigs fed ractopamine HCl had improved (P<0.03) ADG and F/G, compared with performance of pigs fed the control diet. But there was no improvement (P = 0.53) among treatments in final BW. The results of this experiment indicate that gilts fed 4.5 g per ton of ractopamine HCl should be fed at least 0.95% TID lysine, or 23.9 g of TID lysine per day, which is 23.3 g of TID lysine per kg of gain.

For carcass characteristics, there was an increase (linear; P<0.05) in percentage BW shrinkage with increasing rates of TID lysine in the diet. With increasing rates of TID lysine in the diet, backfat decreased (linear; P<0.04). Pigs fed ractopamine HCl had improved FFLI (P<0.03), compared with that of pigs fed the control diet and tended (P<0.10) to have heavier carcass weight and increased income per pig.

In conclusion, dietary lysine must be increased in diet containing ractopamine HCl before slaughter for optimum growth performance and carcass characteristics, compared with a typical late finishing diet without ractopamine HCl. The results of these experiments indicate that gilts fed ractopamine HCl (5 to 6.75 ppm) should be fed a corn-soybean meal diet formulated to at least 0.95% TID lysine, which supplies the gilts with 26 g/d of TID lysine and at least 25 g of TID lysine/kg of gain for optimal live growth performance and carcass composition.

Table 1. Diet Composition for Exp. 1 (As-fed Basis)

	TID Lysine Level %					
Ingredient, %	0.65	0.75	0.85	0.95	1.05	1.15
Corn	82.58	83.45	79.47	75.48	71.50	67.51
Soybean meal (46.5% CP)	13.25	12.00	15.95	19.91	23.86	27.81
Choice white grease	2.00	2.00	2.00	2.00	2.00	2.00
Monocalcium phosphate (21% P)	0.60	0.60	0.60	0.60	0.60	0.60
Limestone	0.85	0.85	0.85	0.85	0.85	0.85
Salt	0.40	0.40	0.40	0.40	0.40	0.40
L-lysine HCl	0.15	0.325	0.325	0.325	0.325	0.325
DL-methionine	0.00	0.038	0.061	0.084	0.106	0.129
L-threonine	0.025	0.138	0.153	0.169	0.184	0.20
L-tryptophan	0.00	0.0175	0.013	0.009	0.0045	0.00
Vitamin premix	0.025	0.05	0.05	0.05	0.05	0.05
Trace mineral premix	0.07	0.05	0.05	0.05	0.05	0.05
Copper sulfate	0.05	0.05	0.05	0.05	0.05	0.05
Paylean[a]	0.00	0.025	0.025	0.025	0.025	0.025
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis						
Total lysine, %	0.73	0.86	0.97	1.08	1.19	1.30
TID ratio, %						
Methionine:lysine	32	32	33	34	34	35
Methionine & cystine:lysine	66	60	60	60	60	60
Threonine:lysine	67	70	70	70	70	70
Tryptophan:lysine	18	17	17	18	17	17
ME, Kcal/lb	1,509	1,512	1,507	1,503	1,498	1,494
CP, %	13.31	15.83	17.40	18.97	20.56	22.14
Ca, %	0.48	0.50	0.51	0.52	0.54	0.55
P, %	0.45	0.48	0.49	0.51	0.53	0.55
Available P, %	0.18	0.19	0.19	0.20	0.20	0.21

[a]Experimental diets fed for 21 d before slaughter.
[b]Paylean fed at a rate of 5 ppm of ractopamine HCl per complete ton of feed.

Table 2. Diet Composition for Exp. 2 (As-fed Basis)[a]

	TID Lysine Level %					
Ingredient, %	0.65	0.75	0.85	0.95	1.05	1.15
Corn	82.58	76.02	72.03	68.02	64.00	59.98
Soybean meal (46.5% CP)	13.25	19.85	23.83	27.81	31.79	35.77
Choice white grease	2.00	2.00	2.00	2.00	2.00	2.00
Monocalcium phosphate (21% P)	0.60	0.60	0.60	0.60	0.60	0.60
Limestone	0.85	0.85	0.85	0.85	0.85	0.85
Salt	0.40	0.40	0.40	0.40	0.40	0.40
L-lysine HCl	0.15	0.075	0.075	0.075	0.075	0.075
DL-methionine	0.00	0.00	0.00	0.01	0.03	0.05
L-threonine	0.025	0.028	0.044	0.059	0.075	0.091
Vitamin premix	0.025	0.05	0.05	0.05	0.05	0.05
Trace mineral premix	0.07	0.05	0.05	0.05	0.05	0.05
Copper sulfate	0.05	0.05	0.05	0.05	0.05	0.05
Paylean[b]	0.00	0.025	0.025	0.025	0.025	0.025
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis						
Total lysine, %	0.73	0.84	0.94	1.05	1.16	1.27
TID amino acids, %						
Methionine:lysine	32	32	30	30	31	32
Methionine & cystine:lysine	66	65	62	60	60	60
Threonine:lysine	67	70	70	70	70	70
Tryptophan:lysine	18	21	21	21	21	21
ME Kcal/lb	1,509	1,500	1,496	1,491	1,487	1,482
CP, %	13.31	13.07	14.64	16.20	17.77	19.34
Ca, %	0.48	0.47	0.49	0.50	0.51	0.52
P, %	0.45	0.44	0.46	0.48	0.49	0.51
Available P, %	0.18	0.18	0.18	0.19	0.19	0.20

[a]Experimental diets fed for 21 d before slaughter.
[b]Paylean fed at a rate of 5 ppm of ractopamine HCl per complete ton of feed.

Table 3. Lysine Requirement of Gilts Fed Ractopamine HCl in a Commercial Facility (Exp. 1)[a]

	TID Lysine, %							Probability, P <			
	Control	With Ractopamine HCl									
Item	0.65	0.75	0.85	0.95	1.05	1.15	SE	Treatment	Linear	Quad[b]	Ractopamine HCl vs. Control
Initial wt, lb	218.3	215.4	215.6	218.3	217.8	219.4	3.7	0.85	0.19	0.99	0.75
Day 0 to 21											
ADG, lb	1.85	2.03	2.07	2.09	2.31	2.20	0.11	0.01	0.02	0.75	0.01
ADFI, lb	5.75	5.64	5.77	5.73	5.84	5.71	0.20	0.96	0.67	0.48	0.96
F/G	3.13	2.78	2.78	2.70	2.56	2.56	0.14	0.01	0.01	0.78	0.01
TID lysine/d, g	16.96	19.21	22.3	24.72	27.78	29.78	0.858	0.01	0.01	0.51	0.01
TID lysine/kg of gain, g	20.1	21.25	23.78	26.13	26.62	29.73	0.91	0.01	0.01	0.76	0.01
Final wt, lb	259.0	259.7	261.0	263.0	268.5	268.1	4.78	0.17	0.02	0.99	0.18
Final wt after removals, lb[c]	259.7	260.8	265.7	263.0	269.6	266.5	4.74	0.32	0.15	0.59	0.14
Plant wt, lb	256.2	258.6	263.7	262.1	267.0	263.0	4.27	0.19	0.22	0.30	0.44
Shrink, %[d]	1.37	0.84	0.74	0.26	1.01	1.31	0.54	0.33	0.32	0.16	0.20
Carcass wt, lb	194.0	196.9	201.9	200.2	203.9	200.4	3.8	0.14	0.29	0.26	0.03
Yield, %	75.7	76.1	76.6	76.3	76.4	76.2	0.01	0.72	0.99	0.54	0.16
Backfat, in	0.69	0.66	0.66	0.66	0.64	0.62	0.02	0.15	0.10	0.42	0.03
Loin depth, in	2.28	2.39	2.45	2.48	2.41	2.49	0.07	0.04	0.33	0.77	0.01
FFLI	49.96	50.44	50.63	50.55	50.92	51.01	0.253	0.01	0.02	0.73	0.01
Income/pig, $	136.06	138.79	141.3	140.15	142.57	142.61	2.322	0.07	0.10	0.83	0.01

[a]A total of 983 gilts (PIC L337 × L42), initially 217.4 lb, were used in a 21-d experiment, with 7 pens per treatment and a total of 42 pens.
[b]Quadratic.
[c]Average final weight after pigs with defects (belly ruptures and/or abscesses) were removed before being transported to the slaughter facility. The range of pigs removed was 1 to 3 per treatment.
[d]Shrink was calculated as the difference between average weight after removals and plant weight, divided by average weight after removals.

