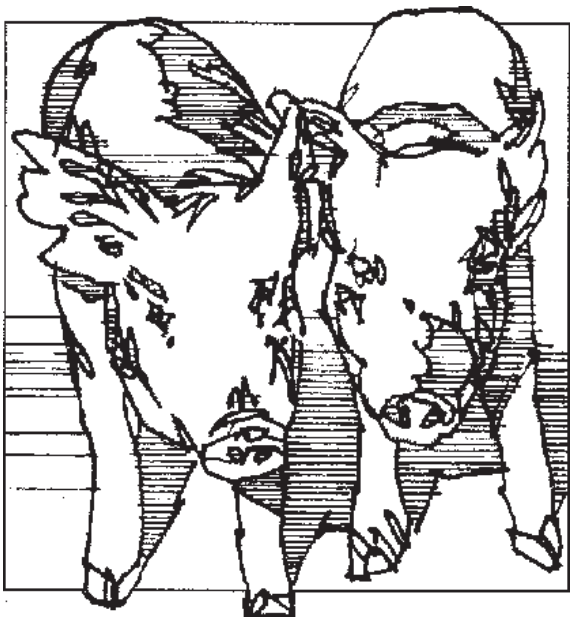

KANSAS
STATE
UNIVERSITY

SWINE DAY 1995

REPORT OF PROGRESS 746, AGRICULTURAL EXPERIMENT STATION, MARC A. JOHNSON, DIRECTOR

FOREWORD

It is with great pleasure that we present to you the 1995 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, 1995 Swine Day Report of Progress,

Bob Goodband Mike Tokach

ABBREVIATIONS USED IN THIS REPORT

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

KSU VITAMIN AND TRACE MINERAL PREMIXES

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

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

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

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

NOTICE

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

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

CONTENTS

BIOLOGICAL VARIABILITY AND CHANCES OF ERROR

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

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

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

In other papers, you may see an average given as $2.5 \pm .1$. The 2.5 is the average; .l 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.

MATURATION OF THE GILT'S UTERUS BEFORE PUBERTY: RESPONSE TO PROGESTERONE AT DIFFERENT AGES

P. G. Groothuis, R. M. Blair, and D. L. Davis

Summary

We determined the age at which progesterone induced certain responses in the gilt's uterus. The prepubertal maturation permitting each response is being studied currently with the intent of using the information to develop methods to improve litter size in pigs, perhaps by identifying markers for uterine function that could be used before gilts enter the breeding herd.

(Key Words: Gilt, Uterus, Progesterone.)

Introduction

Considerable information has been developed on the physiology of reproduction at the time of and after puberty. In contrast, relatively little is known about the reproductive development of young pigs. For example, at birth, the gilt possesses a uterus that resembles the adult uterus only in its general characteristics. The lining of the uterus, the endometrium, is only a poorly defined tissue. During the first few weeks of extrauterine life, the uterine glands develop, and the uterus assumes the general architecture of the adult organ. However, development is far from complete, and it is not until approximately 100 days of age that the gilt might initiate pregnancy if she were induced to ovulate by injecting gonadotropins. Still her uterus is far from completely developed, and the pregnancy is likely to be lost. Although the gilt is only 3 to 4 months older before she would enter the gilt pool on a swine farm, her reproductive system has undergone a considerable amount of maturing towards the adult phenotype. The physiology to this stage and during the remainder of the prepubertal period is responsible for producing a fertile female. We believe it is important to understand the changes occurring between birth and puberty to determine the processes that may affect fertility. That is, it may be possible to either modify prepubertal development to improve fertility or to develop tests that identify the most fertile females before they reach puberty.

In the present work, we studied the ability of the gilt's uterus to respond to progesterone and secrete the components of the uterine milk that nourish and support pig embryos both before and after they attach to the uterus.

Procedures

Prepubertal gilts were assigned to begin receiving treatment at 6, 46, 76, 106, or 136 days of age. Daily treatment was either progesterone (1 mg/lb) dissolved in corn oil and injected subcutaneously or only the corn oil (controls). Treatments were administered for 14 consecutive days, and then the gilts were hysterectomized, the uterus trimmed and weighed, and .85% saline was flushed through one uterine horn to obtain a sample of the uterine secretions. The flushings were evaluated for the presence of uteroferrin and retinol binding protein, two proteins present in the uterine milk during early pregnancy, as well as prostaglandin E2 and the total secretory protein. These are components of the uterine milk known to be induced by progesterone during early pregnancy. The presence of the two specific proteins were evaluated using western blots, prostaglandin E2 by radioimmunoassay, and total protein by the Lowry procedure.

Results and Discussion

The uteri of gilts beginning treatment at 6 days of age were unresponsive to progesterone; however, responses in all the characteristics studied were detected among comparative older gilts. Data are presented as the increases induced by progesterone over control gilts of the same age (Figure 1). Four distinct patterns of response were detected among the characteristics studied. Only uterine weight was increased by progesterone in gilts receiving it from 46 to 59 days of age. The increases over controls were similar for all but the youngest age group and ranged from 3.8- to 4.8-fold. The amount of protein recovered in the uterine flushings increased only marginally after progesterone treatment beginning at 46 days of age or younger but was increased 4.4- to 6.9-fold for older gilts. The presence of uteroferrin and retinol binding protein was first detected in the uterine flushings of gilts that began their progesterone treatment at 76 days of age, and the response to progesterone appeared to increase in magnitude for later age groups.

Our results indicate that the prepubertal gilts uterus develops responsiveness to progesterone in stages over the prepubertal period. The earliest progesterone-induced response was an increase in uterine weight. The mechanism for this response is not known and is the subject of our continued investigations. The induction of uteroferrin and retinol binding protein can be considered to indicate the secretion of components important for the maintenance of pregnancy. The appearance of these proteins occurs in the uterus of progesterone-treated gilts as they reach the age when pregnancy can first be established. Therefore, their appearance is consistent with their presumed necessity for the establishment and maintenance of pregnancy. In other studies, we quantified uteroferrin and retinol binding protein and found a graded response with increased amounts of these proteins in the uterus of older gilts treated with progesterone. This could be interpreted to indicate that the uterus of prepubertal gilts matures quantitatively and does not reach full function until at or after puberty.

Progesterone-induced responses in prostaglandin E were strikingly different from the other responses measured. Levels were as much as 150-fold higher than those of controls (Figure 1). Perhaps prostaglandin E is associated with proliferation of cells in the endometrium or with cellular remodelling. These possibilities will require further evaluation. The increase in luminal protein induced by progesterone in gilts treated from 46 to 59 days indicated increased secretory response of the endometrium at this age.

An understanding of each of the responses observed in this study may lead to ways to improve uterine function and fertility. For example, an understanding of the ability of progesterone to increase uterine weight may reveal previously unknown mechanisms controlling uterine growth and lead to treatments that increase uterine capacity in postpubertal gilts. Further, an understanding of the physiology leading to enhanced secretion of progesterone-induced uterine secretions may lead to approaches to enhance the uterine environment during pregnancy.

Figure 1. Progesterone-Induced Increase in Certain Uterine Traits.

INFLUENCE OF INCREASED VITAMIN LEVELS FOR THE FIRST 35 D POSTWEANING ON BREEDING AND SUBSEQUENT LACTATION PERFORMANCE OF SOWS [1]

S. S. Dritz [2], M. D. Tokach [3], J. L. Nelssen, R. D. Goodband, and G. Lynch [4]

Summary

Four hundred and eight sows were used to evaluate the effects of feeding high levels of vitamins (2 to 7 times average inclusion rate) for the first 35 d postbreeding on later reproduction performance. Number of pigs born alive and number born dead following feeding high vitamin levels showed a numeric advantage compared with sows fed the control diet. These numeric responses resulted in trends toward higher number weaned (9.75 vs 9.54) and litter weaning weight (107.8 vs 105.4 lb). Further research needs to be conducted to determine which vitamin or vitamins may have an influence on embryo survival.

(Key Words: Sows, Gestation, Reproduction, Vitamins.)

Introduction

Research at North Carolina State University has demonstrated that a single injection of beta carotene at weaning will increase the number of pigs born alive at the subsequent farrowing. Further research demonstrated that injecting beta carotene or vitamin A at weaning, breeding, and 7 days after breeding increased subsequent litter size from 10 to 10.6 pigs per litter. The mechanism for this effect is not known but appears to involve increased embryo survival. Other research has indicated improved embryonic survival and (or) live births when various supplemental vitamins were added during the gestation period. The vitamins examined have included riboflavin, folic acid, and biotin. Two questions that remain are: 1) will embryonic survival be affected when increased vitamin A levels are provided in the feed for the first 35 days postweaning and 2) will other supplemental vitamins affect subsequent reproductive performance under commercial conditions? Therefore, the objective of this experiment was to examine the effects of elevated supplemental levels of vitamins for the first 35 days postweaning on subsequent reproductive performance.

Procedures

A total of 408 sows on a commercial operation in Northeast Kansas were used in this study. At weaning, the sows (≥ parity 2) were assigned randomly to one of two dietary treatments for the first 35 days postweaning (Table 1). Following weaning, sows were moved to an environmentally controlled breeding facility. Sows were checked for estrus twice daily with a boar. Once estrus was detected, sows were mated naturally once every 24 hours until they were not in standing estrus. Sows that did not exhibit estrus by 7 days postweaning were removed from the experiment. Sows then were checked daily for signs of return to estrus

[1]Appreciation is expressed to Rick Richards, Michelle Walter, and Dale Keesecker of Keesecker Agribusiness, Washington, KS for use of animals and facilities and data collection. Appreciation also is expressed to BASF for vitamin premixes and financial support.

[2]Food Animal Health and Management Center.

[3]Northeast Area Extension Office.

[4]BASF Canada Inc.

postbreeding. Sows returning to estrus postbreeding were removed from experiment and culled.

All diets fed from weaning to the subsequent farrowing were 14% crude protein (.65% lysine), milo-soybean meal based diets (Table 1). Supplemented vitamin levels are listed in Table 2. The control diet was formulated to closely match the average industry supplemental levels (BASF, 1992). The fortified diet was formulated to include between 2 and 7 times the industry average fortification levels. Sows were fed ad libitum from weaning to estrus. After insemination, sows were fed from 4 to 5.5 lb of feed per day throughout gestation. During the subsequent lactation, sows were fed ad libitum a 1.00% lysine milo-soybean meal based lactation diet. At farrowing, number of pigs born alive and dead and number of mummies were recorded. Pigs were cross-fostered within treatment, within the first 48 hours postweaning. At weaning, litter weaning weight and number of pigs weaned were recorded.

A chi square statistic was calculated for breeding performance and farrowing rate. Subsequent litter performance data were analyzed using analysis of covariance to determine if current lactation length was a significant covariant. Lactation length had a significant effect on litter weaning weight. Therefore, the analysis of variance model included treatment and lactation length as the independent variables.

Results and Discussion

Percentages of return to estrus by d 7 postweaning, pregnant by d 35 postweaning, and deaths were not affected by treatment (Table 3). Farrowing rate was excellent for both groups and was not affected by treatment. Sows fed high supplemental vitamins for the first 35 d postweaning had numerically more pigs born alive and fewer dead compared with those fed the control diets (Table 4). Sows fed high supplemental vitamins for the first 35 d postweaning tended to have more pigs ($P<.08$) and had heavier litters at weaning ($P<.18$).

The results of this study indicate that feeding increased vitamin levels for the first 35 d postweaning in sows did not influence breeding performance. However, embryo survival may have been affected, as indicated by the increased number of pigs weaned. This resulted in a heavier litter weaning weight. Therefore, further research needs to be conducted to determine which vitamin or vitamins may have an influence on embryo survival.

Table 1. Diet Composition[a]

Ingredient, %	Breeding (d 0 to 35 postweaning)	Gestation	Lactation
Milo	80.15	79.69	64.12
Soybean meal (46.5% CP)	15.52	15.52	28.33
Choice white grease	--	--	3.00
Monocalcium phosphate (21% P)	2.50	2.50	2.32
Limestone	1.14	1.14	1.08
Salt	.50	.50	.50
Breeding premix	.04	--	--
Vitamin premix	--	.25	.25
Sow add pack	--	.25	.25
Trace mineral premix	.15	.15	.15

[a]Diets were formulated to contain .65% lysine in breeding and gestation and 1.00% lysine in lactation. All diets were formulated to contain .9% calcium and .8% phosphorus.

Table 2. Supplemental Vitamin Levels (per Ton of Complete Feed)

	Breeding (d 0 to 35 postweaning)		
Nutrient	Control	Fortified	Gestation and lactation
Vitamin A, IU	8,200,000	20,000,000	10,000,000
Vitamin D3, IU	1,800,000	3,000,000	1,000,000
Vitamin E, IU	34,500	130,000	40,000
Riboflavin, mg	5,700	50,000	7,500
d-Pantothenic acid, mg	19,600	40,000	26,000
Niacin, mg	35,350	100,000	45,000
Vitamin B12, mg	25	80	30
Thiamine, mg	850	5,000	--
Pyridoxine, mg	1,050	5,000	--
Biotin, mg	135	1,000	300
Folic acid, mg	800	6,000	1500
Menadione, mg	2,075	4,000	4,000
Choline, g	500	500	500

Table 3. Effect of Increased Vitamin Levels in Early Gestation (Weaning to d 35) on Breeding Performance

Item	Control	Fortified	χ^2
Sows on Test	205	203	--
Removals			
% estrus by d 7 postweaning (No.)	98.5 (203)	98.0 (199)	.49
% pregnant d 35 postweaning (No.)	91.7 (188)	89.2 (181)	.19
% Death (No.)	.5 (1)	.5 (1)	.99
% Unknown (No.)	1.0 (2)	--	--
Sows farrowed	185	179	--
Farrowing rate, %[a]	91.1	88.6	.20

[a]Farrowing rate = number farrowed/ (number on test - number deaths - number unknown removals).

Table 4. Effect of Increased Vitamin Levels in Early Gestation (Weaning to d 35) on Subsequent Parity Litter Performance

Item	Control	Fortified	P-value	CV
Born alive	10.72	10.82	.73	23.6
Born dead	.90	.76	.27	142.7
Mummies	.11	.12	.82	326.7
Weaned	9.75	9.94	.08	10.0
Litter wean weight, lb[a]	105.4	107.8	.18	16.1

[a]Average lactation length of 14.4 days. Lactation length used as a covariant.

IN VITRO BRANCHED CHAIN AMINO ACID OXIDATION BY PORCINE MAMMARY TISSUE

B. T. Richert, R. D. Goodband, M. D. Tokach [1], and J. L. Nelssen

Summary

Mammary secretory tissue from six (three each of parity 1 and 2) lactating sows (d 10 to 17 of lactation) was obtained via biopsy for in vitro incubation to determine CO_2 production from individual branched chain amino acids. Carbon dioxide production levels as percentages of the ^{14}C-labeled amino acid metabolized by the mammary tissue were 2.57, 1.86, and 4.07% for isoleucine, leucine, and valine, respectively ($P<.03$). These results indicate that, in the lactating sow mammary gland, valine has the greatest oxidation rate of the branched chain amino acids.

(Key Words: Mammary Gland, Sows, Isoleucine, Leucine, Valine.)

Introduction

The lactating cow and goat have received more emphasis in determining nutrient utilization by the mammary gland than the lactating sow. This is because of the difficulty of cannulating the sow's mammary glands, which are supported metabolically through many feeder arteries and veins. Because of this difficulty, mammary biopsy and in vitro culture of mammary tissue offer potential to study utilization of nutrients. Research reported in the 1994 Swine Day Report of Progress (p 10 and 15) demonstrated that the dietary valine requirement of the high-producing lactating sow is higher than NRC (1988) and ARC (1981) estimates. Additionally, the known differences between species in milk profile, with swine having greater DM, lipid, and protein than dairy cattle, indicates the potential for different metabolic use of the branched chain amino acids. Therefore, the objective of this experiment was to determine the in vitro CO_2 production from ^{14}C labeled L-valine, L-isoleucine, and L-leucine by sow mammary tissue.

Procedures

Six sows (half parity 1 and half parity 2) of maternal line genetics (PIC Line C15) were used. The first and second productive mammary glands on the right side of the sow were biopsied to collect mammary tissue. Sows were between d 10 and 17 of lactation at time of the biopsy. Sows were allowed ad libitum access to an experimental diet high in all three branched chain amino acids. The diet was formulated to contain .90% lysine, .85% isoleucine, 1.35% leucine, and 1.07% valine.

The incubation medium used in this experiment was a RPMI-1640 select amine® kit (Life Technologies, Grand Island, NY). The medium was complete, with no antibiotics, fetal bovine serum, or supplemental hormones because of the short duration of the incubation. All nutrients were mixed in the medium except isoleucine, leucine, and valine. After purification, the medium was aseptically divided into four equal vials with a sterile syringe, needle, and .2 micron filter. One vial was deficient in each of the three amino acids and the fourth deficient in all three (for transportation of tissue biopsies). The individual branched chain amino acids were added to their respective vials using the

[1]Northeast Area Extension Office.

same aseptic technique as described above. All radioisotopes used were at an activity of 100 µCi/mL. However, each isotope had a slightly different molar concentration: isoleucine, 240 mCi/mmol; leucine, 324.9 mCi/mmol; and valine, 225 mCi/mmol. The initial medium pH was 7.4.

Approximately equal weights of tissue from each gland (100 to 150 mg) were used. The tissue slices (approximately 2 to 3 mm^3 and 50 mg) were weighed and placed in a 50 mL flask with 5 mL of tissue medium. Five µL of ^{14}C-U-valine, isoleucine, or leucine (100 µCi/ml) was added to the medium. The flask then was purged with 95:5 (oxygen: CO_2) for 1 min, sealed with a rubber stopper, and placed in a water bath. The rubber stopper contained a suspension center well with 2^2 cm piece of filter paper inside it. The tissue samples were incubated in a 37°C shaker water bath for 1 h. Then .3 mL of 2 M KOH was injected through the rubber stopper into the center well to capture CO_2 released when the incubation period was terminated. The tissue incubation then was terminated by the injection of 1 mL of 1 N H_2SO_4 into the medium. The tissue then was incubated again for another 1 h period for CO_2 collection.

After CO_2 collection, the flasks were removed from the water bath, and the center wells were placed in a 6 mL liquid scintillation vial. Tissue was removed from the vial and rinsed with 2 mL of distilled deionized water, with the rinsing added to the incubation medium. The rinsed tissue then was placed in 5 mL of distilled deionized water and homogenized for 4 min. using a Tekmar Tissuemizer®. Fifty µL of homogenized tissue and 40 µL of medium + washings were pipetted into liquid scintillation vials, to which 5 mL of scintillation fluid was added before they were counted on the next day. Sample degradations were counted for 4 min. on a Tri-carb 4000® liquid scintillation counter. Quench curves were performed for all three types of samples. The external standardization method using the spectral index of the sample was used to generate the counting efficiency of the samples.

Results and Discussion

The ^{14}C concentration in CO_2 was not different between branched chain amino acids ($P < .33$). When CO_2 production was expressed as a percentage of label incorporated into tissue, valine had the highest CO_2 production (4.07%) followed by isoleucine (2.57%) and leucine (1.57%). These values are similar to those reported in the literature for total ^{14}C recovered as CO_2. However, contrary to our results, in lactating bovine mammary tissue, leucine has greater CO_2 production followed by isoleucine and then valine. This suggests that species differences occur in the metabolism of the branched chain amino acids.

Valine had the lowest incorporation rate ($P < .001$) of the branched chain amino acids into the mammary tissue when measured as quantity of ^{14}C in the tissue homogenate. However, when comparing the branched chain amino acids on a molar concentration basis of radioactive amino acid, no differences occurred ($P < .16$). However, isoleucine had a numerically higher incorporation rate than valine or leucine when considered on the molar basis.

Production of labeled CO_2/mg/h was similar between parities. However, parity 1 sows had greater labeled CO_2 production as a percent of the branched chain amino acid metabolized (3.4 vs 2.3%) than parity 2 sows. Parity 2 sows had 46% greater uptake rates of the branched chain amino acids than parity 1 sows, accounting for most of the difference in CO_2 as a percentage of branched chain amino acids extracted. The increased uptake rates by parity 2 sows is related to the greater milk synthesis rates observed with increasing parity, as the sow reaches her maximum productivity. Also, the higher CO_2 production by the parity 1 sows may relate to greater activation of catabolism enzymes because of their smaller BW and their need to use more of the branched chain amino acids for energy.

In conclusion, in vitro CO_2 production rates in sow mammary tissue were greatest for valine and least for leucine. Isoleucine

appears to have the greatest uptake rate by mammary tissue of the branched chain amino acids. Of the previously reported 30 to 80% excess uptake of the branched chain amino acids by the mammary gland above the requirement for milk protein synthesis, only a small fraction appears to be utilized strictly as an energy source. This suggests that the branched chain amino acids play a large part as carbon and nitrogen donors for synthesis of nonessential amino acids, lactose, and(or) lipid.

Table 1. In Vitro CO_2 Production from ^{14}C-L-isoleucine, Leucine, and Valine by Sow Mammary Tissue

	Amino acid				
Item	Isoleucine	Leucine	Valine	SE	P <
Added amino acid, nmol	2.08	1.5	2.2	—	—
Tissue wt, mg	281.5	278.1	295.6	18.2	.77
Radio label recovery, %					
Residual media	59.89	60.73	76.24	1.85	.001
Tissue homogenate	19.45	21.44	13.15	1.31	.001
CO_2	.50	.39	.55	.06	.33
Total	79.84	82.52	89.94	1.57	.001
CO_2 as a percentage of uptake	2.57	1.86	4.07	.55	.03
Tissue uptake rate, pmol/mg/h	1.11	.91	.89	.004	.16
CO_2 production rate, pmol/mg/hr	.0259	.0114	.0315	.09	.02

[a]Means represent values from six sows for a 1 h incubation at 37°C conducted in duplicate.

Swine Day 1995

EVALUATION OF SEGREGATED EARLY WEANING TO CONTROL SALMONELLOSIS AND PROLIFERATIVE ENTERITIS

J. C. Nietfeld[1], I. Feder[1], D. Schoneweis[2], and B. Kelly[1]

Summary

This trial indicates that segregated early weaning has potential as a management tool in the control and possible elimination of salmonellosis and that a contaminated environment is an important source of *Salmonella* infection.

(Key Words: Salmonellosis, Early Weaning.)

Introduction

Segregated early weaning (SEW) has shown beneficial effects in the elimination and reduction of many swine diseases. This trial was designed to evaluate the effects of segregated early weaning on the transmission of salmonellosis and porcine proliferative enteritis in a herd known to have recurring problems with both diseases. Although there are over 2,000 species of *Salmonella*, *S. choleraesuis* is by far the most common cause of clinical salmonellosis in pigs. In most diagnostic laboratories, 50 to 70% of the salmonella isolates from dead and sick pigs are *S. choleraesuis*. With the exception of *S. typhimurium*, the other major cause of salmonellosis in pigs, and possibly *S. agona*, which some people feel also is capable of causing diarrhea, the remaining *Salmonella* species rarely cause problems in pigs, but represent food safety problems. In human medicine, all *Salmonella* species are regarded as causes of food poisoning. Porcine proliferative enteritis is another important cause of diarrhea, poor growth, and death of pigs. Until recently, the cause was unknown. A bacterium that is extremely difficult to grow in the laboratory was isolated recently from affected pigs and used to reproduce the disease, establishing it as the cause of proliferative enteritis. This bacterium has not been officially named but is currently known as Ileal Symbiont Intracellularis.

Procedures

Fifty six 10- to 16-day-old pigs were purchased from a commercial pig farm and transported to Kansas State University. During the preceding 9 months, the farm had experienced a 24% death loss from the time the pigs were moved from the nursery until they were marketed. *Salmonella choleraesuis* was isolated from multiple organs from multiple pigs on each of three earlier submissions to the KSU Veterinary Diagnostic Laboratory. In addition, on one occasion, proliferative enteritis was diagnosed on the basis of gross and microscopic lesions. The sows were vaccinated with an autogenous *S. choleraesuis* bacterin at 5 and 2 weeks prior to farrowing. Beginning with the pigs in the farrowing from which our pigs were purchased, the owners began vaccinating with a modified live *S. choleraesuis* vaccine (SC-54®, NOBL Laboratories, Sioux City, IA). At KSU, the early-weaned pigs initially were fed an SEW diet that contained carbadox. They were then switched to a standard corn-soybean diet with no antibacterial agents. No vaccinations were given. All pigs were bled, and the serum was harvested and frozen upon arrival and at three additional times at 4- to 6-wk intervals. In addition, at each bleeding,

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[2]Department of Clinical Sciences.

fecal and tonsil swabs were obtained from each pig and cultured for *Salmonella* species using two enrichment techniques. After the fourth sampling, the sera were analyzed for antibody to *S. choleraesuis* by Dr. Ted Kramer, Iowa State University.

On the day of purchasing the pigs, rectal swabs were obtained from 24 sows in the farrowing house, milk samples were obtained from nine sows, and nine rats were caught. All samples were cultured for *Salmonella* species. In addition, 30 farrowing house sows were bled, and the sera frozen. When moved from the nursery to the outdoor pens where they were raised to market, 15 on-farm, age-matched pigs were bled, cultured for *Salmonella* species, and ear tagged. Eight mud holes in the pens and 20 sow fecal samples also were cultured. Five weeks later, 13 of the 15-ear tagged pigs were rebled and recultured. Four pigs, two nursery and two finisher, were brought to KSU for necropsy, microscopic examination, and bacterial culture. In addition, six environmental samples were obtained from the grower-finisher pens for culture. On one additional occasion, 16 fecal cultures and 10 environmental samples were obtained for culture, and two pigs were submitted to the diagnostic laboratory.

Results

The early-weaned pigs averaged 8.3 lb at purchase and were kept for 140 d, when 50 were sold at a commercial auction market. The pigs averaged 215.3 lb with an average daily gain of 1.48 lb. Two pigs were euthanized during the trial, one because of a stomach ulcer and a second because of a rectal prolapse. Both pigs were necropsied, cultured, and examined microscopically. Otherwise, all pigs remained healthy and required no medication during the trial. *Salmonella* species was not isolated from any pig. At purchase, 35 pigs were serologically positive for *S. choleraesuis*, the titer for 10 pigs was in the suspicious range, and 11 pigs were serologically negative. There was a steady decline in antibody titers, and by 83 d, all pigs were serologically negative, but 26 d later, titers of two pigs were in the suspicious range. These pigs plus one small pig and one pig with a large hernia were kept and necropsied, examined microscopically, and cultured for *Salmonella* species. *Salmonella* was not isolated, and no microscopic lesions indicative of either salmonellosis or proliferative enteritis were found in any of the pigs necropsied.

After initiating *S. choleraesuis* vaccination of the pigs at weaning, the owner felt that septicemic salmonellosis ceased to be a problem. However, when we bled the on-farm, age-matched pigs for the second time, approximately half of the pigs were thin and rough-haired and had diarrhea. Necropsy revealed that all four pigs brought to the Diagnostic Laboratory had proliferative enteritis. *Salmonella derby* and *S. agona* were isolated from the intestine and a lymph node of the finisher pigs; *S. choleraesuis* was not isolated. At later samplings, *S. choleraesuis* was isolated from a water bowl and from the intestine of a finisher pig. Both isolates were evaluated by Dr. Ted Kramer, the researcher in whose laboratory the vaccine (SC-54) was developed, and both were biochemically compatible with the vaccine strain. Seven serotypes of *Salmonella* were isolated from the farm (Table 1). Twenty eight *Salmonella* isolates were obtained from 136 (20.6%) samples (Table 2).

On the day the piglets were purchased, 29 of 30 sows were strongly positive for *S. choleraesuis*, and the remaining sow was a strong suspect. On the day the on-farm, age-matched pigs, which had been vaccinated with SC-54 at weaning, were moved from the nursery, two were antibody positive, four were suspect, and eight were negative for *S. choleraesuis*; *S. agona* was isolated from one pig. Forty days later, five were antibody positive for *S. choleraesuis*, four were suspect, and four were negative; *S. agona* was isolated from seven of 13 pigs.

Table 1. Salmonella Serotype and Source

Salmonella species	Source
S. choleraesuis	1 finisher pig, 1 water bowl
S. agona	8 fecal swabs (finishers), 5 environment
S. derby	6 environment, 1 finisher pig
S. drypool	2 environment, 1 finisher pig
S. anatum	1 fecal swab (nursery pig)
S. brandenburg	1 fecal swab (sow)
S. heidelberg	1 fecal swab (sow)

Table 2. Samples for *Salmonella* Isolation and the Number of Isolates

Sample	# Cultured	# Isolates
Milk	9	0
Fecal swabs	88	12
Pigs at necropsy	6	3
Environment	24	13
Rat tissues	9	0
Total	136	28

Discussion

These results demonstrate that SEW can drastically reduce *salmonella* shedding, control clinical salmonellosis, and possibly eliminate *salmonella* infection. *Salmonella* species were never isolated from any of the SEW pigs, and none of the pigs displayed any clinical evidence of salmonellosis. On the other hand, *S. agona* was isolated from fecal swabs from one of 15 on-farm, age-matched pigs when moved from the nursery and from seven of 13 age-matched pigs 40 d later. In addition, *S. drypool* and *S. derby* were grown from the two necropsied finisher pigs, and four species of *Salmonella* were isolated from their environment. Fourteen of 21 (67%) environmental samples were *Salmonella* positive. The positive samples consisted of water from mud holes and water bowls; *Salmonella* was not isolated from water taken directly from the hydrants. It appears that several of the *Salmonella* species were being cycled between the pigs and the environment. It is interesting that *S. choleraesuis*, except for the vaccine strain, was not isolated from any pig or their environment after the initiation of vaccination at weaning. The farm's owner felt that the vaccine was responsible for cessation of clinical signs of salmonellosis. Whether the vaccine or some other unknown factor was responsible remains unknown. Among *Salmonella* species, *choleraesuis* is by far the most common cause of death and clinical disease. The other species that were isolated from the farm, with the possible exception of *S. agona*, probably did not cause any problems to the pigs, but they

represent potential sources of contamination of pork at slaughter. Thus, eliminating them is important from a food safety standpoint.

When we sampled the finisher pigs, they had a serious problem with diarrhea and poor growth. The primary cause of this was porcine proliferative enteritis, although *S. agona* may have contributed to the problem. When we initiated the project, we were interested only in elimination of *S. choleraesuis*, which appeared to be the farm's primary problem. Proliferative enteritis had not been diagnosed for some time. Therefore, samples were not saved for identification of its cause, Ileal Symbiont Intracellularis, so that we do not know if the organism was present. In any event, the SEW pigs displayed no clinical signs of proliferative enteritis, and no gross or microscopic lesions of proliferative enteritis were seen in the six pigs that were euthanized, indicating that the disease had been effectively controlled, if not eliminated.

The presence of an antibody response in infected pigs usually is recognized as a much more sensitive method of detecting *S. choleraesuis* than culture. The majority of pigs were serologically positive for *S. choleraesuis* when weaned, but all were negative by the third bleeding at 83 d after weaning. This indicates antibodies were transferred from the sows' colostrum to the piglets and that they had not been infected. Because antibody titers of two pigs were in the high suspicious range 26 d later, we cannot be sure that *S. choleraesuis* was eliminated totally. Since performing the serologic analyses, Dr. Kramer has found that his test cross reacts with other *Salmonella* species and possibly other non-salmonella bacteria. He is modifying the test so that it will be *S. choleraesuis*-specific and, when he has the test perfected, he will redo our sera to determine if the response in the two pigs was indeed to *S. choleraesuis*. Because *S. choleraesuis* occasionally can infect pigs in utero, it does not seem likely that SEW would work all the time. If the pigs are infected at birth or if the sow is actively shedding the organism, early weaning probably would not eliminate the organism. Two isolates, *S. brandenburg* and *S. heidelberg*, were grown from 44 sow fecal cultures, and both were present in very low numbers, because prolonged incubation in enrichment broth was required for each isolate. Neither isolate was cultured from the environment or the growing pigs. Recent work at the National Animal Disease Center indicates that SEW will work only if the sows are not actively shedding *Salmonella* species during the nursing period. If SEW is to work, pigs should be weaned into facilities that can be totally emptied and thoroughly cleaned and disinfected between each group. Then salmonellosis does occur in a group of pigs, environmental carryover between groups will be prevented, and infected pigs from an earlier group will not serve as a source of infection for new pigs.

INFLUENCE OF LIPOPOLYSACCHARIDE-INDUCED IMMUNE CHALLENGE AND DIET COMPLEXITY ON GROWTH PERFORMANCE AND ACUTE-PHASE PROTEIN PRODUCTION IN SEGREGATED EARLY-WEANED PIGS [1]

S. S. Dritz [2], K. Q. Owen, R. D. Goodband, J. L. Nelssen, M. D. Tokach [3], M. M. Chengappa [4], and F. Blecha [5]

Summary

When eating the same amount of feed, pair-fed pigs were more efficient at using nutrients for growth than pigs injected with lipopolysaccharide (LPS). Approximately 2/3 of the decreased growth of LPS-challenged pigs was due to decreased ADFI and 1/3 was due to decreased feed efficiency (F/G). Determining the optimum diet complexity for a nursery feeding program will depend on the desired balance between growth performance and feed cost per lb of gain but appears to be independent of immune response to inflammatory challenge. On a practical basis, this suggests that nursery diet complexity should not be influenced by health status.

(Key Words: Diet Complexity, Lipopolysaccharide, Growth.)

Introduction

The increased growth observed in segregated early weaning (SEW) production systems is thought to be a result of decreased stimulation of the immune system and is supported by research indicating that immune challenge results in decreased feed intake as well as partitioning nutrients away from growth. When developing production strategies that minimize immune challenge, it is important to determine if the reduced growth rate is a result of decreased feed intake and (or) nutrients being diverted away from growth to the immune response. These two causes have different economic costs. The goal when formulating nursery diets is to choose ingredients that are highly palatable and digestible. Because feed intake is decreased during an immune challenge, the selection and level of the highly palatable and digestible ingredients may be altered. If diet complexity can be reduced in pigs without an immune challenge while maintaining growth performance, diet cost and cost per unit of gain can be reduced. Therefore, our objective was to examine the influence of LPS-induced immune challenge and nursery diet complexity on the growth performance and plasma acute-phase protein production of SEW pigs.

Procedures

SEW pigs (initially 8.8 lb and 14 ± 1.5 d of age) were used to quantify the effects of LPS-induced immune challenge and nursery diet complexity (complex, medium, and simple) on growth performance and haptoglo-

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bin production. The three treatments of immune challenge consisted of pigs: 1) given ad libitum access to feed (control), 2) challenged with LPS and given ad libitum access to feed (LPS-challenged), and 3) pair-fed to receive the same amount of feed as the LPS-challenged pigs (pair-fed).

Pigs were housed in groups of five in pens (4 × 4 ft) with slotted metal flooring. The initial room temperature (90°F) was reduced by 2°F each week. Pigs had access to a nipple waterer and a self-feeder. Lipopolysaccharide was injected intramuscularly (68 µg/lb BW) on d 5, 8, 11, and 14 postweaning.

Pigs were fed a common diet from d 0 to 5 postweaning (Table 1). Pigs then were fed one of the three experimental diets from d 5 to 18 postweaning. All pigs then were fed a common corn soybean meal-based diet from d 18 to 32 postweaning.

Feeders in the pens containing the pigs injected with LPS were weighed daily to calculate feed disappearance for the previous 24 h. Subsequently, feed intake for the pair-fed pigs in each block was determined by taking the average feed intake for the previous 24 h of the two pens in each block challenged with LPS and adjusted up or down based on a comparison of the cumulative feed intake between pair-fed and LPS-challenged pens. The 24 h feed allotment for the pair-fed group was divided into four aliquots and fed every 6 h. Pig weights and feed consumption were determined on d 5, 8, 11, 14, 18, and 32 postweaning to calculate ADG, ADFI, and F/G. On d 8, 11, and 14 postweaning, plasma was collected from two pigs per pen. Plasma was analyzed for the immune response acute phase protein, haptoglobin. Data were analyzed as a randomized complete block design in a 3 × 3 factorial arrangement.