Table 4. Lysine Requirement of Gilts fed Ractopamine HCl in a Commercial Facility (Exp. 2)[a]

	TID Lysine, %							Probability, P <			
	Control	With Ractopamine HCl									
Item	0.65	0.75	0.85	0.95	1.05	1.15	SE	Trt[b]	Linear	Quad[c]	Ractopamine HCl vs. Control
Initial wt, kg	226.2	226.4	226.4	226.4	226.2	226.0	1.569	1.00	0.98	0.93	0.90
D 0 to 21											
ADG, lb	1.94	2.12	2.20	2.31	2.25	2.34	0.043	0.01	0.01	0.07	0.03
ADFI, lb	5.75	5.68	5.68	5.64	5.53	5.53	0.067	0.62	0.17	0.75	0.26
F/G	2.94	2.70	2.56	2.44	2.44	2.38	0.014	0.01	0.01	0.05	0.01
TID lysine/d, g	16.77	19.34	21.75	23.86	26.32	29.99	0.581	0.01	0.01	0.74	0.01
TID lysine/kg of gain, g	17.43	19.33	20.81	23.34	25.05	34.67	1.202	0.01	0.01	0.83	0.01
Final wt, lb	267.9	271.2	273.1	274.9	274.0	274.9	1.895	0.53	0.09	0.48	0.43
Plant wt, lb	266.1	268.5	270.9	272.7	269.0	270.7	2.022	0.76	0.73	0.53	0.20
Shrink, %[d]	0.68	0.93	0.78	0.84	1.53	1.49	0.415	0.19	0.05	0.45	0.19
Carcass wt, lb	199.3	202.6	204.1	204.8	203.5	203.9	1.500	0.60	0.80	0.61	0.09
FFLI	50.5	50.66	50.67	50.95	51.1	50.82	0.191	0.05	0.09	0.17	0.03
Backfat, in	0.66	0.67	0.66	0.64	0.62	0.65	0.459	0.14	0.04	0.14	0.41
Yield, %	74.9	75.4	75.4	75.1	75.0	75.3	0.005	0.85	0.85	0.74	0.22
Loin depth, in	2.48	2.51	2.52	2.50	2.52	2.52	0.968	0.80	0.68	0.94	0.19
Lean/pig, $	3.88	3.78	3.85	4.04	4.22	3.99	0.198	0.29	0.08	0.26	0.53
Value live/cwt, $	52.04	52.12	51.93	52.18	52.5	52.01	0.504	0.89	0.75	0.68	0.78
Income/pig, $	138.49	139.95	140.7	142.21	141.72	140.79	1.953	0.48	0.54	0.31	0.10

[a]A total of 932 gilts (PIC L337 × C22), initially 226.2 lb, were used in a 21-d experiment, with 7 pens (replications) per treatment and a total of 42 pens.

[b]Treatment.

[c]Quadratic.

[d]Shrink was calculated as the difference between average final weight, and plant weight, divided by average final weight.

THE EFFECTS OF FREQUENT OUT-OF-FEED EVENTS ON GROWTH PERFORMANCE OF NURSERY, GROWING, AND FINISHING PIGS

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Summary

An "out-of-feed" event is defined as a period of time that pigs do not have access to feed as a result of late feed delivery (feeders running empty) or bridging of bulk bins, feed lines, or feeders. To determine the effects of these out-of-feed events on pig growth performance, nursery and growing-finishing pig studies were conducted. In Exp. 1, 190 pigs (initial wt 14.0 lb) were allotted to one of four experimental treatments. Treatments included a 20-hour feed withdrawal for 1, 2, or 3 randomly selected times during the 35-d trial or a control treatment in which feeders were never withdrawn. Feeders were withdrawn on d 11 for pigs with 1 out-of-feed event, d 8 and 23 for pigs with 2 out-of-feed events, and d 9, 14, and 20 for pigs with 3 out-of-feed events. Throughout the study, the week in which an out-of-feed event occurred, ADG and ADFI were decreased ($P<0.06$), compared with those of control pigs. In some instances, if the out-of-feed event occurred early in the week, pig growth performance was intermediate to that of control pigs and the other pigs with an out-of-feed event later in the week. In the following week, however, pigs that had an out-of-feed event in the previous week had improved ADG and F/G, compared with performance of the others. For the overall study, there were no differences in growth performance among pigs with 0, 1, 2, or 3 out-of-feed events. In Exp. 2, 479 growing-finishing pigs were used in an 85-d trial in a commercial finishing barn to determine the effects of frequency and timing of out-of-feed events on pig performance. Treatments included feed withdrawal (20 h) weekly for the duration of the trial, feed withdrawn weekly from d 45 to 85 (market wt), or a control treatment in which pigs had access to feed for the duration of the trial. Feed withdrawal occurred on a randomly selected day, with the exception of Saturday, Sunday, or a day before a weigh day (usually a Wednesday every other week). There were no differences ($P>0.13$) in growth performance throughout the 85-d trial. With weekly out-of-feed events in the finishing phase, there is a possibility that pigs may quickly learn to adjust their feed intake for the out-of-feed event. In this study, however, results suggest that out-of-feed events (20 h or less) will have no long-term effects on growth performance in nursery or growing-finishing pigs.

(Key Words: Finishing Pigs, Feed Management, Out-of-feed Events, Starter Pig.)

Introduction

Out-of-feed events, when pigs do not have access to feed, can be caused by delayed feed

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delivery or feed bridging in bulk bins, feed lines, or feeders. Recent research conducted by the University of Nebraska observed that, in finishing pigs, when feeders were withdrawn (20 h) on a randomly selected day, weekly for 16 weeks, pigs with weekly out-of-feed events had decreased ADG and ADFI. The reduction in performance was a result of decreased ADG and ADFI in the first 8 weeks of the study. The authors suggested that, with weekly out-of-feed events, it seemed that pigs adjusted their feed intake to account for the days without feed.

Many dietary recommendations, such as fine grinding and adding fat, increase the potential for feed bridging in bulk bins and feeders, resulting in an out-of-feed event. In addition, there are times when feed orders and/or deliveries are late, again resulting in an out-of-feed event. The objective of these experiments was to evaluate the effect on growth performance when out-of-feed events take place randomly in both nursery and growing-finishing phases.