Results and Discussion

Means of responses are presented in Table 2. No interactions were observed for any of the response criteria between immune status and diet complexity (P>.10), indicating that the responses were independent. Therefore, if the LPS stimulation model is representative of the complex interplay of immunostimulants present in many commercial swine production systems, these results indicate that immune status does not need to be taken into account when determining the appropriate complexity of nursery diets.

From d 5 to 18 postweaning, ADG of the control pigs was higher (P<.05) than that of either the LPS-challenged or pair-fed pigs (Table 2). Average daily gain of the pair-fed pigs was higher than that of the pigs challenged with LPS (P<.01), although both groups of pigs ate the same amounts of feed (P>.10). The control pigs had higher (P<.05) ADFI than either the LPS-challenged or pair-fed pigs. The pair-fed pigs had improved F/G (P<.05) compared to the LPS-challenged pigs for that time period. The pair-fed pigs also had improved F/G compared to the control pigs (P<.05). No difference occurred in F/G between LPS-challenged and control pigs (P>.10).

The increased ADG of the pair-fed pigs compared to the pigs challenged with LPS was due to the pair-fed pigs having a better F/G. This can be explained by the fact that LPS has been shown to increase metabolic heat production. Because more energy is partitioned to metabolic heat production, the efficiency of utilization of dietary energy and, therefore, the efficiency of growth is reduced.

The increased F/G of the pair-fed pigs compared to control pigs can be accounted for by the fact that heat production is lower in animals fed below ad libitum. Heat production is related to energy intake and BW. Approximately 26% of energy intake is partitioned to heat production. Thus, the metabolic heat production in immune-challenged pigs was the sum of the increased rate from immune stimulation and the decreased rate from decreased feed intake.

When all pigs were fed a common diet from d 18 to 32 postweaning, ADG of the LPS-challenged pigs was similar to that of the pair-fed pigs. However, pigs previously

challenged with LPS had lower ADFI than either the control (P<.10) or pair-fed (P<.01) pigs. The lower ADFI of the LPS-challenged pigs indicates a carryover effect of LPS-induced immune challenge on feed intake.

The control pigs were heavier (P<.01) than either the LPS-challenged or pair-fed pigs on d 18 and 32 postweaning. Pair-fed pigs were heavier (P<.01) than the LPS-challenged pigs on d 18 and 32 postweaning. The difference in weight on d 18 postweaning between the pair-fed and control pigs was due to the decreased growth from decreased feed intake by the former. The difference in weights between the LPS and pair-fed pigs probably was due to the different efficiency of nutrient use for growth, because both groups ate the same amount of feed. Consequently, the 2.4-lb decrease in weight per pig at d 18 postweaning of the LPS-challenged pigs compared to the control pigs was the result of both decreased efficiency of gain and decreased feed intake. The .9 lb difference in pig weight between pair-fed and pigs injected with LPS was due to the decreased efficiency of gain from immune challenge, and the 1.5 lb difference in pig weight between control and pair-fed pigs was indicative of the amount of decreased growth from the lower feed intake of the LPS and pair-fed pigs.

The magnitude of the ratio between the two factors is important for economic considerations, because inefficient nutrient use for growth will have a larger economic impact than decreased nutrient intake. This is because the former incurs the expense of the increased nutrients used per unit of output (gain). Although decreased nutrient intake results in decreased gain, it does not incur increased cost per unit of gain. The only cost incurred is the lost opportunity cost that more pounds of pork can be generated per unit of time and space.

From d 5 to 18 postweaning, pigs fed the complex diets had greater ADG and ADFI (P<.05) than pigs fed either the medium or simple diets (Table 2). Furthermore, pigs fed the medium complexity diet had greater ADG and ADFI (P<.05) than pigs fed the simple diet from d 5 to 18 postweaning. Pigs fed the complex and medium diets had better F/G (P<.05) than pigs fed the simple diets. The growth performance indicates that the difference between pigs fed the complex and medium diets was solely due to the pigs fed the complex diet eating more feed per day. The differences between pigs fed the simple diet and medium or complex diets was due to decreased ADFI and increased F/G. The increased F/G of pigs fed the simple diet could be an indication that either the ingredients used were not as digestible or the absorptive capacity of the intestine was damaged by the diet.

For the overall d 5 to 32 postweaning period, pigs fed the complex and medium diets had higher ADG (P<.05) than pigs fed the simple diets. No differences (P>.10) were observed in ADFI. Feed efficiency was similar (P>.10) between pigs fed the complex or medium diets; however, pigs fed the complex or medium diets had improved F/G (P<.05) than pigs fed the simple diet for the overall period. The increased F/G of pigs previously fed the simple diet compared to pigs previously fed the complex or medium diets in the subsequent d 18 to 32 postweaning period when all pigs were fed the same diet indicates that the absorptive capacity of the intestine was compromised by the diet fed from d 5 to 18 postweaning. Pigs fed the simple diets had a 6.7% poorer F/G for the overall d 5 to 32 postweaning period compared to pigs fed the complex or medium diets.

No diet by immune status interactions occurred (P>.10) for haptoglobin concentration. Pigs injected with LPS had higher (P<.01) mean haptoglobin concentrations than control or pair-fed pigs. Diet did not have an effect (P>.10) on haptoglobin concentration. Lipopolysaccharide is a potent stimulator of inflammatory cytokine production leading to acute-phase protein production. Thus, increased haptoglobin concentrations in the pigs injected with LPS indicate increased inflammatory cytokine production. However, the lack of an influence of diet on haptoglobin concentration suggests that diet complexi-

ty does not influence feed intake by altering the balance of inflammatory cytokines.

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

	d 0 to 5	d 5 to 18 postweaning			d 18 to 32
Ingredient, %	postweaning	Complex	Medium	Simple	postweaning
Corn	31.80	37.70	35.59	36.35	60.94
Soybean meal (46.5% CP)	--	--	28.12	49.00	34.74
Moist extruded soy protein concentrate	8.58	9.96	--	--	--
Dried whey, edible-grade	30.00	20.00	20.00	5.00	--
Lactose	5.00	8.50	--	--	--
Select menhaden fish meal	6.00	6.00	2.50	--	--
Spray-dried plasma protein	7.50	7.50	2.50	--	--
Spray-dried blood meal	1.75	1.75	2.50	--	--
Soy oil	6.00	5.00	5.00	5.00	--
Monocalcium phosphate (21% P)	1.13	1.37	1.35	1.63	1.45
Limestone	.21	.30	.51	.79	.90
Antibiotic[b]	1.00	1.00	1.00	1.00	1.00
Zinc oxide	.38	.38	.38	.38	--
Copper sulfate	--	--	--	--	.075
Salt	--	.05	.05	.37	.35
Vitamin premix	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15
DL-Methionine	.15	.08	.10	.08	.025
L-Lysine ·HCl	.10	--	--	--	.13
Total	100.00	100.00	100.00	100.00	100.00
Calculated composition, %					
Lysine	1.70	1.60	1.60	1.60	1.30
Methionine	.50	.44	.47	.44	.36
Methionine + cystine	.95	.88	.88	.90	.75

[a]Diets were formulated to contain .9% Ca and .8% P.
[b]To provide 25 µg/lb carbadox.

Table 2. Influence of LPS-Induced Immune Challenge and Diet Complexity on Growth Performance and Haptoglobin Production[a]

	Control			LPS-challenged			Pair-fed			P value (P<)		
Item	Complex	Medium	Simple	Complex	Medium	Simple	Complex	Medium	Simple	Immune	Diet	CV
Day 5 to 18 postweaning												
ADG, lb	.81[b,e]	.73[b,f]	.62[b,g]	.60[c,e]	.55[c,f]	.48[c,g]	.63[d,e]	.63[c,f]	.53[d,g]	.01	.01	9.4
ADFI, lb	.88[b,e]	.82[b,f]	.74[b,g]	.66[c,e]	.62[c,f]	.57[c,g]	.65[c,e]	.62[c,f]	.57[c,g]	.01	.01	6.8
F/G	1.09 [b,e]	1.14 [b,e]	1.19[b,f]	1.11[b,e]	1.12[b,e]	1.19[b,f]	1.03[c,e]	.98[c,e]	1.06[c,f]	.01	.01	6.7
Day 18 to 32 postweaning												
ADG, lb	1.25	1.24	1.28	1.19	1.20	1.24	1.23	1.22	1.22	.14	.52	5.8
ADFI, lb	1.86[b,c]	1.81[b,c]	1.94[b,c]	1.71[b]	1.79[b]	1.87[b]	1.93[c]	1.78[c]	1.94[c]	.07	.03	6.9
F/G	1.49	1.45	1.52	1.43	1.49	1.52	1.54	1.45	1.59	.27	.14	6.6
Day 5 to 32 postweaning												
ADG, lb	1.04[b,e]	1.00[b,e,f]	.96[b,f]	.91[c,e]	.88[c,e,f]	.87[c,e]	.95[b,e]	.94[b,e,f]	.89[b,e]	.01	.01	4.9
ADFI, lb	1.39[b]	1.34[b]	1.36[b]	1.21[c]	1.22[c]	1.25[c]	1.32[c]	1.22[c]	1.28[c]	.01	.17	5.7
F/G	1.33[e]	1.33[e]	1.41[f]	1.33[e]	1.39[e]	1.43[f]	1.39[e]	1.30[e]	1.43[f]	.80	.01	5.6
Pig weight, lb												
d 18 postweaning	21.4[b,e]	20.5[b,f]	19.0[b,g]	18.7[c,e]	18.1[c,f]	17.2[c,g]	19.2[d,e]	19.2[d,f]	17.9[d,g]	.01	.01	4.0
d 32 postweaning	39.0[b,e]	37.7[b,e,f]	36.8[b,f]	35.3[c,e]	34.8[c,e,f]	34.4[c,f]	36.4[d,e]	36.1[d,e,f]	35.0[d,e]	.01	.01	3.5
Haptoglobin, mgHgb/dL	10.7[b]	8.7[b]	10.5[b]	28.0[c]	19.4[c]	22.4[c]	7.8[b]	6.4[b]	11.7[b]	.01	.17	112

[a]All pigs were fed a complex common diet from d 0 to 5 postweaning. Pigs then were fed the complex, medium, and simple diets from d 5 to 18 postweaning. All pigs were fed a common diet from d 18 to 32 postweaning. The pigs challenged with LPS were injected with LPS (68 µg/lb BW) on d 5, 8, 11, and 14 postweaning. Weight on d 5 postweaning was used as a covariate. Each number represents the mean of 6 pens with 5 pigs per pen. Pigs were 8.8 lb and 14 ± 1.5 d of age at weaning. Interactions between immune status and diet complexity were not observed (P>.10) for any of the response criteria.

[b,c,d] Means within the main effect of immune challenge and within row lacking a common superscript letter differ (P<.05).

[e,f,g] Means within the main effect of diet complexity and within row lacking a common superscript letter differ (P<.05).

COMBINATIONS OF SELECT MENHADEN FISH MEAL AND SPRAY-DRIED PLASMA PROTEIN IN THE TRANSITION DIET (11 TO 15 LB) FOR THE EARLY-WEANED PIG[1]

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Summary

Early-weaned pigs (weaned at 7 to 14 d of age) that are managed in a conventional, one-site production system require a more complex diet in the transition phase (11 to 15 lb) than early-weaned pigs that are managed in a segregated early weaning (SEW), multiple-site, production system.

(Key Words: Pigs, Growth Performance, Fish Meal, Plasma.)

Introduction

Segregated early weaning (SEW) technology has become more practical with the development of complex diets containing highly palatable ingredients for the early-weaned pig. Phase feeding also has become a very important concept for the modern swine producer, who strives to attain superior growth performance at the least possible cost. In order to improve upon current phase feeding practices, the traditional phase I portion of the starter period has been replaced with an SEW and transition phase, which reduces feed costs and more accurately meets the pigs' changing nutritional needs. The SEW diet is formulated to be fed to pigs weaned at 7 to 14 days of age until they weigh 11 lb. Pigs are then switched to a transition diet, which is fed from 11 to 15 lb. However, the degree of complexity required in the subsequent transition diet has been questioned. Differences in early-weaning schemes, such as on-site and off-site (SEW) nursery facilities, and health status may influence the degree of complexity required to obtain optimal growth performance.

Therefore, the objectives of the following two growth trials were to determine which combination of protein sources (soybean meal, select menhaden fish meal, and spray-dried plasma protein) would support optimal growth performance of the early-weaned pig during the transition phase and to determine if pigs managed in SEW conditions require a less complex transition diet than those managed in a conventional, one-site, production system.

Procedures

Experiment 1. A total of 300 pigs (PIC C15 × 326, and initially 14 ± 2 d of age and 8.8 ± 2.0 lb) was used in a 33 d growth trial to determine the degree of complexity required in the transition diet to optimize growth performance of the SEW pig. The pigs were delivered to the SEW facilities at Kansas State University, blocked by weight, and placed on a common SEW diet from d 0 to 5 postweaning. This pelleted diet contained 25% dried whey, 5% lactose, 7.5%

[1]The authors appreciate the assistance provided by Eichman Bros. Farms of St. George, KS, who donated the use of pigs and facilities in Exp. 2. We would also like to thank Global Ventures of Pipestone, MN for providing the pigs in Exp. 1, Merrick's for providing partial financial support and the spray-dried plasma, and Zapata Haynie for providing the select menhaden fish meal.

[2]Northeast Area Extension Office.

[3]Food Animal Health and Management Center.

spray-dried plasma protein (SDPP), and 6% select menhaden fish meal (SMFM) and was formulated to 1.7% lysine, 0.49% methionine, 0.9% Ca, and 0.8% P. On d 5, the pigs were weighed (10.6 ± 2.0 lb) and allotted randomly to one of 12 experimental diets, with five pigs/pen and five replicate pens/treatment. The experimental diets were pelleted and fed from d 5 to 19 postweaning and consisted of three levels of SDPP (0, 2.5, or 5%) and four levels of SMFM (0, 2.5, 5, or 7.5%) in a 3 × 4 factorial arrangement. A corn-soybean meal basal diet containing 20% dried whey and 2.5% spray-dried blood meal was formulated to 1.6% lysine, 0.9% Ca, 0.8% P, and at least .44% methionine. This diet contained 33.4% soybean meal. Select menhaden fish meal (0, 2.5, 5, or 7.5%) and/or SDPP (0, 2.5, or 5%) replaced soybean meal in the basal diet on an equal lysine basis (Table 1).

From d 19 to 26 postweaning, all pigs were fed a common phase II diet in meal form. This corn-soybean meal-based diet contained 10% dried whey and 2.5% spray-dried blood meal and was formulated to 1.35% lysine, 0.9% Ca, and 0.8% P.

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

The pigs were weighed and feed disappearance was determined on d 5, 12, 19, 26, and 33 postweaning. Average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G) were the response criteria.

The data were analyzed as a randomized complete block design, with pen as the experimental unit. Pigs were blocked on the basis of initial weight. Analysis of variance was performed using the GLM procedure of SAS, with d 5 weight used as a covariate. Both linear and quadratic polynomials were evaluated for SDPP level; and linear, quadratic, and cubic polynomials were evaluated for SMFM level. The data also were analyzed for SDPP × SMFM interactions.

Experiment 2. A total of 326 pigs (PIC C15 × 326, and initially 12 ± 2 d of age and 8.6 ± 2.6 lb) was used in a 28-d growth trial to determine the degree of complexity required in the transition diet to optimize growth performance of the early-weaned pig reared in a conventional one-site production system. The pigs were fed a common SEW diet from d 0 to 7 postweaning. This diet was the same as that used in Exp. 1. On d 7, the pigs were weighed (10.6 ± 2.6 lb) and allotted randomly to one of six experimental diets, with 7 to 11 pigs/pen (depending upon the block) and six pens/treatment. The experimental diets were fed from d 7 to 21 and consisted of two levels of SDPP (0 and 2.5%) and three levels of SMFM (0, 2.5, or 5%) in a 2 × 3 factorial arrangement. These six diets were identical to six of those used in Exp. 1.

From d 21 to 28, all pigs were fed a common phase II diet identical to that fed in Exp. 1.

The pigs were housed in an environmentally-regulated nursery in 5 × 5 ft pens for the duration of the trial. Pens were equipped with one self-feeder and two nipple waterers to provide ad libitum access to feed and water.

The pigs were weighed and feed disappearance was determined on d 7, 14, 21, and 28 postweaning, with ADG, ADFI, and F/G as the response criteria.

Data were analyzed as a 2 × 3 factorial, with d 7 weight used as a covariate. Both linear and quadratic polynomials were evaluated for SMFM level.

Results and Discussion

Experiment 1. From d 0 to 5, when the pigs were on a common SEW diet, ADG, ADFI, and F/G were 0.41, 0.34, and 0.83, respectively. No significant SDPP × SMFM interactions were observed during this trial

for any of the response criteria, and no differences in ADG or ADFI were observed during the study (Table 2).

From d 5 to 19, when the experimental diets were fed, F/G was improved (linear, P<.01) as SDPP increased. There was also a tendency (linear, P<.07) for improved F/G with increasing SMFM.

From d 19 to 26 postweaning, when all pigs were fed a common phase II diet, F/G was improved (linear, P<.06; quadratic, P<.04) by increasing SMFM in the diet from d 5 to 19 postweaning. However, no differences in ADG, ADFI, or F/G existed during the overall phase II period of the trial (d 19 to 33 postweaning).

For the overall trial (d 5 to 33 postweaning), there was a tendency for improved F/G (P<.11) with increasing SDPP fed from d 5 to 19. However, overall ADG was not improved by including SDPP and/or SMFM in the transition diet.