Procedures

Experiment 1. A total of 190 pigs (initially 14.0 lb) were used in a 35-d trial. Pigs were blocked by weight and randomly allotted to one of four treatments with 6 pigs/pen and 8 pens/treatment. The trial was conducted at the Kansas State Swine Teaching and Research Center in an environmentally controlled nursery. Pigs were assigned to 5 × 5 ft pens with one self-feeder and one nipple waterer to allow *ad libitum* access to water and feed (except during the 20 h feed withdrawal).

Pigs were fed standard starter diets based on a feed budget with 1 lb/pig of a SEW diet, 5 lb/pig of a transition diet, 15 lb/pig of the phase 2 diet and a Phase 3 diet fed for the rest of the trial. Treatments included a control in which pigs had continual access to feed, or 1, 2, or 3 out-of-feed events over the 35-d study. Feeders were removed from pens for 20 h (12:00 noon to 8:00 a.m. the following morning). The out-of-feed events occurred on d 11 for the pigs with 1 event, d 8 and 23 for pigs with 2 events, and d 9, 14, and 20 for pigs with 3 out-of-feed events. The withdrawal days were chosen at random, with exclusion of the first week after the pigs were weaned to allow for acclimation to the nursery. Pigs and feeders were weighed on d 0, 7, 14, 21, 28, and 35 to determine ADG, ADFI, and F/G.

Experiment 2. A total of 479 pigs (BW of 91.7 lb) were used in an 85-d study. Pigs were allocated to pens based on sex, then were blocked by weight, and were randomly allotted to one of three treatments. Each pen contained 20 pigs, with 8 pens/treatment with the exception of 1 pen that contained 19 pigs. Pigs were housed at a commercial research finishing barn in southern Minnesota. Facilities included 8 × 18 ft pens with totally slatted floors and provided 7.2 sq ft per pig. Pens were equipped with a cup waterer and 4-hole self feeder. Pen gating was adjusted to provide the same square footage per pig for the pen that contained 19 pigs or when a pig died.

Diets were typical grower-finisher diets with minimal amounts of added crystalline lysine to maintain recommended amino acid ratios. Pigs were fed on the basis of a feed budget, with pigs in the first three phases allocated 150 lb/pig, and the fourth phase fed until market weight (no Paylean® was fed in this trial). Treatments included a control with no out-of-feed events for the duration of the trial, out-of-feed events occurring each week for the duration of the trial, and out-of-feed events occurring each week beginning on d 45 of the study. Feed withdrawal occurred on a randomly selected day each week, with the exception of Saturday, Sunday, or the day before a weigh day (usually a Wednesday every other week). Pigs were weighed, and feed measurements were recorded, on d 0, 16, 29, 45, 59, 73, and 85 to determine ADG, ADFI, and F/G.

Growth data in Exp. 1 were analyzed as a randomized complete-block design, with pen as the experimental unit. In Exp. 2, data were analyzed as a completely random block, with pen as the experimental unit. For both studies, the MIXED procedure of SAS and least squares means were used to determine treatment differences.

Results

Experiment 1. The first out-of-feed event for the three treatment groups occurred between d 7 and 14 of the study (Table 1). During this time, ADG and ADFI were decreased ($P<0.07$) for pigs with an out-of-feed event on d 11 (1 out-of-feed event), compared with performance of control pigs. Performance of pigs with an out-of-feed event on d 8 or 9 (2 and 3 out-of-feed events, respectively) was intermediate. From d 14 to 21, pigs that previously had an out-of-feed event during d 7 to 14, (1 and 2 out-of-feed events) had similar ADG, ADFI, and F/G, compared with those of the control pigs. Pigs with 3 out-of-feed events had an out-of-feed event on d 20, the 20 h immediately before they were weighed. Thus their ADG, ADFI, and F/G were dramatically poorer ($P<0.05$) than those of pigs on all other treatments, which did not have an out-of-feed event. From d 21 to 28, the pigs with an out-of-feed event on d 20 had increased ADG and improved F/G, compared with those of the other treatment groups. Despite having feed withdrawn on d 23, pigs with 2 out-of-feed events had similar ADG, ADFI, and F/G to those of control pigs or pigs with only 1 previous out-of-feed event. From d 28 to 35, there were no out-of-feed events and no differences ($P = 0.15$) among the four treatment groups. Likewise, for the overall experimental period (d 0 to 35), there were no differences ($P>0.87$) in ADG, ADFI, F/G, or final pig weight among pigs with 0, 1, 2, or 3 out-of-feed events.

Experiment 2. From d 0 to 45, 45 to 85, or the overall d 0 to 85 period, there were no differences in ADG, ADFI, F/G, or average final weight among pigs with weekly out-of-feed events from d 0 to 85 or d 45 to 85, compared with the control pigs that did not have an out-of-feed event.

Discussion

In nursery pigs, an out-of-feed event resulted in decreased ADG for the week in which it occurred, but pigs quickly compensated in the following week. This might suggest that the weight loss in a 20-h out-of-feed event is primarily from contents of the gastrointestinal system, and likely is not tissue loss. Once pigs had access to feed again, their weight returned to similar values to those of pigs without an out-of-feed event, and there were no differences for overall ADG or final weight.

In the growing-finishing trial, because the earlier data from the University of Nebraska reported differences, we were surprised that multiple out-of-feed events had no effects on growth or final weight. In the Nebraska study, a weekly out-of-feed event decreased ADG and ADFI as a result of poorer growth in the first half of the study (50 to 150 lb). The authors suggested that, with weekly out-of-feed events, despite occurring on randomly selected days of each week, that pigs adjusted their feed intake to account for the out-of-feed event. Perhaps with a weekly out-of-feed event, despite occurring on randomly selected days of the week, pigs will quickly compensate for any decrease in performance that occurred during the 20 h without feed. In our study, pigs were able to compensate as early as the nursery phase and throughout the growing-finishing phase, unlike the Nebraska study, in which growing pigs (50 lb) were not able to compensate. Future research might examine the effects of fewer out-of-feed events spaced out randomly over longer periods of time. Under the conditions of our studies, however, out-of-feed events did not effect overall pig growth performance.

Table 1. Effects of Feeder Withdrawal on Nursery Pig Performance[a]

	Feeder Withdrawal on Day[b]					
Item	0	11	8 and 23	9, 14, and 20	SED	P <
Initial weight, lb	14.02	14.01	14.00	14.00	0.635	0.47
d 0 to 7						
ADG, lb	0.35	0.40	0.40	0.39	0.029	0.42
ADFI, lb	0.31	0.33	0.33	0.35	0.021	0.42
F/G	0.90	0.82	0.82	0.93	0.045	0.28
d 7 to 14						
ADG, lb	0.96[c]	0.85[d]	0.90[d]	0.88[d]	0.033	0.06
ADFI, lb	1.02[c]	0.92[d]	0.93[d]	0.93[d]	0.044	0.07
F/G	1.06	1.09	1.04	1.05	0.045	0.28
d 14 to 21						
ADG, lb	1.03[c]	1.07[c]	1.09[c]	0.53[d]	0.049	0.01
ADFI, lb	1.45	1.56	1.51	1.26[d]	0.072	0.02
F/G	1.43[c]	1.47[c]	1.40[c]	2.44[d]	0.098	0.01
d 21 to 28						
ADG, lb	1.47[c]	1.37[c]	1.36[c]	1.85[d]	0.059	0.01
ADFI, lb	2.08	2.01	2.03	2.23	0.094	0.35
F/G	1.41[c]	1.47[c]	1.49[c]	1.20[d]	0.035	0.01
d 28 to 35						
ADG, lb	1.61	1.66	1.71	1.72	0.042	0.15
ADFI, lb	2.51	2.55	2.61	2.54	0.071	0.68
F/G	1.57	1.53	1.53	1.48	0.033	0.20
d 0 to 35						
ADG, lb	1.08	1.07	1.09	1.07	0.032	0.94
ADFI, lb	1.48	1.47	1.48	1.46	0.046	0.96
F/G	1.37	1.38	1.36	1.36	0.015	0.87
Final weight, lb	51.93	51.49	52.12	51.57	1.592	0.94

[a]A total of 192 pigs, initially 14.0 lb, were used, with 6 pigs per pen and 8 pens per treatment.

[b]Feeders withdrawn on random days for 20 hours each from 12:00 noon to 8:00 a.m.

[c,d]Means in the same row with different superscripts differ (P<0.05).

Table 2. Effects of Feeder Withdrawal on Finishing Pig Performance (Exp. 2)[a]

	Weekly Feed Removal Period[b]				Sex			Probability, P <	
Item	None	d 0 to 85	d 45 to 85	SE	Barrow	Gilt	SE	Treatment	Sex
d 0 to 45									
ADG, lb	2.10	2.04	2.08	0.026	2.19	1.96	0.021	0.34	0.01
ADFI, lb	5.16	5.15	5.11	0.058	5.47	4.81	0.047	0.86	0.01
F/G	2.46	2.52	2.46	0.027	2.50	2.45	0.022	0.22	0.13
d 45 to 85									
ADG, lb	2.14	2.19	2.21	0.026	2.19	2.17	0.022	0.16	0.59
ADFI, lb	6.71	6.91	6.78	0.069	7.11	6.49	0.057	0.15	0.01
F/G	3.14	3.15	3.07	0.030	3.25	3.00	0.024	0.15	0.01
d 0 to 85									
ADG, lb	2.12	2.11	2.14	0.022	2.19	2.06	0.018	0.64	0.01
ADFI, lb	5.88	5.98	5.89	0.056	6.24	5.60	0.046	0.46	0.01
F/G	2.78	2.83	2.75	0.024	2.85	2.72	0.020	0.13	0.01
Weight, lb									
d 0	91.3	91.4	92.4	1.5	93.6	89.8	1.3	0.87	0.05
d 45	185.8	183.6	186.4	2.2	192.2	178.4	1.8	0.64	0.01
d 86	271.4	271.2	274.8	2.7	280.0	264.9	2.2	0.59	0.01

[a]A total of 479 pigs, initially 91.7 lb, were used, in this study, with 8 replications per treatment.
[b]Feed removal was simulated by feeders being closed, or by running the feeder empty. Out-of-feed events were weekly for the specified period for 20-h periods on random days.

EFFECT OF MIXING PIGS OR MAINTAINING PEN INTEGRITY ON THE RESPONSE TO GROWING-FINISHING SPACE ALLOCATION[1]

R. D. Goodband, M. C. Brumm[2], L. J. Johnston[3], K. Stalder[4], and the NCERA-89 Committee on Swine Management[5]

Summary

A cooperative study using 906 pigs was conducted to evaluate either mixing pigs or maintaining pen integrity during the move from nursery to finishing, and its effect on finishing space allowance. Treatments were arranged in a 2 × 2 factorial, with main effects of mixing or maintaining pen integrity as pigs were moved to finishing facilities (BW 54.9 lb) and providing either 6.0 or 8.0 ft^2 per pig. There were 8 pens per block and 7 blocks. In 2 pens, when moving from nursery to finishing, pen integrity was maintained and pens were allocated either 6.0 or 8.0 ft^2 per pig. For mixed treatments, pigs from 3 pens were mixed into 3 new pens and were assigned 6.0 ft^2 per pig. Likewise, 3 more pens were mixed and were assigned 8.0 ft^2 per pig. Individual pen was the experimental unit. From d 0 to 14, no treatment effects were observed ($P>0.16$). A mixing by space allocation interaction was observed ($P<0.05$) for overall ADG and F/G. The interactions were a result of mixed pigs at 6.0 ft^2 having better ADG and F/G than unmixed pigs, whereas unmixed pigs had better ADG and F/G at 8.0 ft^2. Despite the interactions, the actual differences between treatment groups were relatively small. Overall (d 0 to 118), maintaining pen integrity did not affect ADG or ADFI, compared with mixing pigs (1.92 and 5.20 vs. 1.93 and 5.20 lb/d, respectively). But pigs provided 6.0 ft^2 had decreased ADG ($P<0.01$) and ADFI ($P<0.01$), compared with those of pigs provided 8.0 ft^2 (1.90 and 5.16 vs. 1.95 and 5.25 lb/d, respectively). These results confirm expected reductions in growth and feed intake of pigs restricted in space. In this study, maintaining pen integrity when moving pigs from nursery to finishing facilities had no beneficial effect on pig performance, compared with mixing pigs into new social groups.

(Key Words: Mixing, Pigs, Space.)

Introduction

The NCERA-89 Committee on Swine Management is a multi-state committee that focuses on applied swine management issues related to animal welfare and performance. Previous NCERA-89 studies suggest that when pigs are mixed into new social groups

[1]The authors thank Kelly Brown for conducting the statistical analysis portion of this study.

[2]University of Nebraska.

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[5]Committee members during the study in addition to those listed above were G. Apgar, SIU; M. Carlson, UMO; R. K. Christenson, USDA; L. Christianson, UIL; M. Ellis, UIL; S. J. Moeller, OSU; B. Richert, Purdue; and R. C. Thaler, SDSU.

after the nursery phase, space restrictions during the growing-finishing phase result in a decrease in daily feed and daily gain. When the social group remained intact during the move from nursery to growing-finishing, space restrictions during the growing-finishing phase had no effect on daily feed or daily gain. If maintaining social hierarchy (pen integrity) during the move from nursery to growing-finishing alters the response to space allocation, this could have a tremendous impact on producer profitability, as well as redefining animal welfare implications and recommendations. Weaning-to-finishing production systems rely on maintenance of pen integrity from weaning to slaughter. Space allocation recommendations for weaning-to-finishing currently are based on data sets derived from studies moving pigs from nursery to growing-finishing. It's possible that the maintenance of social hierarchy common to weaning-to-finishing production systems alters the response to space allocation in a similar manner to that hypothesized for pigs moved from nursery to growing-finishing facilities. Therefore, the objective of this study was to determine the effect of maintaining social hierarchy (pen integrity) on space requirements for growing-finishing pigs reared in conventional nurseries and moved to growing-finishing facilities, and for pigs reared in weaning-to-finishing facilities.

Procedures

This study was conducted in facilities at the University of Nebraska, Concord; The University of Minnesota, Morris; and the University of Tennessee, Jackson. Nebraska and Minnesota contributed two replications and Tennessee contributed three replications.

The experiment was divided into two separate but similar experiments. The first was conducted with conventional nursery and growing-finishing facilities (MN and TN). The other used weaning-to-finishing facilities (NE).