Experiment 2. When all pigs were fed a common SEW diet from d 0 to 7, ADG, ADFI, and F/G were 0.31, 0.38, and 1.22, respectively. No SDPP × SMFM interactions occurred during this trial for any of the response criteria (Table 3).

From d 7 to 14 postweaning, pigs fed the diets containing 2.5% SDPP had improved ADG (P<.004) and F/G (P<.02) when compared to pigs fed diets without SDPP (Table 3). Also, increasing SMFM tended to reduce ADFI (linear, P<.10) and improve F/G (quadratic, P<.05).

From d 14 to 21 postweaning, no differences in ADG or F/G were observed. However, ADFI tended to increase (linear, P<.07) as SMFM increased from 0 to 5%.

For the entire d 7 to 21 period, no differences in ADG were observed, but pigs that were fed diets containing 2.5% SMFM tended to have lower ADFI (quadratic, P<.07) and improved F/G (quadratic, P<.09).

No differences in growth performance occurred during phase II (d 21 to 28 postweaning), when all pigs were fed a common diet.

For the overall trial (d 0 to 28 postweaning), the inclusion of 2.5% SMFM in the diet from d 7 to 21 tended to improve F/G (linear, P<.12; quadratic, P<.13). The numerical improvement in ADG and F/G that resulted from including 2.5% SDPP in the transition diet during d 7 to 21 and the numerical differences d 21 to 28 led to an improvement in ADG (P<.08) and F/G (P<.05) for the overall trial.

Conclusions

The results obtained in these two experiments indicate that different management practices and the resulting differences in health status may influence the degree of complexity required in the transition diet for the early-weaned pig. Feeding a transition diet containing 2.5% SDPP and 2.5% SMFM to pigs managed in a one-site production system improved growth performance in Exp. 2. However, results of Exp. 1 indicated that SEW pigs of extremely high-health status can be fed a less complex (33.4% soybean meal) transition diet. Currently, Kansas State University recommendations suggest the inclusion of 2.5% SDPP and 2.5% SMFM in the transition diet for early-weaned pigs from 11 to 15 lb.

Table 1. Composition of Experimental Diets[a]

	0% Plasma protein				2.5% Plasma protein				5% Plasma protein			
Item, %	0	2.5	5	7.5[b]	0	2.5	5	7.5[b]	0	2.5	5	7.5[b]
Corn	34.67	36.70	38.73	40.76	37.35	39.38	41.41	43.44	40.03	42.06	44.09	46.12
Soy oil	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Select menhaden fish meal	-	2.50	5.00	7.50	-	2.50	5.00	7.50	-	2.50	5.00	7.50
Spray-dried plasma protein	-	-	-	-	2.50	2.50	2.50	2.50	5.00	5.00	5.00	5.00
Spray-dried blood meal	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Monocalcium phosphate	1.55	1.31	1.07	0.82	1.66	1.42	1.17	0.94	1.78	1.53	1.29	1.05
Antibiotic[c]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Limestone	0.67	0.49	0.32	0.15	0.67	0.50	0.33	0.16	0.67	0.50	0.33	0.16
Zinc oxide (72%)	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Vitamin premix	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
L-lysine ‑HCl	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
DL-methionine	0.14	0.13	0.12	0.11	0.13	0.12	0.11	0.10	0.12	0.11	0.10	0.09
Salt	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[a]Diets were formulated to contain 1.6% lysine, .9% Ca, .8% P, and at least .44% methionine.
[b]Fish meal, %.
[c]Provided 50 g/ton carbadox.

Table 2. Effect of Spray-Dried Plasma Protein and Select Menhaden Fish Meal in the Transition Diet on Pig Performance (Exp. 1)[a]

	0% Plasma protein				2.5% Plasma protein				5% Plasma protein				
Item	0	2.5	5	7.5[b]	0	2.5	5	7.5[b]	0	2.5	5	7.5[b]	CV
d 5 to 19													
ADG, lb	.75	.73	.74	.73	.75	.78	.74	.80	.77	.74	.73	.75	7.1
ADFI, lb	.89	.90	.90	.88	.90	.97	.86	.91	.90	.87	.83	.87	6.5
F/G[c]	1.18	1.23	1.21	1.21	1.21	1.25	1.16	1.13	1.17	1.17	1.13	1.16	4.3
d 19 to 33													
ADG, lb	1.13	1.16	1.13	1.16	1.07	1.16	1.17	1.15	1.17	1.15	1.11	1.13	7.5
ADFI, lb	1.77	1.74	1.74	1.79	1.76	1.73	1.74	1.72	1.79	1.70	1.70	1.68	5.1
F/G	1.58	1.49	1.54	1.54	1.68	1.50	1.49	1.50	1.54	1.48	1.52	1.50	6.5
d 5 to 33													
ADG, lb	.94	.95	.93	.95	.91	.97	.95	.97	.97	.95	.92	.94	5.5
ADFI, lb	1.33	1.32	1.32	1.33	1.32	1.35	1.30	1.31	1.35	1.28	1.26	1.28	4.2
F/G[d]	1.42	1.39	1.41	1.41	1.46	1.39	1.36	1.35	1.39	1.36	1.37	1.36	3.9

[a]Three hundred weanling pigs were used (initially 8.8 lb and 14 d of age), 5 pigs/pen, 5 pens/treatment.
[b]Fish meal, %.
[c]Linear effect of plasma protein (P<.01).
[d]Linear effect of plasma protein (P<.11).

Table 3. Effect of Spray-Dried Plasma Protein and Select Menhaden Fish Meal in the Transition Diet on Pig Performance (Exp. 2)[a]

	0% Plasma protein			2.5% Plasma protein			
Item	0	2.5	5[b]	0	2.5	5[b]	CV
d 7 to 14							
ADG, lb[c]	.54	.52	.48	.56	.60	.57	10.5
ADFI, lb[d]	.73	.68	.66	.73	.68	.72	8.0
F/G[e]	1.35	1.32	1.39	1.30	1.14	1.25	10.9
d 14 to 21							
ADG, lb	.75	.78	.79	.79	.75	.72	11.4
ADFI, lb[f]	.95	.97	1.02	.96	.95	1.01	6.7
F/G	1.27	1.23	1.28	1.20	1.27	1.37	11.2
d 7 to 21							
ADG, lb	.65	.66	.64	.68	.68	.65	7.9
ADFI, lb[g]	.85	.83	.85	.85	.82	.87	5.0
F/G[h]	1.30	1.27	1.32	1.23	1.20	1.32	7.7
d 21 to 28							
ADG, lb	.93	.88	.90	.90	.96	.91	10.1
ADFI, lb	1.50	1.47	1.50	1.39	1.46	1.52	6.6
F/G	1.61	1.64	1.67	1.49	1.54	1.67	12.3
d 0 to 28							
ADG, lb[i]	.64	.63	.62	.65	.67	.64	5.5
ADFI, lb	.91	.89	.90	.88	.89	.92	4.3
F/G[j]	1.41	1.41	1.43	1.35	1.32	1.43	5.6

[a]Three hundred and twenty six weanling pigs were used (initially 8.6 lb and 12 d of age), 7-11 pigs/pen, 6 pens/treatment.
[b]Fish meal, %.
[c]Plasma effect (P<.004).
[d]Linear effect of fish meal (P<.09).
[e]Plasma effect (P<.02), quadratic effect of fish meal (P<.05).
[f]Linear effect of fish meal (P<.06).
[g]Quadratic effect of fish meal (P<.07).
[h]Quadratic effect of fish meal (P<.09).
[i]Effect of plasma (P<.08).
[j]Effect of plasma (P<.05), linear effect of fish meal (P<.12), and quadratic effect of fish meal (P<.13).

INTERACTIONS AMONG LACTOSE, SPRAY-DRIED ANIMAL PLASMA, AND SOYBEAN MEAL LEVELS MAY AFFECT SEGREGATED EARLY-WEANED PIGS

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Summary

Pigs weaned in a segregated early weaning (SEW) environment achieved maximum performance when fed a sequence of diets containing a gradual decrease in spray-dried animal plasma. Furthermore, pigs weaned at approximately 19 days responded positively to 20% soybean meal. Increased levels of lactose enhanced the increases in performance from soybean meal.

(Key Words: Lactose, Spray-Dried Plasma, Soybean Meal, Early-Weaned Pigs.)

Introduction

Segregated early weaning (SEW) has enabled swine producers to maximize the efficiency of their operations through maximum efficiency of their breeding herd, decreased postweaning mortality, and increased throughput of the operation. Research at Kansas State University has been dedicated to developing diets for the early-weaned pig. In the development of these diets, the goal has been to maximize performance while minimizing the cost of the diet. This research has developed an SEW diet containing 6.7% animal plasma, 6% select menhaden fish meal, 25% dried whey, and 23% total lactose. This diet is formulated to 1.7% lysine and .47% methionine. After this complex initial diet, a defined sequence of diets is fed, matching the animal's increased feed consumption with less nutrient dense and less expensive diets.

Research has shown that the early-weaned pig requires a diet consisting of available protein and highly digestible carbohydrate sources. However, very few data show how these ingredients interact to influence performance of the early-weaned pig. Therefore, it is our goal to determine if increased levels of highly digestible carbohydrate sources will maintain performance in animals fed low levels of complex protein sources and if high levels of complex protein sources will maintain performance in pigs fed a diet low in highly digestible carbohydrate sources.

Procedures

Two experiments were conducted to realize the interaction between lactose and protein source in SEW diets. All pigs were housed in off-site, environmentally controlled nurseries in 4 × 4 ft pens. Animals were allowed ad libitum access to water and feed for the duration of the trial. For the first week of the trial, temperature was maintained at 98°F and then reduced 3 to 5 degrees per week for pig comfort.

In the first experiment, 360 barrows were used in a 35-day growth assay. Initial weight and age were 11.7 lb (16.8 to 8.0) and 19 d (17 to 21 d), respectively. Pigs were allotted by initial weight in a 3×2×2 factorial arrangement with five pigs per pen and six replicate pens per treatment. Twelve dietary treatments were fed from d 0 to 14 (Table 1). Diets consisted of three levels of pure lactose (0, 20, and 40%); two levels of animal

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plasma (0 and 7.5%); and two levels of soybean meal (SBM, 0 and 20%). Formulated to 1.7% lysine, .48% methionine, .9% calcium, and .8% phosphorus, the experimental diets were fed in a pelleted form. A 50% casein - 50% fish meal blend was used as a protein source in diet formulation with SBM and plasma replacing the blend. Experimental diets were followed by a common phase II (d 14 to 28) diet formulated to 1.35% lysine, .41% methionine, .9% calcium, and .8% phosphorus. This diet, containing 10% dried whey and 2.5% spray-dried blood meal, was fed in a meal form. From d 28 to 34, a common phase III diet, formulated to 1.3% lysine, .36% methionine, .9% calcium, and .8% phosphorus, was fed in a meal form. Pigs in trial 1 were weighed and feed disappearance measured on d 7, 14, 21, 28, and 35 to calculate ADG, ADFI, and F/G.

In the second trial, 324 pigs were used in a 26 d growth assay. Initial weight and age were 8.2 lb (5.5 to 10.6 lb) and 10 d (8 to 12 d), respectively. Pigs were allotted by initial weight in a 3×2×2 factorial arrangement with four to five pigs per pen and five replicate pens per treatment. Twelve dietary treatments were fed from d 0 to 10 (Table 2). Diets were similar to those fed in trial 1, except extruded soy protein concentrate replaced the fish meal - casein blend as the protein source substituted when plasma and SBM were added to the diet. Additionally, all experimental diets in this trial contained 6% fish meal. A common transition diet followed the experimental diets from d 10 to 17. Formulated to 1.45% lysine, .40% methionine, .9% calcium, and .8% phosphorus, the common transition diet was fed in pelleted form. The transition diet consisted of 2.5% spray-dried animal plasma, 2.5% spray-dried blood meal, 2.5% fish meal, and 20% dried whey. From d 17 to 26, pigs were fed a common phase II diet formulated to 1.3% lysine .36% methionine, .9% calcium and .8% phosphorus. This diet, containing 10% dried whey and 2.5% spray-dried blood meal, was fed in a meal form. Pigs in trial 2 were weighed and feed disappearance measured on d 5, 10, 17, and 26 to calculate ADG, ADFI, and F/G.

Data were analyzed as a randomized block design in a 3×2×2 factorial arrangement. Data were analyzed for lactose × soybean meal × plasma interactions. Analysis of variance was performed using the GLM procedure of SAS. Linear and quadratic polynomials were evaluated for lactose.

Results and Discussion

In the first experiment, no 3-way interactions occurred between lactose, soybean meal, and spray-dried animal plasma. Individual treatment means are presented in Table 3, and treatment main effect means are presented Table 4. From d 0 to 7, ADG and ADFI increased ($P<.05$) for pigs fed diets containing 6.7% spray-dried animal plasma compared to pigs fed diets without plasma. A linear improvement ($P<.05$) in ADFI also was shown for pigs fed diets containing increasing levels of lactose. A trend for lower ($P<.17$) ADFI was observed for pigs fed diets containing SBM compared to pigs fed diets without SBM. A plasma by lactose interaction ($P<.05$) affected F/G from d 0 to 7. Adding plasma to a diet containing 0% lactose resulted in an improvement in F/G. However, when pigs were fed a diet with lactose levels of 20 or 40%, F/G was not affected when plasma was added to the diet. Pigs fed diets containing SBM had improved ($P<.05$) F/G compared to pigs fed diets without SBM.

From d 7 to 14, pigs fed diets containing 20% SBM had higher ($P<.05$) ADG than pigs fed diets without SBM. This increase in ADG was improved with increasing levels of lactose in the diet, resulting in a lactose by SBM interaction ($P<.05$). Increasing levels of lactose in the diet resulted in a linear improvement in ADFI. Pigs fed diets containing SBM had increased ADFI with the greatest responses observed at the highest levels of lactose, resulting in a lactose by SBM interaction ($P<.05$). A trend for improvements ($P<.17$) in ADFI was observed for pigs fed diets containing plasma compared to pigs fed diets without plasma. A trend for poorer ($P<.1$) F/G was observed for pigs fed diets containing plasma compared to pigs fed diets without plasma. Furthermore, pigs fed

diets containing SBM had improved (P<.05) F/G compared to pigs fed diets with no SBM.

For phase I (d 0 to 14), ADG was improved (P<.05) for pigs fed the diets containing plasma. Similar to the d 7 to 14 period, a SBM by lactose interaction (P<.05) affected ADG. Average daily gain was increased as SBM was added to the diet, with the greatest benefit in the diets containing higher levels of lactose. Pigs fed diets with plasma and SBM had improved (P<.05) ADFI for phase I. There was a trend for a lactose by SBM interaction (P<.1) affecting ADFI. The greatest improvement in ADFI from SBM was in pigs fed diets containing high levels of lactose. Pigs fed diets containing 20% SBM had improved F/G compared with pigs fed diets with 0% SBM. However, the greatest improvement resulted when the diet did not contain plasma, resulting in a plasma by SBM interaction (P<.17).

While pigs were fed a common diet during phase II (d 14 to 28), ADG was decreased (P<.05) for pigs fed diets with 7.5% plasma in phase I. Feed intakes during phase II were improved subsequently for pigs fed soybean meal in the phase I diet. Pigs that were fed plasma in the phase I diet had lower ADFI in phase II than pigs fed diets that did not contain plasma. Additionally, the positive ADFI effect of SBM was decreased in phase II if plasma was included with SBM in the phase I diet, resulting in a plasma by SBM interaction (P<.10). Adding lactose to the phase I diet resulted in a linear trend (P<.10) for an improvement in F/G during phase II. However, adding plasma or SBM to the phase I diet resulted in a trend for poorer (P<.10) F/G in phase II.

For the overall trial (d 0 to 34), ADG was increased (P<.05) for pigs fed SBM in the phase I diet compared to pigs fed diets without SBM during phase I. Surprisingly, adding lactose or plasma to the phase I diet had no influence on performance for the overall trial. There was a trend for a plasma by lactose interaction (P<.17) affecting overall ADFI. When the phase I diet did not contain lactose, adding plasma to the diet increased ADFI. However, when the phase I diet contained high levels of lactose, adding plasma to the diet did not consistently influence ADFI. A similar interaction (P<.17) between plasma and lactose was present for F/G. Adding plasma to the diets containing 0% lactose negatively influenced F/G. When plasma was added to diets containing 20 or 40% lactose, the response was inconsistent. The SBM level in the phase I diet had no influence on F/G for the overall trial.

In the second experiment, from d 0 to 5, ADG was increased (P<.05) for pigs fed diets containing plasma (individual treatment means are presented in Table 5, and treatment main effects are presented in Table 6). Pigs fed increasing levels of lactose had linear improvements (P<.05) in ADFI. A trend for improved (P<.17) F/G was observed for pigs fed diets containing SBM compared to pigs fed diets without SBM.

From d 5 to 10, pigs fed increasing levels of lactose had linear improvements (P<.05) in ADG. In addition, pigs fed diets containing SBM had lower (P<.05) ADG than pigs fed diets without SBM. From d 5 to 10, ADFI was increased linearly (P<.05) for pigs fed increasing levels of lactose. Pigs fed diets containing plasma had higher (P<.05) ADFI from d 5 to 10 compared with pigs fed diets without plasma. A trend for lower (P<.17) ADFI was observed for pigs fed diets with SBM compared to pigs fed diets without SBM. Pigs fed diets with SBM and plasma had the poorest F/G, resulting in an SBM and plasma interaction (P<.1).

During phase I (d 0 to 10), adding lactose to the diet improved ADG (linear, P<.05). Adding plasma to the diet also tended to improve (P<.17) ADG. Both of these responses were the result of an improvement (P<.05) in ADFI from adding lactose or plasma to the diet. Unlike the response in trial 1, the SBM level in the phase I diet had no influence on ADG or ADFI. This different response may have been due to the different protein source replaced when SBM was added to the diet in the second trial. Dietary treatment during phase I had no influence on F/G.