Pens of pigs were assigned to treatment at weaning. The experimental treatments were arranged in a 2 × 2 factorial, with main effects of mixing or maintaining pen integrity as pigs were moved to finishing facilities (BW 54.9 lb) and providing either 6.0 or 8.0 ft^2 per pig. To accomplish this, pigs from 3 pens were evenly distributed from each nursery or weaning-to-finishing pen to 3 finishing pens (Figure 1; one-third of the pigs in the new pen coming from each of the 3 nursery or weaning-to-finishing pens). In addition, 1 pen of pigs was kept intact (no mixing) and moved to finishing facilities. These mixing/no mixing treatments were replicated within growing-finishing space allocation of either 6.0 or 8.0 ft^2. Both space-allocation treatments during the growing-finishing phase had similar numbers of pigs per pen. Pen sizes were adjusted to maintain the appropriate stocking density.

There were 8 pens per block and 7 blocks. In 2 pens, pen integrity was maintained, and pens were allocated to either 6.0 or 8.0 ft^2 per pig. For mixed treatments, pigs from 3 pens were mixed into 3 new pens and assigned to 6.0 ft^2 per pig. Likewise, 3 more pens were mixed and assigned to 8.0 ft^2 per pig. All pigs and feeders were weighed every 2 weeks, and 1 and 2 weeks after mixing to calculate ADG, ADFI, and F/G. The study was terminated at 118 days, when the average pen weight approached 250 lb.

Each experiment station followed its own standard nutrition and management protocols from weaning to approximately 50 lb. From 50 lb to market weight, the same dietary sequence was used, including corn-soybean meal diets formulated to 1.20, 1.00, 0.85, and 0.75% total lysine from 50 to 80, 80 to 150, 150 to 200, and 200 to approximately 250 lb, respectively.

Data were analyzed as a 2 ×2 factorial by using the MIXED procedure of SAS. Main effects of mixing or maintaining pen integrity,

space allowance (6.0 or 8.0 ft^2), and their interactions were evaluated. Mean values of the 3 mixed pens within each space were combined and used as a single observation. Fixed model effects included space allowance, pen integrity, and their interaction, and random effects included experimental station, replication, and their interaction.

Results and Discussion

There were no mixing by space allocation interactions observed (P>0.05), with the exception of overall ADG and F/G (Table 1). The interactions were a result of mixed pigs at 6.0 ft^2 having better ADG and F/G than unmixed pigs, whereas unmixed pigs had better ADG and F/G at 8.0 ft^2. Despite the interactions, the actual differences between treatments groups were relatively small and, therefore, main effects of mixing and space allocation are discussed.

From d 0 to 14 after the mixing and space allocations were implemented, there were no differences (P>0.20) between either mixing pigs or maintaining pen integrity. Furthermore, there were no differences (P>0.75) between pigs allocated 6.0 or 8.0 ft^2. One would not expect a difference in pig performance with either 6.0 or 8.0 ft^2 during the first two weeks of the study. At this weight (54 lb), approximately 4 ft^2 is adequate to optimize pig performance. But any potential differences among pigs due to mixing would be expected to be found these first two weeks. The re-establishment of the pens' social hierarchy, and associated fighting that comes with it, might be expected to decrease ADG among mixed pigs but not in pens where pen integrity was maintained. This was not observed in this study, and if there were a slight decrease in ADG associated with mixing pigs into new pens, they quickly compensated.

For the overall study (d 0 to 118), there were no differences (P>0.94) between pigs that were either mixed or not when moved from nursery to growing-finishing facilities. But pigs allowed 6.0 ft^2 had decreased (P<0.01) ADG and tended to have decreased (P = 0.11) ADFI. This response is consistent with other studies evaluating stocking density and space allocation among pigs, and indicates that pigs require greater than 6.0 ft^2 in the finishing phase for maximum growth performance.

In conclusion, these results confirm expected reductions in growth and feed intake of pigs restricted in space (6.0 vs. 8.0 ft^2), although the reductions were relatively small. In this study, maintaining pen integrity when moving pigs from nursery to finishing facilities had no beneficial effect on pig performance.

Table 1. Effects of Mixing Pigs or Maintaining Pen Integrity and Space Allowance on Pig Performance[a]

	Space Allowance × Pen Integrity						Main Effects							
	Crowded (6 ft^2)		Uncrowded (8 ft^2)				Space Allowance				Pen Integrity			
Item	Mixed	Unmixed	Mixed	Unmixed	SED	Interaction	6 ft^2	8 ft^2	*P*-value	SED	Mixed	Unmixed	P-value	SED
Day 0-14														
ADG, lb	1.79	1.73	1.77	1.72	0.068	0.92	1.76	1.74	0.76	0.048	1.78	1.72	0.25	0.048
ADFI, lb	3.45	3.37	3.52	3.26	0.177	0.46	3.41	3.39	0.88	0.130	3.49	3.32	0.20	0.130
F/G	1.91	1.94	1.99	1.89	0.063	0.16	1.93	1.94	0.75	0.045	1.95	1.92	0.40	0.045
Day 0-118														
ADG, lb	1.92^{bc}	1.88^{b}	1.93^{c}	1.97^{c}	0.025	0.05	1.90	1.95	0.01	0.018	1.93	1.92	0.91	0.018
ADFI, lb	5.17	5.14	5.24	5.26	0.079	0.61	5.16	5.25	0.11	0.056	5.20	5.20	0.95	0.056
F/G	2.69^{bc}	2.73^{b}	2.71^{bc}	2.67^{c}	0.027	0.04	2.71	2.69	0.34	0.019	2.70	2.70	0.94	0.019

[a]Data were analyzed as a 2 × 2 factorial design with the Mixed procedure of SAS as a means-over-block approach (the combined values for the 3 mixed pens within a space allocation were used as a single observation). Fixed model effects included space allowance, pen integrity, and their interaction, and random effects included experimental station, replication, and their interaction. The Kenward-Roger adjustment was used for the degrees of freedom. Pigs were moved from nursery to finishing facilities at approximately 54.9 lb, when they were mixed or not, and moved to pens with either 6 or 8 ft^2.

[b,c]Means in the same row with different superscripts differ (P<0.05).

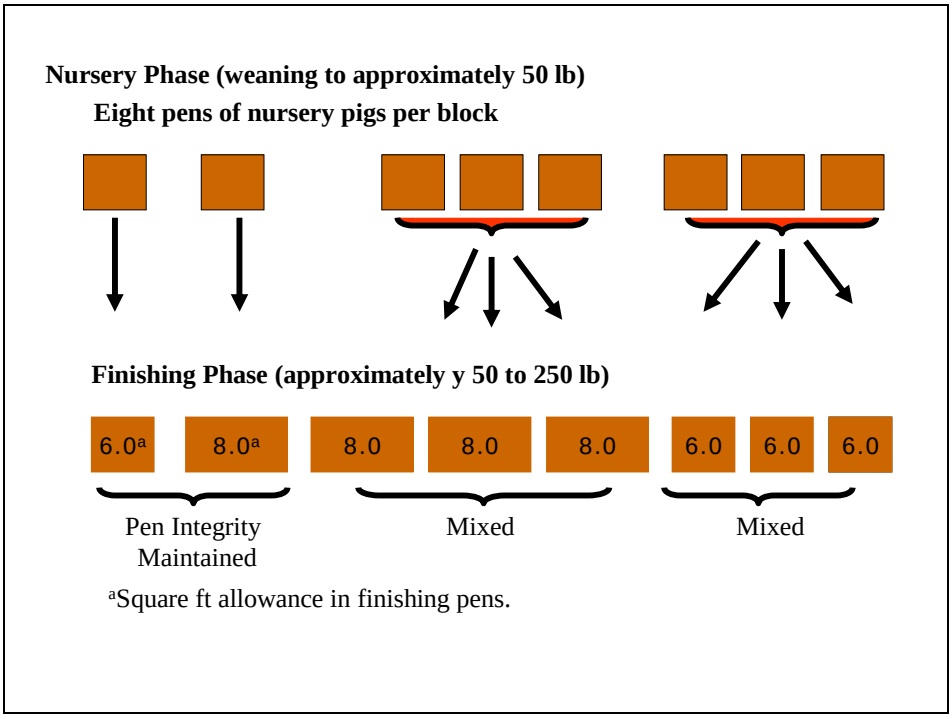

Figure 1. Diagram of Treatment Structure.

COMPARISON OF PARTICLE SIZE ANALYSIS OF GROUND GRAIN WITH, OR WITHOUT, THE USE OF A FLOW AGENT

R. D. Goodband, W. Diederich[1], S. S. Dritz[2], M. D. Tokach, J. M. DeRouchey, and J. L. Nelssen

Summary

The American Society of Biological and Agricultural Engineers' standard for particle size analysis indicates that the analysis can be conducted with or without the use of a flow agent. Because of this allowed variation in procedures, particle size analysis results can be variable and difficult to interpret, depending on whether the laboratory uses a flow agent or not. Therefore, a retrospective analysis was made of 603 samples of ground corn analyzed for particle size with, or without, 0.5 g of synthetic amorphous precipitated silica (Sipernat® 22-S) per 100 g of sample. Results of both analyses were compared with a Method of Agreement analysis. Results indicated that there was a bias between the two procedures for particle size analysis, but that the bias was consistent across the range of particle sizes evaluated (400 to 1000 µ). Particle size analysis conducted with a flow agent will result in a mean particle size that is approximately 80 µ smaller than the result from analysis without a flow agent. The same procedures were used in comparison of particle size standard deviation. Using a flow agent produced a greater particle size standard deviation value than without a flow agent. Unlike the bias for the particle size analysis, which was consistent for the wide range of samples evaluated, the standard deviation values showed a significant bias. As the standard deviation of the sample increased, the magnitude of difference between the two procedures also became greater. Results of this study indicate that there are differences in results between the two procedures; therefore, selection of one of the two procedures as the official standard is necessary. Also, it is important to know if a flow agent was, or was not, used in the analysis when interpreting results.

(Key Words: Flow Agent, Particle Size, Quality Control.)

Introduction

Particle size analyses of ground grain or complete diets are an important quality control procedure used in both commercial and on-farm feed mills. Reducing the particle size of the diet improves feed efficiency, and it has been calculated that every 100 µ increase in particle size above the recommended 700 µ will cost the producer $0.50 per pig in poorer feed efficiency. Therefore, achieving the proper particle size in swine diets has significant financial implications. The Kansas

[1]Midwest Laboratories, Inc., 13611 B Street, Omaha, NE 68144.
[2]Food Animal Health and Management Center, College of Veterinary Medicine.

State University Swine Nutrition Laboratory analyzes approximately 800 samples per year for particle size. Numerous commercial laboratories also perform this test. But the American Society of Biological and Agricultural Engineers' standard for particle size analysis indicates that the analysis can be conducted with, or without, the use of a flow agent. Because of allowed variation in procedures, particle size analysis results can be variable and difficult to interpret, depending on whether the laboratory uses a flow agent or not. A flow agent added to the ground grain would help move particles through the screens and potentially result in a finer particle size and greater particle size standard deviation than results from samples analyzed without a flow agent. Therefore, the objective of this study was to compare the results of particle size analysis conducted either with, or without, the use of a flow agent.

Procedures

A retrospective analysis was made of 603 samples of ground corn analyzed for particle size at a commercial laboratory (Midwest Laboratories, Inc., Omaha, NE). The analysis was conducted using a Ro-Tap shaker with a stack of Tyler screens (Table 1). Rubber balls and/or carmichaels (brushes) also were used on top of the various screens. Samples of ground grain were put on the top sieve, and the sieves were shaken with the Ro-Tap for 10 minutes. The amount of material was then weighed, and the results were entered into a spreadsheet that calculated the mean particle size and its standard deviation. Next, a second sample (≈100 g) was mixed with 0.5 g of synthetic amorphous precipitated silica (Sipernat® 22-S) and the procedure was repeated. Results of both analyses were compared with a Method of Agreement analysis. In brief, this statistical procedure is used to compare results of two different analytical procedures.

Table 1. Tyler Sieve Numbers Used in Analysis

Sieve Openings, microns	Tyler Number (meshes/in)	No. of Balls and Brushes
3360	6	---
2380	8	---
1680	10	3 balls
1191	14	3 balls
841	20	1 ball & 1 brush
594	28	1 ball & 1 brush
420	35	1 ball & 1 brush
297	48	1 ball & 1 brush
212	65	1 ball & 1 brush
150	100	1 brush
103	150	1 brush
73	200	1 brush
53	270	1 brush
Pan	---	---

Results

A comparison was made between samples analyzed for particle size with a flow agent (X axis; Figure 1) and without a flow agent (Y axis; Figure 1). The straight line running diagonally through the middle of the chart is included because, if both methods were in perfect agreement, all values should be on this line. In addition, if the values are consistently distributed on either side of the perfect agreement line, this would indicate that one of the procedures is biased or consistently different than the other. In Figure 1, all the samples are above the line, indicating that there is a bias and that using a flow agent will result in a particle size value smaller than will result from using no flow agent. The next procedure was to see if this bias was consistent across the different particle sizes (Figure 2). On the X axis is the average of the two procedures (mean particle sizes of the analysis

with and without flow agent). On the Y axis is the actual difference between the two results (particle size with flow agent minus particle size without flow agent). The slope of this line (0.027) trended not to be different than zero (P = 0.13), indicating a similar bias across the range of particle sizes tested, but the intercept (-80 µ) was highly significant (P<0.001). This indicates that, across the range of particle sizes tested, the analysis with a flow agent will consistently be 80 µ less than the analysis without a flow agent. For example, if the same sample is split and sent to two labs, one lab is using a flow agent and the other lab is not, and the value from the lab using the flow agent is 620 µ, the expected value from the lab not using flow agent is 700 µ.

The same comparison of the particle size standard deviation with, or without, a flow agent was conducted (Figure 3). This compared results of the standard deviation between samples of corn analyzed with a flow agent (X axis) and without a flow agent (Y axis). Using a flow agent will produce a greater standard deviation value than not using a flow agent. The diagonal through the center of the chart would represent a perfect comparison between the two procedures. The Method of Analysis procedure then compared the average of the two procedures (Figure 4; X axis = mean of the particle size standard deviations, with and without flow agent) with the actual difference between the two results (Y axis = standard deviation with flow agent minus standard deviation without flow agent). Unlike the bias for the particle size analysis, which was very consistent for the wide range of samples evaluated, the standard deviation values showed a significant bias. There was strong evidence (P<0.05) that the slope of this line (0.4596) was different than zero, indicating that the magnitude of difference between the two procedures increased as the standard deviation of the sample increased.

Discussion

Particle size analysis is an economically important quality control component of a feeding program. In addition, particle size standard deviation is an indicator of the flow ability of the diet. Because the American Society of Biological and Agricultural Engineers' standard for particle size analysis is not specific for the use of a flow agent, this can lead to variation in how results are interpreted. The results for mean particle size analysis between the two methods seem to have good agreement. Although there is an 80-µ difference, this bias could be adjusted for when comparing or reporting results. Because research studies evaluating the effects of particle size on pig performance are conducted on grain or feed samples analyzed without a flow agent, reporting results obtained with a flow agent is confusing, unless those results are adjusted (by adding 80 microns).