Dietary treatments fed during phase I had no subsequent influence on performance during phase II (d 10 to 26). No differences in growth performance were observed for the overall trial (d 0 to 26). There were two major differences in experimental designs between the two trials. First, the ages of the pigs used in the trials were different. Pigs used in the first trial were 9 days older and 5.5 lb heavier than pigs used in the second experiment. Furthermore, the dietary sequences fed in the two experiments were different. Spray-dried animal plasma was fed in the first trial at 7.5% of the SEW diet for 14 days, whereas pigs in the second trial consumed a 7% plasma SEW diet for only 10 days then were switched to a transition diet containing 2.5% plasma for 7 days. Additionally, protein in diets without SBM and/or plasma was replaced differently. In the first trial, a casein/fish meal blend was used as the replacement. However, the second trial utilized extruded soy protein concentrate as the protein replacement. In reviewing the data from these experiments, it is important to keep these differences in mind.

From these experiments, some conclusions can be drawn to help maximize the performance of early-weaned pigs. Looking for similar ingredient responses between trials shows the positive aspects of plasma early in both trials. However, some negative responses are shown later (phase II and overall) in the first trial. Noting that these negative effects did not happen in the second trial, and remembering the different ways plasma was fed between trials, we may assume that gradually lowering the plasma level fed to early-weaned pigs will maximize performance compared to very rapidly lowering the plasma from a high level (> 5%) to 0%.

We were surprised at the relatively small response to the lactose level in the diet. Previous research at several universities has established lactose as a key component of the diet to encourage consumption and maximize performance of the early-weaned pig. The data from our second trial certainly supports this conclusion.

Data from trial 1 show strong positive responses to including SBM in the initial diet after weaning. However, these responses did not occur in trial 2. Age of pigs in the two experiments may have contributed to this differing response. However, the most likely reason is the different protein sources replaced when SBM was added to the diet. In either case, adding SBM to the diet during the initial period after weaning had no negative impact on ADG.

Table 1. Diet Composition in Trial 1, %[a]

	Lactose, %	0	0	0	0	20	20	20	20	40	40	40	40	
	SBM, %	0	0	20	20	0	0	20	20	0	0	20	20	
Ingredients	Plasma, %	0	7.5	0	7.5	0	7.5	0	7.5	0	7.5	0	7.5	Phase II[b]
Corn		64.70	65.60	54.30	55.10	43.70	44.50	33.20	34.00	22.60	23.50	12.10	13.00	53.80
Soybean meal (48 % CP)		--	--	20.00	20.00	--	--	20.00	20.00	--	--	20.00	20.00	23.90
Porcine plasma		--	7.50	--	7.50	--	7.50	--	7.50	--	7.50	--	7.50	--
Lactose		--	--	--	--	20.00	20.00	20.00	20.00	40.00	40.00	40.00	40.00	--
Soybean oil		6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	3.00
Fish-casein blend		26.10	16.90	15.80	6.50	27.00	17.90	16.70	7.60	28.00	18.80	17.70	8.50	--
Spray dried blood meal		--	--	--	--	--	--	--	--	--	--	--	--	2.50
Dried whey		--	--	--	--	--	--	--	--	--	--	--	--	10.00
Monocalcium phosphate		.65	.92	1.10	1.40	.80	1.10	1.30	1.60	1.00	1.30	1.50	1.70	11.90
Antibiotic		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Limestone		.33	.86	.65	1.20	.18	.71	.5	1.00	.02	.56	.35	.88	.81
Cystine		--	.01	.04	--	.05	.07	.09	.03	.11	.13	.15	.07	--
L-lysine ‑HCl		.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.15
DL-methionine		--	--	--	.06	--	--	--	.08	--	--	--	.10	.10
L-threonine		--	--	--	--	--	--	--	--	.06	--	.02	--	--
Vitamin premix		.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25
Trace mineral premix		.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15
Zinc oxide		.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.25
Salt		.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.25
Total		100	100	100	100	100	100	100	100	100	100	100	100	100

[a]Phase I diets were formulated to contain 1.7% lysine, .48% methionine, .9% calcium, and .8% phosphorus.
[b]Phase II diet was formulated to contain 1.35% lysine, .37% methionine, .9% calcium, and .8% phosphorus.

Table 2. Diet Composition in Trial 2, %[a]

Lactose, %	0	0	0	0	20	20	20	20	40	40	40	40		
SBM, %	0	0	20	20	0	0	20	20	0	0	20	20		
Ingredients Plasma, %	0	7	0	7	0	7	0	7	0	7	0	7	Transition[b]	Phase II[c]
Corn	57.40	62.00	51.40	56.00	36.00	40.60	30.00	34.60	13.00	19.10	8.50	13.10	42.00	52.70
Soybean meal (48 % CP)	--	--	20.00	20.00	--	--	20.00	20.00	--	--	20.00	20.00	21.30	26.80
Porcine plasma	--	7.00	--	7.00	--	7.00	--	7.00	--	7.00	--	7.00	2.50	--
Lactose	--	--	--		20.00	20.00	20.00	20.00	40.00	40.00	40.00	40.00	--	--
Soybean oil	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	3.00
Ex. soy concentrate	26.80	15.30	12.90	1.30	28.10	16.50	14.20	2.60	3.90	17.80	15.40	3.87	--	--
Spray dried blood meal	--	--	--	--	--	--	--	--	--	--	--	--	2.50	2.50
Fish meal	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	2.50	--
Dried whey	--	--	--	--	--	--	--	--	--	--	--	--	20.00	10.00
Monocalcium phosphate	1.3	1.12	1.20	1.00	1.50	1.40	1.40	1.30	1.50	1.60	1.70	1.50	1.30	1.90
Antibiotic	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Limestone	.6	.76	.63	.77	.51	.65	.52	.66	.54	.54	.41	.55	.75	1.00
Cystine	--	--	--	--	.03	--	.03	--	.06	.06	.06	.06	--	--
L-lysine -HCl	.15	.15	.15	.15	.5	.15	.15	.15	.15	.15	.15	.15	.10	.15
DL-methionine	.09	.10	.08	.10	.12	.17	.11	.16	.17	.17	.15	.17	.12	.10
Vitamin premix	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15
Zinc oxide	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.25
Salt	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.10	.20	.25
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100

[a]Phase I diets were formulated to contain 1.7% lysine, .48% methionine, .9% calcium, and .8% phosphorus.
[b]Transition diet was formulated to contain 1.45% lysine, .4% methionine, .9% calcium, and .8% phosphorus.
[c]Phase II diet was formulated to 1.3% lysine, .36% methionine, .9% calcium, and .8% phosphorus.

Table 3. Response Criteria from Trial 1[a]

Lactose, %	0	0	0	0	20	20	20	20	40	40	40	40									
SBM, %	0	0	20	20	0	0	20	20	0	0	20	20									
Plasma, %	0	7.5	0	7.5	0	7.5	0	7.5	0	7.5	0	7.5	L	S	P	L*S	L*P	S*P	Lin	Quad	CV
Week 1																					
ADG, lb	.46	.56	.49	.55	.51	.59	.53	.58	.48	.59	.51	.59			**						15.2
ADFI, lb	.41	.48	.40	.44	.44	.53	.41	.52	.43	.53	.42	.51	**	†	**				**	†	8.7
F/G	.92	.87	.82	.79	.85	.90	.78	.89	.91	.90	.84	.87		**			**				8.1
Week 2																					
ADG, lb	.91	.91	.96	.93	.79	.79	.97	.91	.72	.71	1.01	1.07	*	**		**			*	†	12.0
ADFI, lb	.89	.93	.92	1.00	.84	.80	.87	.89	.71	.76	.92	1.00	**	**	†	**			**	†	14.2
F/G	.98	1.03	.95	1.07	1.08	1.01	.89	1.02	.99	1.08	.90	.93		**	*						13.5
Phase I (0 - 14)																					
ADG, lb	.68	.73	.72	.74	.65	.69	.75	.75	.60	.65	.76	.83	**	**	**						11.0
ADFI, lb	.65	.71	.66	.72	.64	.66	.64	.71	.57	.65	.67	.75	**	**	*						11.4
F/G	.95	.97	.91	.97	.99	.96	.85	.96	.96	.99	.88	.91	**	*				†			9.1
Phase II (14 - 28)																					
ADG, lb	1.16	1.14	1.17	1.13	1.13	1.03	1.19	1.11	1.27	1.04	1.16	1.15			**						10.6
ADFI, lb	1.62	1.62	1.64	1.63	1.58	1.43	1.64	1.62	1.62	1.40	1.65	1.62		**	**			*	†		7.9
F/G	1.39	1.43	1.40	1.45	1.41	1.40	1.38	1.51	1.27	1.34	1.41	1.41	*	*	*				*		8.0
Overall (0 - 34)																					
ADG, lb	1.01	1.03	1.03	1.02	.99	.96	1.05	1.02	1.02	.93	1.04	1.07		**							7.3
ADFI, lb	1.30	1.36	1.32	1.38	1.29	1.24	1.34	1.34	1.30	1.20	1.33	1.35		**			†		*		7.3
F/G	1.28	1.32	1.28	1.35	1.30	1.30	1.29	1.32	1.27	1.30	1.28	1.26	*		**		†		**		3.7

[a]Means represent 364 barrows (initially 11.7 lb and 19 d).

[b]**Represents mean differences or interactive means of P<.05. * Represents mean differences or interactive means of P<.1

†Represents mean differences or interactive means of P<.17.

Table 4. Main Effects of Treatment in Trial 1[a]

	Lactose, %			SBM, %		Plasma, %	
Item	0	20	40	0	20	0	7.5
Week 1							
ADG, lb	.52	.56	.54	.53	.54	.50	.58
ADFI, lb[d]	.43[b]	.48[c]	.47[c]	.47	.45	.42	.50
F/G	.85	.86	.88	.89[b]	.83[c]	.85	.87
Week 2							
ADG, lb	.93	.86	.88	.80[b]	.98[c]	.89	.89
ADFI, lb[d]	.94[b]	.85[c]	.85[c]	.82[b]	.93[c]	.86	.90
F/G	1.01	1.00	.98	1.03[b]	.96[c]	.97	1.02
Phase I (0 - 14)							
ADG, lb	.72	.71	.71	.67[b]	.76[c]	.70	.73
ADFI, lb	.68	.66	.66	.65[b]	.69[c]	.64	.70
F/G	.95	.94	.94	.97[b]	.91[c]	.92	.96
Phase II (14 - 28)							
ADG, lb	1.15	1.11	1.16	1.13	1.15	1.18	1.10
ADFI, lb	1.63	1.57	1.57	1.54[b]	1.63[c]	1.62	1.55
F/G	1.42	1.42	1.36	1.37	1.43	1.38	1.42
Overall (0 - 34)							
ADG, lb	1.02	1.00	1.01	0.99	1.04	1.02	1.00
ADFI, lb	1.34	1.31	1.29	1.28[b]	1.34[c]	1.31	1.31
F/G[d]	1.31	1.30	1.28	1.30[b]	1.30[c]	1.28	1.31

[a]Means represent 364 barrows (initially 11.7 lb and 19 d).
[bc]Represent mean differences (P<.05).
[d]Represent a linear lactose response (P<.05).

Table 5. Response Criteria from Trial 2[a]

Lactose, %	0	0	0	0	20	20	20	20	40	40	40	40									
SBM, %	0	0	20	20	0	0	20	20	0	0	20	20									
Plasma, %	0	7	0	7	0	7	0	7	0	7	0	7	L	S	P	L*S	L*P	S*P	Lin	Quad	CV
Day 0 - 5																					
ADG, lb	.20	.25	.23	.29	.25	.25	.23	.32	.26	.27	.24	.34			**						36.9
ADFI, lb	.18	.18	.19	.21	.22	.25	.20	.25	.23	.23	.22	.26	*						**		27.8
F/G	.92	.84	.84	.73	.90	.93	.87	.78	.90	1.00	.83	.77		†							32.7
Day 5 - 10																					
ADG, lb	.45	.55	.43	.37	.55	.58	.46	.54	.57	.57	.51	.48	**	**					**		23.3
ADFI, lb	.44	.55	.46	.47	.53	.60	.49	.65	.60	.61	.47	.55	**	†	**				**	*	17.6
F/G	1.04	1.02	1.12	1.31	.98	1.04	1.09	1.21	1.05	1.06	.97	1.14		**	**			*			15.0
Phase I (0 - 10)																					
ADG, lb	.32	.40	.33	.33	.40	.41	.35	.43	.41	.42	.37	.41	*		†				**		22.4
ADFI, lb	.31	.36	.32	.34	.37	.42	.35	.45	.42	.42	.34	.41	**		**				**	*	17.3
F/G	1.03	.92	1.02	1.05	.96	1.02	1.02	1.04	1.00	1.00	.92	1.00									11.8
Phase II (10 - 26)																					
ADG, lb	.93	.94	.96	.99	.90	.95	1.01	.95	.96	.94	.96	.90									12.6
ADFI, lb	1.17	1.28	1.27	1.26	1.20	1.22	1.26	1.27	1.30	1.23	1.24	1.16									12.6
F/G	1.26	1.35	1.32	1.28	1.33	1.29	1.26	1.34	1.35	1.31	1.29	1.29									7.3
Overall																					
ADG, lb	.69	.73	.72	.73	.71	.74	.75	.75	.75	.74	.73	.71									11.2
ADFI, lb	.83	.92	.90	.91	.88	.91	.90	.95	.96	.91	.89	.87									12.1
F/G	1.20	1.25	1.26	1.24	1.24	1.23	1.22	1.27	1.28	1.24	1.21	1.22									6.5

[a]Means represent 364 barrows (initially 8.2 lb and 10 d).
[b]** Represents mean differences or interactive means of P<.05. *Represents mean differences or interactive means of P<.1
†Represents mean differences or interactive means of P<.17.

Table 6. Main Effects of Treatment in Trial 2[a]

	Lactose, %			SBM, %		Plasma, %	
Item	0	20	40	0	20	0	7
Day 0 - 5							
ADG, lb	.24	.26	.28	.24	.27	.23[b]	.28[b]
ADFI, lb	.19	.23	.24	.22	.22	.21	.23
F/G	.83	.87	.87	.91	.80	.87	.83
Day 5 - 10							
ADG, lb	.45	.53	.53	.55[b]	.47[c]	.50	.52
ADFI, lb[d,e]	.48[b]	.56[c]	.56[c]	.55	.52	.50[b]	.57[c]
F/G	1.12	1.08	1.05	1.03[b]	1.14[c]	1.04[b]	1.13[c]
Phase I (0 - 10)							
ADG, lb	.34	.40	.40	.40	.37	.36	.40
ADFI, lb	.34[b]	.40[c]	.40[c]	.38	.37	.35[b]	.40[c]
F/G	1.01	1.01	.98	.99	1.01	.99	1.00
Phase II (10 - 26)							
ADG, lb	.95	.95	.94	.94	.96	.95	.94
ADFI, lb	1.24	1.24	1.23	1.23	.124	1.24	1.24
F/G	1.30	1.30	1.31	1.32	1.30	1.30	1.31
Overall							
ADG, lb	.72	.74	.73	.73	.73	.72	.73
ADFI, lb	.89	.91	.91	.90	.90	.89	.91
F/G	1.24	1.24	1.24	1.24	1.24	1.24	1.24

[a]Means represent 364 barrows (initially 8.2 lb and 10 d).
[b,c]Represent mean differences of P<.05.
[d]Represent linear response to lactose (P<.05).
[e]Represent quadratic response to lactose (P<.1).

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

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Summary

A 35-day growth trial was conducted to determine the threonine:lysine ratio necessary to optimize growth performance of the segregated early-weaned (SEW) pig. Twelve experimental diets included two levels of lysine (1.15% and 1.5% digestible lysine) and six digestible threonine:lysine ratios (50, 55, 60, 65, 70, and 75%) in a 2 × 6 factorial arrangement. Growth performance was improved by feeding 1.5% digestible lysine, rather than 1.15% digestible lysine. However, growth performance was not improved by increasing dietary threonine. These data indicate that the threonine requirement is no more than 50% of digestible lysine.

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

Introduction

The development of high nutrient dense diets for early-weaned pigs has facilitated the implementation of segregated early weaning (SEW) as a common management practice. Segregated early weaning involves weaning pigs at 10 to 16 days of age and moving them to a site separate from the sow herd. This allows producers to break disease cycles in the operation, which substantially improves overall herd health and pig performance. Our current limitation in the nutrition of the early-weaned pig is the lack of a thorough understanding of appropriate dietary amino acid levels. Research at Iowa State University has shown that high health pigs require a higher dietary lysine level than pigs of low health status. Additional research from Kansas State University indicates that high-lean growth SEW pigs, weaned at 12 to 14 days of age, require 1.65% to 1.8% dietary lysine to maximize growth rate.

The appropriate level of the other amino acids necessary to optimize growth performance has been an area of considerable debate. The ideal amino acid ratio developed by the University of Illinois indicates that methionine and threonine are deficient in typical diets formulated to meet the lysine requirement of the SEW pig, unless they are added as synthetic amino acids. Therefore, the objective of this experiment was to determine the appropriate threonine:lysine ratio necessary to optimize growth performance in the SEW pig.

Procedures

Three hundred and sixty high-lean growth pigs (PIC, 326 × C15) were weaned at 14 ± 2 d of age and delivered to the segregated early weaning (SEW) facilities at Kansas State University. The pigs were blocked by weight (initially 10.0 ± 1.0 lb) and allotted to one of 12 experimental diets, with a total of five pigs/pen and six pens/treatment. The twelve experimental diets consisted of two levels of lysine (1.15% and 1.5% digestible lysine) and six digestible threonine:lysine ratios (50, 55, 60, 65, 70, and 75%) in a 2 × 6 factorial arrangement (Table 1). The 1.15% digestible lysine diets (1.32% total lysine) were corn-soybean meal based and contained

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20% dried whey, 15.6% lactose, 6.5% spray-dried plasma protein, and 4% select menhaden fish meal. The levels of digestible threonine in the six low lysine diets were .575, .633, .690, .748, .805, and .863%. The levels of dried whey, soybean meal, spray-dried plasma protein, and select menhaden fish meal were increased and 1% spray-dried blood meal added to achieve the 1.5% digestible lysine diets (1.72% total lysine). The levels of digestible threonine in the six high lysine diets were .750, .825, .900, .975, 1.050, and 1.125%.