For particle size standard deviation, the little data that has been collected evaluating its effects on feed flow ability has been collected by measuring standard deviation without a flow agent. For this parameter, there is no opportunity to standardize the results of one procedure to those of the other. Therefore, if specifying an acceptable particle size standard deviation, the method of analysis (with or without flow agent) must also be specified.

In conclusion, one might argue whether the use of a flow agent may or may not provide a "better" evaluation of a sample's particle size or particle size standard deviation than not using a flow agent. The use of a flow agent facilitates the movement of particles through the screens, resulting in a finer particle size and greater standard deviation of the sample, compared with not using a flow agent. To the best of our knowledge, all existing data reporting the effects of particle size and its standard deviation on growth

performance and diet flow ability have been conducted without the use of a flow agent. Thus, use of a flow agent in analysis would require some type of conversion when interpreting or comparing results. Because there are differences in results between the two procedures, official standard methods of feed grain particle size analysis need clarification. Also, when evaluating particle size analysis results across laboratories, it is important in interpretation of results to know if a flow agent has been used in the analysis.

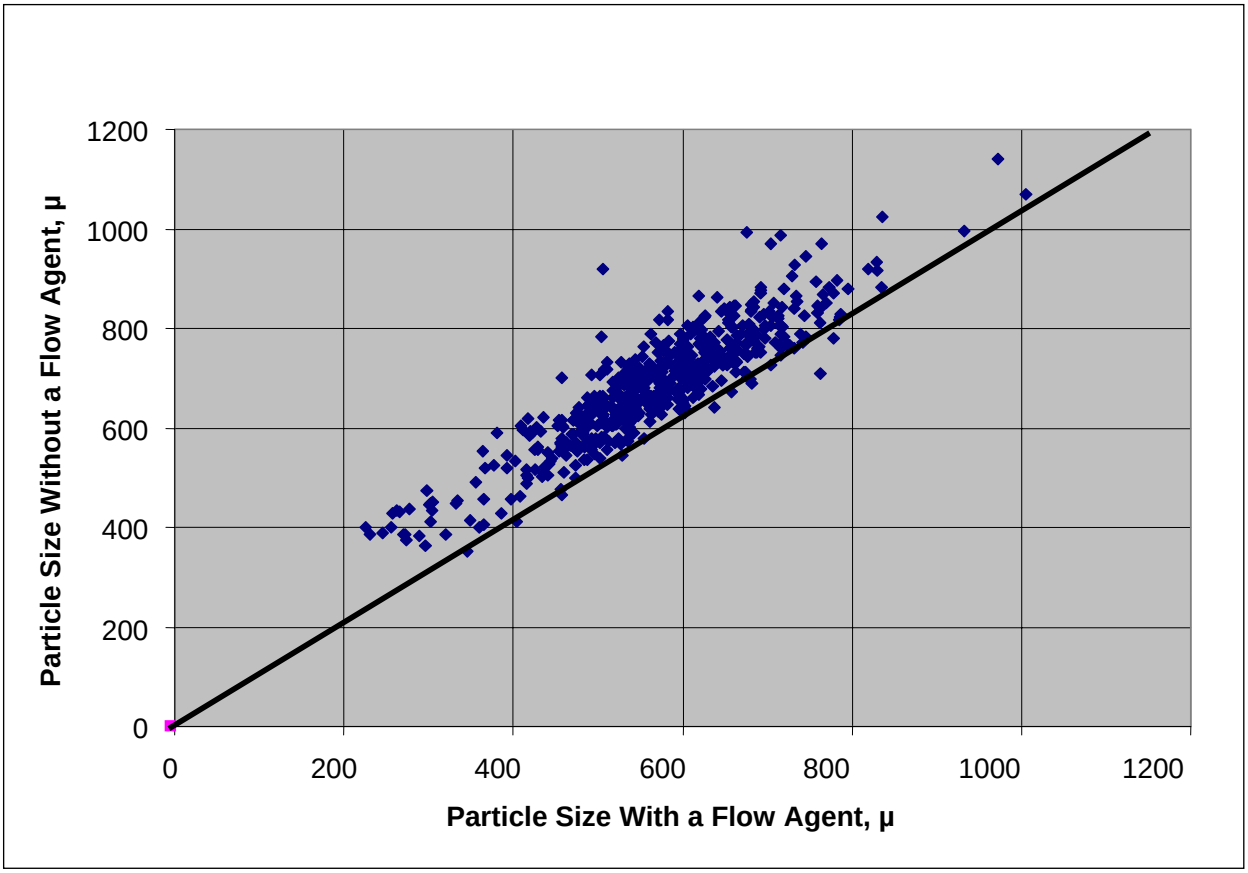

Figure 1. Comparison Between Analysis of Corn Particle Size With, and Without, a Flow Agent.

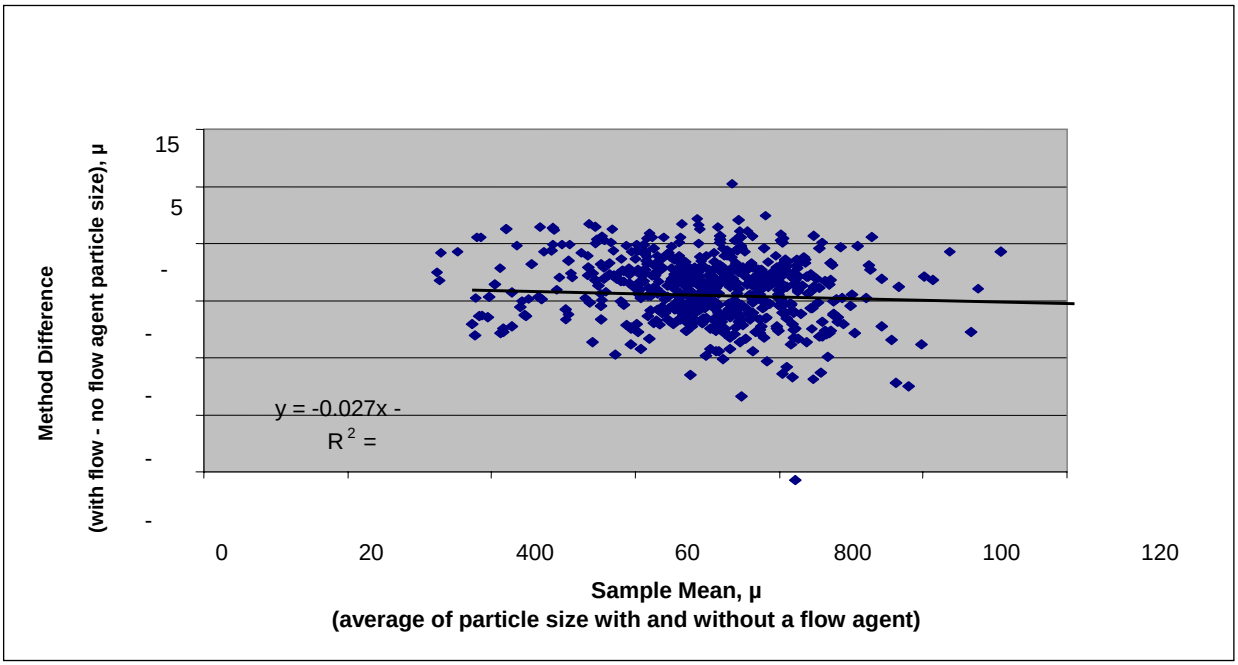

Figure 2. Method of Agreement Between Particle Size Analysis With, and Without, a Flow Agent.

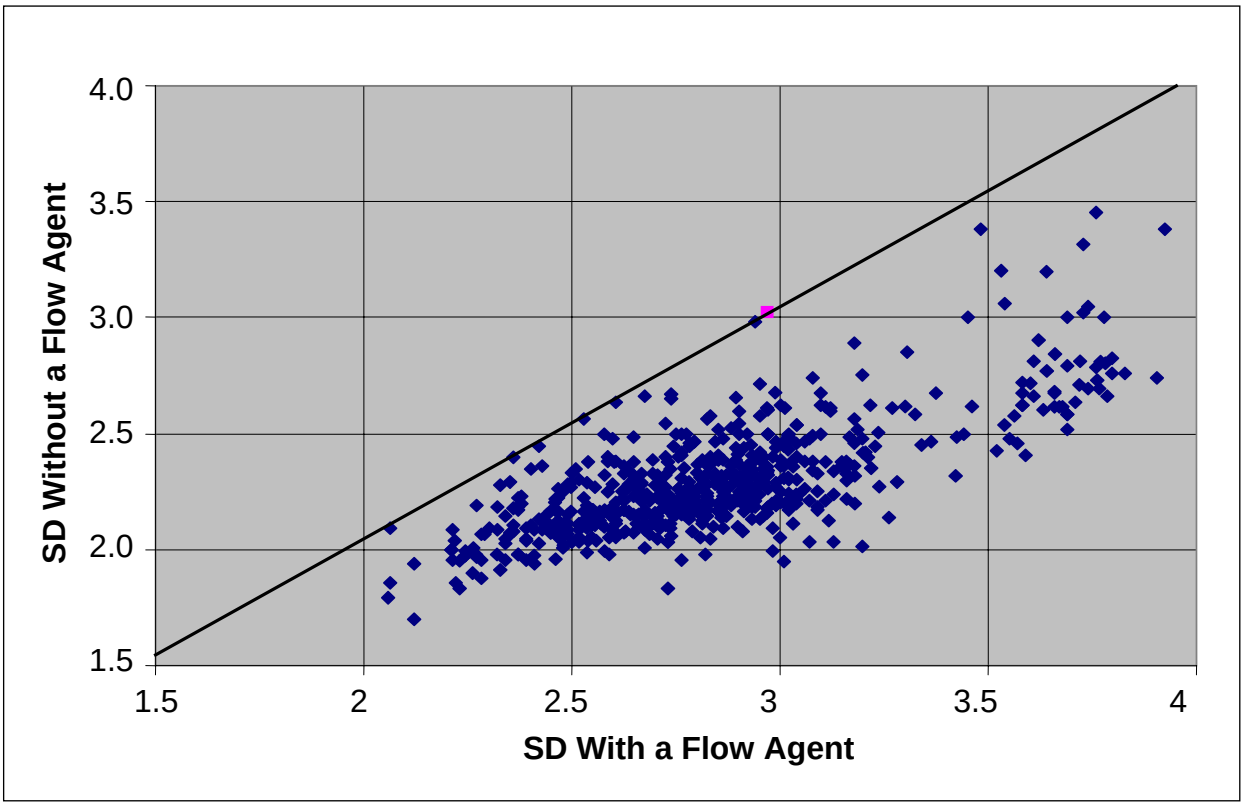

Figure 3. Comparison Between Corn Particle Size Standard Deviation (SD) With, and Without, a Flow Agent.

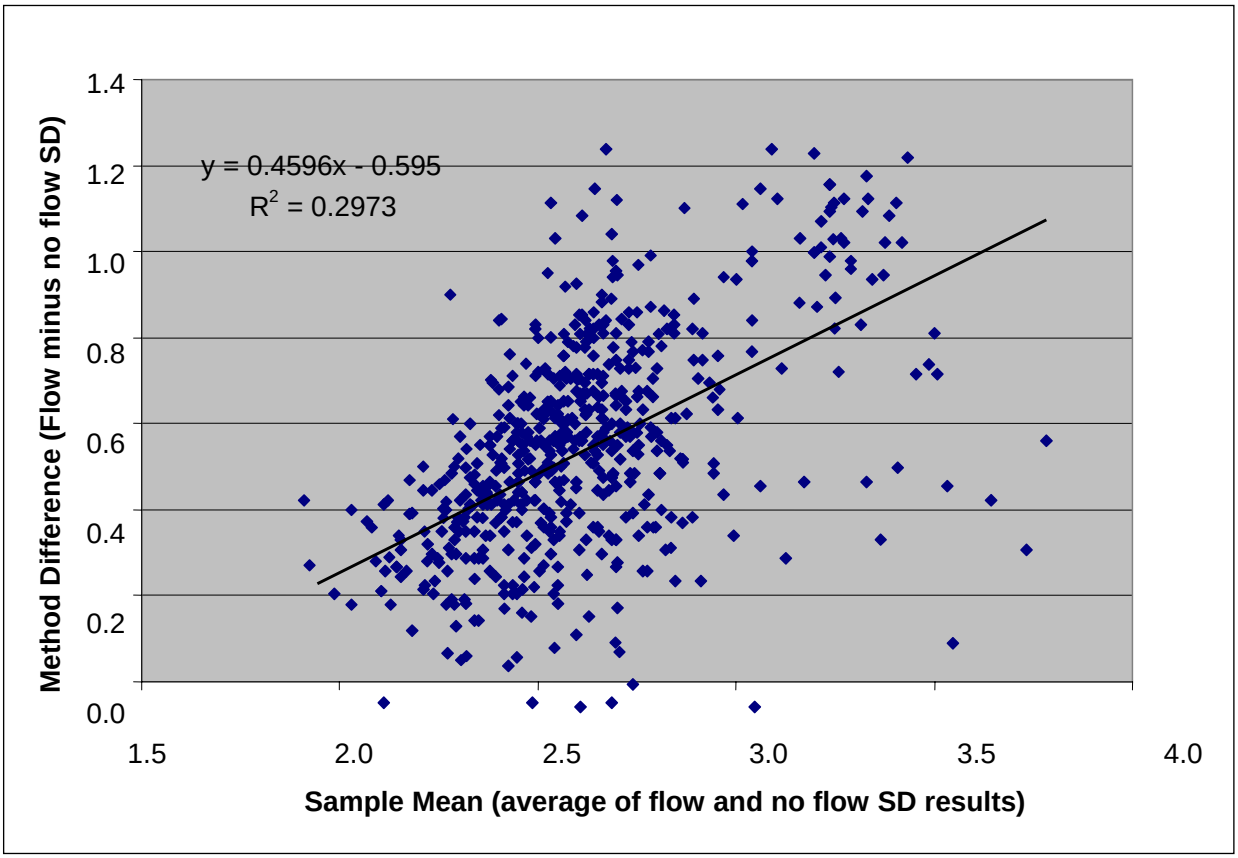

Figure 4. Method of Agreement Between Standard Deviation (SD) With, and Without, a Flow Agent.

INDEX OF KEY WORDS

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Hill's Pet Nutrition Inc., Topeka, KS
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