Synthetic isoleucine, methionine, cystine, valine, and trypthophan (L-isoleucine, DL-methionine, L-cystine, L-valine, and L-tryptophan) were included in the basal diets to ensure that they contained all the essential amino acids suggested by the Illinois ideal amino acid ratio adjusted for an apparent digestible basis. Synthetic threonine (L-threonine) was added to the basal diets at the expense of corn starch to provide the six levels of threonine. The experimental diets were pelleted and fed from d 0 to 21 postweaning.

During phase II (d 21 to 35 postweaning), a common diet was fed. This diet was corn-soybean meal-based; contained 10% dried whey and 2.5% spray-dried blood meal; and was formulated to 1.35% lysine, 0.37% methionine, 0.9% Ca, and 0.8% P.

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

The pigs were weighed and feed disappearance was determined on d 7, 14, 21, 28, and 35 postweaning. Average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G) were the response criteria.

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

Results and Discussion

No dietary threonine by lysine interactions were observed during the trial (Table 2). Increasing the threonine:lysine ratio above 50% did not affect growth performance during any period of the trial. However, pigs that were fed the diets containing 1.5% digestible lysine had improved ADG and F/G ($P<.0001$) when compared to pigs fed the diets containing 1.15% digestible lysine. No differences in ADFI were observed until d 14 to 21, when pigs fed the 1.5% digestible lysine diets had lower ADFI ($P<.04$) than those fed diets containing 1.15% digestible lysine.

No differences occurred in ADG or F/G during phase II (d 21 to 35 postweaning), when all pigs were fed a common diet. However, from d 28 to 35, pigs fed 1.5% digestible lysine from d 0 to 21 had greater ADFI ($P<.002$) than those fed 1.15% digestible lysine during the same period.

For the entire trial period (d 0 to 35 postweaning), no differences in growth performance existed among pigs fed the various levels of threonine. However, pigs that were fed 1.5% digestible lysine from d 0 to 21 had improved ADG ($P<.0001$) and F/G ($P<.0001$) compared to those that were fed 1.15% digestible lysine during the same period.

Although the results of this study did not produce any conclusive evidence of an ideal threonine:lysine ratio, they indicate that most practical diets currently fed to the early-weaned pig may not be deficient in dietary threonine. The addition of synthetic threonine may not be justified, unless the level of digestible threonine:lysine is lower than 50%.

The results obtained during this trial with regard to lysine level, however, are consistent with those obtained in previous trials conducted at Kansas State University. The high-lean growth SEW pigs fed 1.72% total dietary lysine (1.5% digestible lysine) gained

more weight and had better F/G than those fed 1.32% total dietary lysine (1.15% digestible lysine).

Conclusions

Increasing the level of dietary threonine above 50% digestible threonine:lysine did not improve the growth performance of the high-lean growth, high-health status pig.

Table 1. Composition of Experimental Diets

	Digestible lysine, %	
Item, %	1.15%	1.50%
Corn	42.10	33.42
Dried whey	20.00	25.00
Lactose	15.60	12.00
Spray-dried plasma protein	6.50	7.50
Soy oil	6.00	6.00
Select menhaden fish meal	4.00	6.00
Soybean meal (46.5% CP)	0.52	4.27
Spray-dried blood meal	-	1.00
Monocalcium phosphate	1.51	0.97
Antibiotic	1.00	1.00
Limestone	0.57	0.40
L-lysine ·HCl	0.48	0.49
Zinc oxide	0.38	0.38
Corn starch	0.29	0.38
Vitamin premix	0.25	0.25
L-isoleucine	0.21	0.27
DL-methionine	0.17	0.22
Trace mineral premix	0.15	0.15
L-cystine	0.10	0.15
L-valine	0.07	0.05
L-tryptophan	0.05	0.05
Salt	0.05	0.05
Total	100.00	100.00

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

[b]Provided 50 g/ton carbadox.

[c]L-threonine replaced corn starch in the 1.15% and 1.50% digestible lysine basal diets to provide .575, .633, .690, .748, .805, and .863% digestible threonine and .750, .825, .900, .975, 1.050, and 1.125% digestible threonine, respectively. This provided 12 experimental diets in a 2 × 6 factorial arrangement, with two levels of lysine and six levels of digestible threonine:lysine (50, 55, 60, 65, 70, and 75%).

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

	% Digestible threonine:lysine												
	1.15% Digestible lysine						1.50% Digestible lysine						
Item	50	55	60	65	70	75	50	55	60	65	70	75	CV
d 0 to 7													
ADG, lb[b]	0.36	0.29	0.32	0.29	0.29	0.31	0.42	0.37	0.44	0.43	0.43	0.39	19.7
ADFI, lb	0.41	0.42	0.39	0.38	0.37	0.39	0.40	0.38	0.44	0.40	0.38	0.38	14.4
F/G[b]	1.15	1.45	1.23	1.30	1.27	1.28	0.96	1.01	0.98	0.93	0.90	0.95	13.7
d 0 to 21													
ADG, lb[b]	0.61	0.60	0.62	0.58	0.61	0.58	0.71	0.71	0.75	0.72	0.76	0.72	9.7
ADFI, lb	0.81	0.81	0.83	0.81	0.80	0.78	0.77	0.78	0.82	0.77	0.78	0.79	9.0
F/G[b]	1.33	1.35	1.33	1.39	1.30	1.33	1.09	1.10	1.10	1.08	1.02	1.10	4.7
d 21 to 35													
ADG, lb	1.18	1.21	1.29	1.20	1.23	1.28	1.20	1.23	1.20	1.27	1.25	1.24	7.3
ADFI, lb	1.83	1.78	1.81	1.77	1.75	1.84	1.75	1.83	1.82	1.86	1.89	1.85	5.8
F/G	1.54	1.47	1.41	1.47	1.43	1.45	1.45	1.49	1.52	1.45	1.52	1.49	5.9
d 0 to 35													
ADG, lb[b]	0.83	0.84	0.89	0.83	0.86	0.86	0.91	0.92	0.93	0.94	0.95	0.93	6.2
ADFI, lb	1.21	1.20	1.22	1.19	1.18	1.21	1.16	1.20	1.22	1.21	1.22	1.21	5.8
F/G[b]	1.45	1.41	1.37	1.43	1.37	1.39	1.28	1.30	1.32	1.28	1.28	1.32	3.6

[a]Three hundred and sixty weanling pigs were used (initially 10.0 lb and 14 d of age), 5 pigs/pen, 6 pens/treatment.
[b]Effect of lysine ($P<.0001$).

BUILDINGS FOR EARLY-WEANED PIGS

J. P. Murphy[1] *and J. P. Harner*[1]

Summary

Buildings for early-weaned pigs present several challenges to designers and building/equipment manufacturers, but the ability to provide the optimum environmental conditions for the small pig is within the reach of today's technology.

(Key Words: Segregated Early Weaning, Buildings, Engineering.)

Introduction

Buildings for early-weaned pigs are probably the most crucial design challenges of any swine buildings because of the age and size of the pigs. In order to successfully design such a building, the special requirements of the small pig must be analyzed. The building and equipment are key factors for a successful venture with early weaning. Nutrition, sanitation, management, and pig health are also factors that must be considered to bring about a successful building for a segregated early weaning (SEW) operation.

One of the first questions to ask is "How early is early?" The answer to this question may not yet be known, but will be discovered through research and commercial operations. Presently, at university facilities with 200-head rooms, pigs can be weaned as early as 5 days of age and exhibit good growth and continued survival. Many commercial operations are weaning at 14 days. In expectation of future developments, designing an SEW facility for the week-old pig would seem prudent.

The next question is "At what age/size should the pig leave the SEW facility?" This question should consider the quality of the next housing of the pig and the total pig flow capability of the production unit. Most SEW buildings would probably house a pig for at least 3 weeks, because of the labor required to move the pigs and clean/sanitize the room. A time period longer than 8 weeks does not appear to be feasible simply because of the change in physical dimensions of pigs, which causes problems with feeder openings, slatted floor cleaning, ventilation requirements, and pen space. The growth rate in SEW facilities does not appear to be slower than comparable growth on the sow, and may even be accelerated.

The required time period in the SEW facility may be dictated by a specific health problem to be controlled in an operation. Remember, compared to the initial weight, the greatest percentage change of weight per unit of time occurs in SEW rooms than any other swine buildings. A pig initially weighing 5 lb can exit the room in 7 weeks weighing 40 lb — an 800% increase in weight and a considerable increase in physical dimensions and survivability.

Site Considerations

The SEW building should be protected from cross-contamination from other pigs, both from workers moving room to room and from air supply that is contaminated by exhaust air from other buildings. The recommendation of 1/2-mile separation from other buildings is suggested to minimize their

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effects. Success is reported with building distances as little as 200 feet, if location of the building minimizes air contamination from other buildings, i.e., by not being in the prevailing wind direction of other buildings and exhaust fans or not being downhill from other swine buildings. Multiple room construction under a common roof appears possible, but special attention is required to prevent cross-contamination between rooms. Rodent control within and between buildings is critical. Manure drain systems should be trapped to prevent air transfer from building to building through the drain lines.

Walls/Ceiling

Materials used in the construction of the interior walls and ceiling should be chosen to withstand frequent high-pressure washing and to minimize the amount of waste material to which the pig is exposed during daily use. A common wall/ceiling combination involves use of 1/4-in plastic sheets over 1/2-in plywood on the lower 4 ft of the wall and enamelled steel or aluminum on the upper 4 ft of the wall and the ceiling.

Because of the high temperature (90°F+) requirement, insulation is necessary to maintain uniform room temperatures and to reduce heating costs and condensation. Propane heated buildings normally are insulated with R-values of 19 in the walls and 24 in the ceiling. A vapor retarder is necessary on the interior walls and ceiling.

Manure Management

Because of the frequent turnover of pig groups through an SEW facility and the required sanitation, most SEW units are planned to allow removal of manure between each group by draining shallow pits or by flushing manure daily. A common practice is to have a shallow tank to hold 12 to 16 in of liquid. Prior to cleaning the room, the tank is drained. Then, during initial room cleaning, a high pressure washer removes the remaining solids from the floor of the tank. The tank is plugged, and 3 in of water accumulates in the shallow tank as a result of final cleaning prior to the next group of pigs.

Flooring

The largest size opening in a floor should be 3/8 in. Many totally slatted floors (usually plastic and galvanized metal) suitable for farrowing are useable in an SEW building. Producers in the northern United States and areas of Canada are experimenting with a solid portion of flooring for a sleeping area that is heated with hot water or radiant heat (usually in combination with a hover) to reduce whole-room heating costs. Floors should stay clean and dry to maintain high sanitation standards for the pig without daily attention. Ease of cleaning of all floor equipment should be considered, because the pig comes in contact with the floor more than any other area.

Penning/Pen Size

The most common number of pigs per pen is 20, with a maximum of 25 pigs per pen. One-litter pens are used if specific litter growth or health data are important. Within the room, provision should be made for 5% of the pigs to be housed separately, or in reduced numbers, to accommodate problem pigs. The largest opening of the penning and gate hinges should be 1-1/2 in to keep small pigs from becoming entangled in the penning. Vertical rods are recommended to keep pigs from climbing. Allow 1 square foot of floor area for each 10 lb of pig up to 30 lb. The maximum size and number of pigs in the pen will determine the square ft of the pen. Pen width less than 4 ft wide will cause pen circulation (free movement of pigs) problems with pigs above 25 lb. Pigs above 35 lb require a minimum pen width of 5 feet to allow adequate circulation if the feeder normally projects 1 foot into the pen.

Feeders

Feeder spaces should allow at least half of the pigs to eat at one time. The size of the feeder tray opening is controlled by the size of the largest pig in the pen. To eliminate the potential of small pigs becoming trapped in the feeder tray, a tray divider may be needed. Producers usually partially fill feeders or separate pans by hand for the first

week to get pigs eating. Feeders should be located along walkways for ease of filling and management. Removable feeders can be inverted for thorough washing and drying.

Waterers

Nipple waterers are mounted at the height of the pig's back. Waterers need to be adjustable in height if pigs are staying in the room longer than 3 weeks. Water pressure on the nipple, depending on orifice size, should be limited to 20 psi so that the pig can suck/drink water without getting squirted. The mouth size on the pigs makes mini-size nipples a good investment. Nipples that can be adjusted to drip for the first week are also a good investment.

Ventilation/Heating

Because of the small size of the pig, the small amount of air exchange required, and the cost of heating, the ventilating and heating system has very important functions of admitting, distributing, and exhausting air. The air velocity at pig level should be between 5 to 20 ft per minute at normal operation temperature. For pigs up to 30 lb, the ventilation system should provide each pig 2 cubic ft per minute in cold weather and be able to increase to 25 cubic ft per minute during summer. Preheating of air in a hallway can aid distribution of inlet air, but automatic inlets can admit outside air directly (usually from the attic space). Heat exchangers can be used, but they have to be the correct size and need a distribution device (perforated plastic tube) on the incoming air to avoid excessive air velocities at pig level. Furnaces should be located to promote equal air temperature throughout the room. In many situations, placing the furnace with deflectors (to split the hot air into two different directions) near the center of the room helps distribute the heat and provides a good location for thermostat sensing.

Negative pressure systems (a fan exhausting air from room) with automatic adjusting inlets on the ceiling are used commonly. Figure 1 displays a system that distributes both inlet and exhaust air. All of the exhaust air is removed through the floor with the walkway duct system. In buildings without under-floor duct systems, the minimum ventilation fan should be mounted low in the building to remove stale, cool air. Small adjustments in airflow and air temperature are necessary, which make electronic control systems for variable speed fans and heaters popular. Week old pigs are started at 90°F at floor level. After the fifth day, the temperature is decreased about 1°F each day until 75°F is reached. By utilizing hovers/localized heat to obtain the above temperatures in the pig area, the room temperature can be lowered 10 to 15°F. Weekly manual adjustment of the minimum airflow is necessary as the pigs increase in weight.

In an SEW building, a plan is necessary when, not if, temperature control and interruption of electrical service problems arise. The shutters on the minimum fan can be removed and the automatic inlets can be blocked open to have more time before room ventilation problems occur during electrical power outages. Because most SEW buildings are located at a remote site, an alarm system should be considered for both power failure and temperature control problems.

Biosecurity

Figure 1 shows the location of a feed storage room and personnel shower/pathway at one end of the building. Enough sacked feed for a set of pigs normally is stored in this area prior to receiving the pigs to eliminate opening the outside feed door once pigs are in the building. Workers can enter the personnel door to change boots and clothing and shower, as required. Pigs enter the pens through the feed room to minimize the number of doors. Some health problems may require the pigs to be washed and treated prior to placement in the pens. Rules and procedures concerning personnel, boots, clothing, and equipment entering the SEW building should be discussed with the appropriate workers. Reminder/warning signs can help maintain the biosecurity of the building for regular and relief workers. An outside

window to view the pigs and a large, interior thermometer can save unnecessary trips into the building.

In conclusion, SEW buildings present several challenges to designers and building/equipment manufacturers, but the ability to provide the optimum environmental conditions for the small pig is within the reach of today's technology.

Figure 1. Building for Early-Weaned Pigs.

THE EFFECTS OF DIETARY MINERAL REGIMEN ON STARTER PIG GROWTH PERFORMANCE AND BLOOD AND IMMUNE PARAMETERS

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Summary

Two hundred sixty-six weanling pigs (initially 12.46 lb and 21 d of age) were used in a 34-d growth assay to evaluate the effects of various mineral supplementation regimens on starter pig growth, immune status, blood parameters, and liver mineral status. Pigs were fed either a control diet, 3,000 ppm zinc (Zn) in phase I and 2,000 ppm Zn in phase II and III, 250 ppm copper during the entire trial, or a combination of these three diets. These results support our current recommendations of adding zinc oxide in diets of pigs weighing up to 25 lb and copper sulfate in diets fed to pigs from 25 to 50 lb.

(Key Words: Starter, Zinc, Copper, Performance, Pigs.)

Introduction

Recent research at Michigan State University, Louisiana State University, and Kansas State University has shown the benefits of increasing Zn in starter pig diets. Previous research at Kansas State found that feeding 3,000 ppm Zn to pigs weighing less than 15 lb and 2,000 ppm Zn to pigs weighing 15 to 25 lb resulted in the greatest growth response. At Michigan State University, researchers found a similar response to added Zn in starter pig diets. Limited research is available examining the effects of supplementing copper sulfate in diets for pigs previously fed high levels of zinc oxide. Therefore, the objectives of this experiment were to determine the effects of various Zn and Cu supplementation regimens on growth performance, hepatic mineral accumulation, whole blood parameters, and lymphocyte proliferative responses.

Procedures

A total of 266 weanling pigs (initially 12.46 lb and 21 d of age) was used in a 34-d growth assay to compare the effects of various mineral supplementation regimens on the growth performance, mineral status, and immune parameters of starter pigs. The six replicate pens per treatment had six or seven pigs per pen. The pigs were blocked by weight and ancestry, then assigned to one of the seven dietary treatments (Table 1). The diets were fed in three phases: phase I (d 0 to 7), phase II (d 7 to 22), and phase III (d 22 to 34). Diets were formulated to contain 1.6, 1.35, and 1.20% lysine and .44, .40, and .32% methionine during phases I, II, and III, respectively. All of the diets were corn-soybean meal-based. The phase I diets were pelleted and contained 25% dried whey, 7.5% spray-dried porcine plasma, 1.75% spray-dried blood meal, and 5% soybean oil (Table 2). The phase II diets were fed in a meal form and contained 10% dried whey, 2.5% spray-dried blood meal, and 3% soybean oil. Phase III diets were fed in the meal form and were simple corn-soybean meal-based diets containing no alternative protein sources. Zinc oxide (72% Zn) and copper sulfate were added at the expense of cornstarch to provide the experimental mineral treatments. These were designed to represent similar dietary mineral additions in a commercial phase-feeding

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program (Table 1). Phase I diets contained either 3,000 ppm Zn from zinc oxide, 250 ppm Cu from copper sulfate, or no supplemental minerals. Phase II and III diets contained either 2,000 ppm Zn from zinc oxide, 250 ppm Cu from copper sulfate, or no supplemental minerals.

The pigs were housed in an environmentally controlled nursery in 5 ft × 5 ft pens with a self-feeder and two nipple waterers to allow ad libitum access to feed and water. The pigs were weighed and feed disappearance was measured weekly to calculate ADG, ADFI, and F/G. Feed samples were collected and analyzed for total mineral profile and crude protein content.

Blood samples were collected by jugular venapuncture every 7 days to determine white blood cell count, red blood cell count, platelet count, hemoglobin content, and hematocrit (packed cell volume). Additional blood samples were analyzed for ceruloplasmin content on d 0, 7, 22, and 34. Ceruloplasmin is the primary Cu transport protein which is thought to contain as much as 90% of the plasma Cu pool. Leukocyte transformation assays were conducted on d 0 and 34. Leukocyte proliferative responses to mitogen stimulation were conducted on d 0 and 34 for pigs fed no added mineral, or those fed Zn or Cu for the entire trial. Mitogens specific for both B- and T-cell lymphocyte populations were used. To assess the hepatic accumulation of trace minerals, liver biopsies were collected on d 0, 22, and 34.

Results and Discussion

Growth Performance. During phase I (d 0 to 7 postweaning), ADG and F/G were not affected by mineral supplementation. This response contradicts previous research where supplemental Zn from zinc oxide resulted in a dramatic improvement in both ADG and ADFI. Two items may explain the responses observed in phase I: 1) the short period of feeding (7 d versus 14 d in previous research) and 2) the excellent growth of the pigs. The pigs used in this trial were the first set in this nursery following the depopulation/repopulation of our research farm. This contributed to the excellent performance observed in this trial

During phase II (d 7 to 22 postweaning), all pigs remained on the same phase I mineral supplementation except treatment 6. Pigs assigned to treatment 6 were fed a diet containing 3,000 ppm Zn during phase I and a diet with no mineral supplementation during phase II.

Analysis of growth performance during phase II showed that pigs fed the diet containing Zn (treatments 3, 4, and 5) grew faster than pigs fed the diets with no mineral supplementation ($P<.01$) or 250 ppm Cu from copper sulfate ($P<.05$) or the pigs switched from Zn to no supplemental minerals ($P<.01$). Pigs fed the diets with 2,000 ppm Zn had better feed efficiency than pigs fed the control diets ($P<.05$) or pigs fed the diet containing Cu ($P<.10$) and pigs switched from the Zn to the diet containing no supplemental minerals ($P<.10$). Pigs fed the diets containing Zn were almost 1.5 lb heavier ($P<.01$) than pigs fed the control diets and diet containing copper sulfate. This response supports our previous findings that adding Zn in both the phase I and II diets improves growth performance of the weanling pig.

On d 22, pigs were switched to phase III (d 22 to 34) diets. During the first week of phase III (d 22 to 28), pigs fed dietary treatment 6 (Zn d 0 to 22, nothing d 22 to 34) grew faster than the pigs on treatment 5 (Zn d 0 to 22, Cu d 22 to 34; $P<.05$). During the same period, pigs fed treatment 3 (Zn d 0 to 34) had better F/G than pigs fed treatment 5 (Zn d 0 to 22, Cu d 22 to 34). During the second half of phase III (d 28 to 34), no differences were detected for ADG, ADFI, or F/G. However, pigs fed dietary regimen 3 (Zn d 0 to 34) had the lowest ADG and ADFI. This may indicate the start of Zn overload; however, no differences occurred between treatments 3 and 4 in liver mineral levels and whole blood parameters. For the entire phase III period, no differences were detected for ADG, ADFI, or F/G. However, pigs fed dietary regimen 3 (Zn d 0 to 34) and 4 (Zn d 0 to 22, nothing d 22 to 34) were heavier than pigs fed treatment 1 (nothing d 0 to 34).

For the entire 34 d growth assay, pigs fed dietary mineral regimens 3 (Zn d 0 to 34) and 4 (Zn d 0 to 22, nothing d 22 to 34) grew faster than pigs fed the control mineral regimen,

treatment 1 (P<.05). The increased weight of the pigs fed the diets containing Zn in the phase I and II diets demonstrates the importance of including zinc oxide in the diets of weanling pigs.

Blood Analysis. Whole blood analysis revealed that numbers of white blood cells, red blood cells, and platelets; hemoglobin; and hematocrit of all pigs were within normal ranges found in the young pig (data not shown). This indicates that the addition of supplemental Cu and Zn did not have a detrimental effect upon whole blood parameters. Differences were found for pigs fed the diet containing Cu during phase I. They had decreased values compared to pigs fed the control and Zn-containing diets for d 7 red blood cell count, hemoglobin, and hematoctrit. Although these differences were significant, the values did not fall outside of levels accepted as normal for the young pig.

The data collected from the assays showed that supplemental Cu and Zn did not affect the plasma ceruloplasmin concentrations.

Leukocyte proliferative assays were conducted on d 0 and 34 to assess the level of immune system activation and the effects that mineral supplementation might have had upon the immune system. The data from both days indicate that, although levels of mitogenic activity were numerically different between treatments, the addition of supplemental Cu and Zn failed to influence lymphocyte proliferative response to mitogen stimulation.

Liver Analysis. Liver samples collected on d 22 indicated that pigs fed the diet with no added Cu or Zn had decreased concentrations of both of these minerals (Table 4). Pigs fed the diet containing Zn (treatments 3 and 4) had elevated levels for Zn and intermediate levels of Cu in the liver. This indicates that the increased dietary Zn was sequestered by the liver and that the addition of Zn to the diet did not inhibit the uptake of Cu.

When liver samples were collected on d 34, the Zn level for pigs switched from the Zn to control diet were actually higher than that for the pigs maintained on the Zn diet. Unlike d 22 liver samples, Cu levels for the two groups of pigs fed Zn during the first two phases were lower compared to the pigs fed the control and Cu-containing diets. This may have been in response to an antagonistic effect of supplementing high levels of Zn in the diet upon Cu uptake by the intestinal brush border. Copper and Zn, apparently are taken up by the same mechanisms; therefore, overloading the pig's gut with Zn may inhibit the uptake of Cu.

The data from both d 22 and 34 liver samples indicate that plasma mineral levels need to be analyzed to more accurately assess the mineral status of the entire pig. When mineral levels of peripheral tissues drop, the liver sequesters the mineral, without regard to levels in the peripheral tissues, to ensure adequate mineral levels in the liver. If the circulating plasma levels of these minerals are different, we may be able to determine whether supplemental Zn and Cu have an effect upon the mineral status of the young pig.

In conclusion, this trial indicates that feeding 3,000 ppm and 2,000 ppm Zn, from zinc oxide, in the phase I and II diets, respectively, resulted in the greatest growth performance during phases I and II. The data further indicate that following the Zn supplementation with Cu resulted in the greatest growth in phase III. The immune status, determined by leukocyte proliferative assay and ceruloplasmin levels, was not affected by mineral supplementation regimen.

Table 1. Dietary Mineral Supplementation Regimens[a]

	Dietary treatments[b]						
Period	1	2	3	4	5	6	7
d 0 to 7	0	0	Zn	Zn	Zn	Zn	Cu
d 7 to 22	0	0	Zn	Zn	Zn	0	Cu
d 22 to 34	0	Cu	Zn	0	Cu	0	Cu

[a]266 pigs were housed at 6 or 7 pigs/pen with 6 replicate pens/treatment.
[b]Zinc was fed at 2,000 ppm during phase I and 2,000 ppm during phases II and III. Copper was fed at 250 ppm throughout the trial.

Table 2. Composition of Diets[a]

Ingredient, %	Phase I	Phase II	Phase III
Corn	45.21	53.79	62.60
Soybean meal (46.5% CP)	16.90	25.86	31.94
Dried whey	20.00	10.00	--
Spray-dried plasma protein	6.70	--	--
Spray-dried blood meal	1.75	2.50	--
Soybean oil	5.00	3.00	--
Monocalcium phosphate	1.47	1.89	1.51
Limestone	.92	.84	1.95
Antibiotic[b]	1.00	1.00	1.00
Cornstarch[c]	.39	.24	.24
DL-Methionine	.15	.08	--
L-Lysine HCl	.10	.15	.11
Vitamin premix	.25	.25	.25
Trace mineral premix	.15	.15	.15
Salt	.10	.25	.35
Total	100.00	100.00	100.00

[a]Pigs were fed the phase I and phase II diets from d 0 to 14 and d 14 to 28, respectively.
[b]Provided 150 g/ton apramycin in phase I diets and 50 g/ton carbadox in phase II and III diets.
[c]Zinc oxide (.393% in phase I, and .24% in phases II and III) and copper sulfate (.093%) replaced cornstarch to from experimental diets.

Table 3. The Effects of Mineral Supplementation Regimen in Starter Pig Diets on Growth Performance[a]

	Mineral treatments[b]								Contrasts (P <)		
d 0 to 7	0	0	Zn	Zn	Zn	Zn	Cu				
d 7 to 22	0	0	Zn	Zn	Zn	0	Cu				
d 22 to 34	0	Cu	Zn	0	Cu	0	Cu				
Item	1	2	3	4	5	6	7	CV	1 vs 3	1 vs 7	3 vs 7
Phase I (d 0 to 7)											
ADG, lb	.70	.65	.68	.67	.68	.69	.67	11.4	.62	.54	.91
F/G	.89	.87	.92	1.00	1.01	.95	.95	16.2	.78	.55	.75
Phase II (d 7 to 22)											
ADG, lb	.82	.82	.94	.95	.88	.80	.85	10.5	.04	.59	.11
F/G	1.48	1.43	1.28	1.44	1.34	1.58	1.57	15.4	.14	.50	.04
Phase III (d 22 to 34)											
d 22 to 28											
ADG, lb	1.05	1.19	1.19	1.06	0.99	1.23	1.11	16.5	.19	.55	.47
F/G	1.89	1.85	1.68	1.96	2.04	1.70	1.84	7.6	.33	.83	.44
d 28 to 34											
ADG, lb	1.54	1.56	1.48	1.64	1.70	1.50	1.62	14.4	.24	.65	.46
F/G	1.84	1.77	1.78	1.769	1.60	1.82	1.76	14.2	.69	.58	.88
Overall											
ADG, lb	1.29	1.37	1.33	1.35	1.35	1.37	1.37	6.8	.46	.17	.51

F/G	1.86	1.71	1.73	1.83	1.74	1.76	1.76	9.5	.19	.30	.77
d 0 to 34											
ADG, lb	.96	.98	1.02	1.03	1.00	.98	.99	4.9	.04	.29	.31
F/G	1.56	1.49	1.43	1.56	1.48	1.56	1.56	9.2	.11	.98	.11
Pig Weights											
d 7	17.38	17.18	17.25	17.13	17.23	17.29	16.89	3.9	.76	.23	.36
d 22	29.73	29.54	31.34	31.35	30.48	29.29	29.69	4.6	.05	.96	.05
d 28	36.00	36.73	38.47	37.69	36.41	36.67	36.42	4.4	.01	.66	.04
d 34	45.24	46.09	47.32	47.51	46.63	45.69	46.16	3.7	.05	.40	.23

[a]Means derived from 266 pigs housed at 6 or 7 pigs/pen and 6 replicate pens/treatment
[b]Zinc was fed at 2,000 ppm during phase I and 2,000 ppm during phases II and III. Copper was fed at 250 ppm throughout the trial.

Table 4. The Effects of Mineral Supplementation Regimen in Starter Pig Diets on Liver Mineral Levels[ab]

Phase I	0	Zn	Zn	Cu							
Phase II	0	Zn	Zn	Cu							
Phase III	0	Zn	0	Cu		Contrasts (P <)					
Item	1	3	4	7	CV	1 - 3	1 - 4	1 - 7	3 - 4	3 - 7	4 - 7
d 22											
Copper, ppm	8.56	63.13	73.73	280.5	55.7	.59	.77	.0002	.80	.0001	.0001
Iron, ppm	445.00	550.83	424.33	346.33	26.8	.14	.77	.17	..08	.01	.27
Manganese, ppm	12.09	8.94	12.44	9.80	36.3	.18	.88	.33	.14	.71	.26
Zinc, ppm	116.32	335.17	293.30	151.18	52.3	.0056	.02	.61	.55	.02	.05
d 34											

Copper, ppm	57.25	30.09	38.35	247.8	123.9	.72	.79	.02	.91	.01	.01
Iron, ppm	562.17	582.06	600.50	471.50	27.5	.84	.67	.32	.85	.26	.17
Manganese, ppm	9.87	7.72	15.29	9.97	91.5	.73	.36	.99	.24	.72	.37
Zinc, ppm	137.10	148.13	194.33	106.10	34.5	.73	.07	.31	.17	.20	.01

[a]Means derived from liver samples collected from one pig/pen/date/diet (6 pigs/treatment/date).
[b]Baseline (d 0) hepatic mineral levels: Cu = 199.74; Fe = 1175.25; Mn = 8.259; Zn = 337.5 ppm.

EFFECTS OF INCREASING ZINC OXIDE ON STARTER PIG GROWTH PERFORMANCE[1]

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Summary

Four hundred and twenty pigs (initially 9.8 lb and 13 d of age) were used to evaluate the effects of increasing zinc oxide in starter diets. Results that suggest 3,000 ppm and 2,000 ppm zinc, from zinc oxide, improve growth performance in phase I and II diets, respectively.

(Key Words: Starter, Zinc Oxide, Performance.)

Introduction

Recently, researchers at Kansas State University, University of Illinois, and other institutions have investigated the use of supplemental Zn in starter pig diets. The research at Kansas State University showed an advantage to feeding 3,000 ppm Zn. Researchers at the University of Illinois also demonstrated improvements in growth performance from feeding Zn from zinc oxide through 5,000 ppm Zn. At Michigan State University, investigators fed up to 5,000 ppm Zn from zinc oxide before negatively affecting growth. Therefore, the objective of this experiment was to evaluate the effect of increasing Zn (from zinc oxide) in starter pig diets on pig performance and to determine whether high levels of Zn negatively impact growth.

Procedures

A total of 420 weanling pigs (initially 9.8 lb and 13 d of age) were used in a 28-d growth assay to compare the effects of increasing Zn from zinc oxide in diets on the growth of starter pigs. There were eight replicate pens per treatment with 10 or 12 pigs per pen. The pigs were blocked by weight and assigned to one of the five dietary treatments: control (165 ppm Zn and 16.5 ppm copper), 1,000, 2,000, 3,000, or 4,000 ppm Zn. Pigs were maintained on the assigned mineral level throughout the entire 28 d. Diets were formulated to contain 1.6 and 1.25% dietary lysine and .44 and .35% dietary methionine from d 0 to 14 postweaning (phase I) and d 14 to 28 postweaning (phase II), respectively. Both the phase I and II diets were corn-soybean meal based. The phase I diets were pelleted and contained 25% dried whey, 7.5% spray dried plasma protein, 1.75% spray dried blood meal, and 5% soy oil (Table 1). The phase II diets were fed in a meal form and contained 10% dried whey, 2.5% spray dried blood meal, and 3% soy oil. Zinc oxide (72% Zn) was added at the expense of corn starch to achieve the experimental mineral levels.

The pigs were housed in an environmentally controlled nursery in 5 ft × 5 ft pens

[1]The authors with to thank Ellen Johncock and Eichman Brothers, St. George, KS for use of facilities and animals in this experiment.

[2]Northeast Area Extension Office.

with a self-feeder and two nipple waterers to allow ad libitum access to feed and water. The pigs were weighed and feed disappearance was measured weekly to calculate ADG, ADFI, and F/G. Feed samples were collected and analyzed for total mineral profile and crude protein content.

Results and Discussion

During phase I of this trial, increasing dietary Zn resulted in a linear improvement in ADG (Table 2; P<.01), ADFI (P<.01), and F/G (P = .01). Pigs fed the 4,000 ppm zinc diet had the greatest ADG and ADFI and lowest F/G. This indicates the importance of including Zn in the diets of newly weaned pigs.

In phase II, increasing dietary Zn content increased ADG (linear, P<.02; quadratic, P<.01) and ADFI (linear, P<.05). Feed utilization, though not significant, showed a quadratic response, with the best F/G achieved by pigs fed the diet with 2,000 ppm Zn. The lower performance of the pigs fed the 4,000 ppm Zn diet may have been the result of long-term feeding of this high a level of Zn.

For the entire 28-d trial, a curvilinear response was detected for ADG (linear, P<.01; quadratic, P<.11), with the maximum ADG observed at 2,000 ppm Zn. A linear response for ADFI was detected (P<.04), with pigs fed 3,000 ppm Zn consuming the greatest amount of feed over the entire trial. Feed utilization was not significantly affected by dietary Zn in the diet; however, pigs fed the 2,000 ppm Zn diet had the lowest F/G.

In conclusion, this research indicates that diets fed to weanling pigs should contain Zn to achieve optimum growth performance. Current recommendations at Kansas State University are to include 3,000 ppm Zn from zinc oxide in the phase I diet (10 to 15 lb) and 2,000 ppm Zn from zinc oxide in phase II diets (15 to 25 lb).

Table 1. Composition of Diets[a]

Ingredient, %	Phase I	Phase II
Corn	36.93	55.42
Soybean meal (48% CP)	19.30	22.25
Dried whey	25.00	10.00
Spray-dried plasma protein	7.50	--
Spray-dried blood meal	1.75	2.50
Soybean oil	5.00	3.00
Monocalcium phosphate	1.74	1.92
Limestone	.62	.82
Antibiotic[b]	1.00	1.00
Corn starch[c]	.53	.53
DL-methionine	.13	.05
L-Lysine·HCl	.10	.15
Vitamin premix	.25	.25
Trace mineral premix	.15	.15
Total	100.00	100.00

[a]Pigs were fed the phase I and phase II diets from d 0 to 14 and d 14 to 28, respectively.
[b]Provided 150 g/ton apramycin in phase I diets and 50 g/ton carbadox in phase II diets.
[c]Zinc oxide replaced corn starch in experimental diets.

Table 2. The Effects of Increasing Levels of Zinc in Starter Pig Diets on Growth Performance[a]

	Zinc level						Zinc effect (P <)	
Item	165	1,000	2,000	3,000	4,000	CV	Linear	Quadratic
d 0 to 14								
ADG, lb	.36	.38	.40	.41	.47	10.2	.0001	.35
ADFI, lb	.48	.49	.50	.52	.54	7.4	.004	.59
F/G	1.39	1.29	1.26	1.30	1.15	11.9	.01	.98
d 14 to 28								
ADG, lb	.73	.78	.85	.82	.80	7.7	.02	.006
ADFI, lb	1.33	1.37	1.44	1.58	1.53	17.7	.05	.81
F/G	1.84	1.76	1.72	1.90	1.97	13.3	.17	.14
d 0 to 28								
ADG, lb	.54	.58	.62	.61	.63	7.4	.0004	.11
ADFI, lb	.91	.93	.97	1.04	1.02	13.3	.03	.79
F/G	1.69	1.6	1.57	1.70	1.66	11.0	.83	.31

[a]Four hundred twenty weanling pigs (initially 9.2 lb and 12 d of age) were used with 10 or 12 pigs/pen with 8 replicate pens/treatment. Zinc oxide replaced corn starch (165 ppm zinc) in the experimental diets.

WHEAT GLUTEN AND SPRAY-DRIED PLASMA PROTEIN BLENDS FOR NURSERY PIGS

L. L. Burnham, J. D. Hancock, I. H. Kim, and R. H. Hines

Summary

Using a 50:50 blend of spray-dried plasma protein (SDPP):spray-dried wheat gluten (WG) (i.e., with each as approximately 4% of the diet) gave the greatest ADG and ADFI while reducing diet costs compared to the control diet (i.e., 8% SDPP). Even with a slight decrease in efficiency of gain, the marked decrease in diet cost will yield better cost of gain with a 50:50 blend versus using only SDPP.

(Key Words: Nursery, Wheat Gluten, Plasma Protein.)

Introduction

Until recently, milk or milk products were considered essential components of diets for maximum growth and health of early-weaned pigs. Blood products (e.g., plasma protein and blood meal) have been used successfully to replace milk products in nursery diets and typically give greater feed consumption in early-weaned pigs. However, blood products (like milk products) are expensive compared to refined protein products of plant origin.

In previous KSU Swine Day Reports, we suggested that spray-dried wheat gluten (WG) supported greater ADG and ADFI in nursery pigs than did dried skim milk or soy protein isolate. Also, in last year's report, we suggested that a 50:50 blend of wheat gluten (WG) and spray-dried plasma protein (SDPP) gave better overall performance than when either protein source was used individually.

Thus, the experiment reported herein was designed to determine the appropriate ratio of WG and SDPP to minimize diet costs without adversely affecting growth performance of nursery pigs.

Procedures

A total of 150 crossbred (Duroc × Yorkshire × Hampshire × Chester White) weanling pigs (avg initial wt of 12.3 lb) was used in a 32-d growth assay to determine the optimal blend of spray-dried WG and SDPP in diets for nursery pigs. The WG was substituted on a protein basis to yield the desired SDPP:WG blends: 1) SDPP; 2) 75% SDPP and 25% WG; 3) 50% SDPP and 50% WG; 4) 25% SDPP and 75% WG; and 5) WG. The actual amounts (%) SDPP and WG in the diets were 8 and 0, 6 and 1.82, 4 and 3.64, 2 and 5.45, and 0 and 7.25 for the 100:0, 75:25, 50:50, 25:75, and 0:100 ratios, respectively. As WG was added as a greater percentage of the diets, so was crystalline lysine (up to .55% for the 0:100 ratio of SDPP and WG), such that diets for d 0 to 14 were formulated to 1.5% lysine, .42% methionine, .9% Ca, and .8% P, with all other nutrients in excess of NRC (1988) suggestions. For d 14 to 32, the pigs were fed the same corn-soybean meal-whey-based diet formulated to 1.2% lysine, .8% Ca, and .7% P. The pigs were housed in an environmentally controlled nursery room with five pigs per pen and six pens per treatment. Pigs and feeders were weighed on d 0, 14, and 32 to allow for calculation of ADG, ADFI, and F/G. Feces were collected on d 13 from four pigs per pen; pooled; dried; and analyzed for concentrations of DM, N, and Cr.

Data were analyzed as a randomized complete block design with initial wt as the blocking criterion and pen as the experimental unit. Response criteria were ADG, ADFI,

F/G, and digestibilities of DM and N. Polynomial regression was used to describe the shape of the response (i.e., linear, quadratic, cubic, and quartic effects) as WG was added in increasingly greater concentrations.

Results and Discussion

For d 0 to 14, ADG and ADFI increased with up to 50% replacement of the SDPP and decreased when more SDPP was removed from the diet (quadratic effects, P<.004 and .02, respectively). For d 14 to 32, pigs fed the 50:50 blend had the greatest ADFI (quadratic effect, P<.04), resulting in the numerically greatest ADG but poorest (quadratic effect, P<.03) F/G. Overall (d 0 to 32), ADG and ADFI increased as WG was used to replace up to 50% of the SDPP (quadratic effects, P<.04 and .02, respectively). However, the increased ADFI outpaced the increases in ADG, resulting in a trend for a quadratic decrease (P<.06) in efficiency of gain.

No differences occurred in digestibilities of DM or N at d 13 (P>.18). Thus, it seems unlikely that any effects on growth performance for SDPP or WG can be attributed to improved digestibility of nutrients.

In conclusion, using the 50:50 blend of SDPP:WG (i.e., with each as approximately 4% of the diet) gave the greatest ADG and ADFI, while reducing diet costs compared to the 8% SDPP control treatment.

Table 1. Diet Composition, %

	Plasma protein:wheat gluten ratio (d 0 to 14)[ab]					
Item	100:0	75:25	50:50	25:75	0:100	Diet for 14 to 32[c]
Corn	34.45	34.55	34.55	34.65	34.67	49.50
Whey	20.00	20.00	20.00	20.00	20.00	20.00
WG	-	1.82	3.64	5.45	7.25	-
SDPP	8.00	6.00	4.00	2.00	-	-
Lactose	10.00	10.00	10.00	10.00	10.00	-
Soybean meal (48% CP)	18.54	18.54	18.54	18.54	18.54	22.22
Blood meal	1.50	1.50	1.50	1.50	1.50	1.50
Soybean oil	3.00	3.00	3.00	3.00	3.00	3.00
Monocalcium phosphate	1.98	1.96	1.95	1.93	1.91	1.24
Limestone	.65	.66	.67	.69	.69	.70
Vitamins	.25	.25	.25	.25	.25	.25
Minerals	.15	.15	.15	.15	.15	.15
Salt	-	-	.10	.10	.20	.20
Copper sulfate	.08	.08	.08	.08	.08	.08
Chromic oxide[d]	.20	.20	.20	.20	.20	-
Lysine-HCl	.05	.18	.30	.43	.55	.10
DL-methionine	.15	.12	.08	.05	.01	.05
Antibiotic[e]	1.00	1.00	1.00	1.00	1.00	1.00
Total	100.00	100.00	100.00	100.00	100.00	100.00

[a]Diets for d 0 to 14 were formulated to 1.5% lysine, .9% Ca, and .8% P.
[b]WG=spray-dried wheat gluten and SDPP=spray-dried plasma protein.
[c]The diet for d 14 to 32 was formulated to 1.2% lysine, .8% Ca, and .7% P.
[d]Used as an indigestible marker.
[e]Antibiotic supplied 150 g of apramycin per ton of diet for d 0 to 14 and 50 g/ton of carbadox for d 14 to 32.

Table 2. Chemical Composition of the Protein Sources

Item	Spray-dried wheat gluten[a]	Spray-dried porcine plasma[b]
CP, %	74.3	72.0
Amino acids, % of sample		
Arginine	2.6	4.3
Histidine	1.4	2.4
Isoleucine	2.2	2.8
Leucine	4.7	7.3
Lysine	1.3	6.5
Methionine	2.5	.7
Phenylalanine	3.4	4.1
Threonine	2.4	5.2
Tryptophan	.6	1.5
Valine	2.2	4.7
Amino acids, % of CP		
Arginine	3.5	5.6
Histidine	1.9	3.1
Isoleucine	3.0	3.6
Leucine	6.3	9.4
Lysine	1.8	8.5
Methionine	3.4	1.0
Phenylalanine	4.6	5.3
Threonine	3.2	6.8
Tryptophan	.8	1.9
Valine	3.0	6.1

[a]Amino acids analyzed using AOAC (1990) procedures.
[b]Amino acid profile courtesy of Merrick's, Inc.

Table 3. Spray-Dried Wheat Gluten and Porcine Plasma Protein Blends for Nursery Pigs[a]

	Plasma protein:WG ratio (d 0 to 14)[b]						Contrasts			
Item	100:0	75:25	50:50	25:75	100:0	SE	Linear	Quad-ratic	Cubic	Quartic
d 0 to 14										
ADG, lb	.91	.94	.94	.87	.79	.02	.001	.004	-[c]	-
ADFI, lb	.96	1.01	1.01	.96	.87	.03	.05	.02	-	-
F/G	1.05	1.07	1.07	1.10	1.10	.04	.05	-	-	-
d 14 to 32										
ADG, lb	1.21	1.26	1.27	1.21	1.21	.04	-	-	-	-
ADFI, lb	1.77	1.86	1.94	1.86	1.78	.06	-	.04	-	-
F/G	1.46	1.48	1.53	1.54	1.47	.02	-	.03	.09	-
d 0 to 32										
ADG, lb	1.08	1.12	1.13	1.06	1.02	.03	.06	.04	-	-
ADFI, lb	1.42	1.49	1.53	1.46	1.38	.04	-	.02	-	-
F/G	1.32	1.33	1.35	1.38	1.35	.02	.06	.06	.11	-
Apparent digestibility (d 13), %										
DM	88.4	90.5	89.5	89.6	89.5	1.0	-	-	-	-
N	84.0	87.6	86.8	86.8	87.6	1.4	-	-	-	-

[a]A total of 150 weanling pigs (avg initial wt of 12.3 lb) were allotted with five pigs per pen and six pens per treatment.
[b]WG=spray-dried wheat gluten and SDPP=spray-dried plasma protein. Note that the same corn-soybean meal-whey-based diet was fed for d 14 to 32.
[c]Dash indicates P>.15.

Swine Day 1995

EFFECTS OF VARIOUS FRACTIONS OF SPRAY-DRIED PLASMA PROTEIN ON PERFORMANCE OF EARLY-WEANED PIGS[1]

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Summary

Two experiments were conducted to determine the individual protein fraction (IgG, low molecular weight peptides and albumin) contained in spray-dried plasma protein responsible for stimulating feed intake. In Exp. 1, pigs (21 d of age) fed a diet containing the IgG protein fraction had similar performance to pigs fed a plasma protein diet. In Exp. 2, two fractions of spray-dried porcine plasma, IgG and albumin, were evaluated with pigs (10 d of age). Pigs fed either fraction had performance similar to pigs fed plasma protein.

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

Introduction

Previous research at Kansas State University has shown that including spray-dried plasma protein in the phase I high nutrient dense diet will stimulate feed intake and, thus, improve growth performance of pigs weaned at 21 d of age. However, little research has attempted to determine the reason(s) why early-weaned pigs respond to the inclusion of spray-dried plasma protein in the diet. Thus, our objective was to determine whether one of three fractions of spray-dried plasma protein is responsible for these positive responses of early-weaned pigs.

Procedures

Two experiments were conducted to determine the influence of various fractions of spray-dried plasma protein on performance of the early-weaned pig. A total of 216 pigs (initially 9.9 lb and 21-d of age) was used in Exp. 1. Pigs were blocked by weight, sex, and litter and allotted to one of five dietary treatments. Pigs were housed (six pigs/pen and six pens/ treatment) in an environmentally controlled nursery in 5 × 7 ft pens with metal flooring and allowed ad libitum access to feed and water.

Dietary treatments were based on different fractions of spray-dried plasma protein added to the phase I diet (d 0 to 14 postweaning). The different spray-dried plasma protein fractions evaluated were immunoglobulin (IgG), low molecular weight peptides (< 10,000 MW), and albumin. A positive control diet (1.5% lysine and .42% methionine) was formulated to contain 7.5% SDPP, 1.75% spray-dried blood meal, and 25% dried whey (Table 1.). Fractionation of SDPP was conducted by American Protein Inc. A negative control diet was formulated without added SDPP. The three other dietary treatments were formulated replacing dried skim milk in the negative control diet with one of the three plasma fractions on an equal lysine basis. Spray-dried plasma fractions were added to represent the same amount as provided in SDPP. A common diet was fed during phase II (d 14 to 35 postweaning); it

[1]We would like to thank American Protein Inc., Ames, IA, for partial financial support and for providing the plasma fractions used in Exp. 1 and 2.

[2]Northeast Area Extension Office.

[3]American Protein Inc., Ames, IA.

was corn-soybean meal based (1.25% lysine) and contained 2.5% spray-dried blood meal and 10% dried whey (Table 3).

Experiment 2 used a total of 168 pigs (initially 7.0 lb) weaned at approximately 10 d of age. Pigs were blocked by weight and allotted to one of four dietary treatments (Table 2.). There were six pigs/pen and seven pens/treatment. Dietary treatments were based on two different fractions of SDPP (IgG and albumin) and fed to pigs from d 0 to 21 postweaning. The albumin fraction contained 70% crude protein and was 58.5% pure albumin with less than 5% IgG. The IgG fraction contained 80% crude protein and was 48.3% pure IgG with 16% albumin. These analyses were performed on the albumin and IgG fractions used just in Exp. 2 (which were different from lots used in Exp. 1.). A positive control diet (1.7% lysine and .46% methionine) was formulated to contain 25% dried whey, 12% lactose, 10% SDPP, and 6% select menhaden fish meal. The three other dietary treatments were obtained by replacing dried skim milk in a negative control diet with one of the two plasma fractions on an equal lysine basis. A common diet was fed from d 21 to 35 postweaning (Table 3).

For both experiments, pigs and feeders were weighed on d 7, 14, 21, 28, and 35 postweaning to determine ADG, ADFI and feed efficiency (F/G). Both trials were analyzed as randomized complete block designs using nonorthogonal contrasts to separate means.

Results and Discussion

Experiment 1. From d 0 to 14 postweaning, pigs fed the diet containing IgG had higher ADG (P<.07) than pigs fed the negative control or diets containing the low molecular weight or albumin fractions, but were similar to pigs fed the diet containing plasma protein (Table 3.). However, pigs fed the plasma-based diet had the poorest F/G compared to pigs fed the other dietary treatments (P<.10). From d 14 to 35 (when pigs were fed a common diet) and d 0 to 35, no differences were noted for any of the response criteria.

Experiment 2. From d 0 to 21 postweaning, pigs fed either of the two plasma (IgG or albumin) fractions had similar performance compared to pigs fed the positive control diet, but superior performance compared to pigs fed the negative control diet (P<.08; Table 4.). When pigs were switched to a common phase II diet (d 21 to 35 postweaning), no differences in ADG or ADFI occurred among any experimental treatments. However, pigs fed the albumen-based diet during phase I had better F/G compared to pigs fed the IgG fraction (P<.10).

Overall (d 0 to 35 postweaning), pigs fed either the IgG- or albumin-based diets had similar ADG and ADFI compared to pigs fed the positive control diet, but superior performance compared to pigs fed the milk-based diet (P<.08). However, feed efficiency was not effected for the entire nursery period.

Data from Exp. 1 (using pigs weaned at 21 d of age) indicate that pigs fed the IgG fraction had similar performance compared to pigs fed the plasma protein diet. However, in Exp. 2 (using pigs weaned at 10 d of age), pigs fed either IgG or albumin had performance similar to that of pigs fed plasma protein. The use of two different lots of plasma protein to obtain the plasma fractions for Exp. 1 and 2 may explain the differences in results. This research indicates that both the albumin and IgG fractions of SDPP are important in explaining the beneficial response in the early-weaned pig. However, further research is required on the fractionation process to develop purified protein fractions before a specific fraction can be denoted as the cause of the stimulated feed intake observed when SDPP is fed.

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

Item	Neg. control	Plasma protein	Plasma fraction LMW	Plasma fraction IgG	Plasma fraction Albumin	Phase II
Corn	31.33	31.78	29.33	31.51	32.17	58.76
Spray-dried plasma fraction		7.50	2.0	3.84	3.75	
Dried whey	25.00	25.00	25.00	25.00	25.00	10.00
Skim milk	18.00		18.00	8.90	7.60	
Soybean meal, 48.5%	15.03	15.03	15.03	15.03	15.03	21.26
Lactose		9.00		4.55	5.20	
Spray-dried blood meal						2.50
Soybean oil	5.00	5.00	5.00	5.00	5.00	3.00
Fish meal	3.00	3.00	3.00	3.00	3.00	
Antibiotic[b]	1.00	1.00	1.00	1.00	1.00	1.00
Monocalcium phosphate	.736	1.56	.736	1.18	1.23	1.97
Vitamin/mineral premix	.40	.40	.40	.40	.40	.40
Limestone	.21	.384	.21	.30	.32	.83
L-lysine	.15	.15	.15	.15	.15	.15
Copper sulfate	.075	.075	.075	.075	.075	.075
Cystine	.067		.067	.029	.006	
Methionine		.12		.041	.072	.05

[a]All phase I diets were formulated to contain 1.5% lysine, .42% methionine, .90% Ca, and .80% P. The common phase II diet was formulated to contain 1.25% lysine, .35% methionine, .90% Ca, and .80% P.
[b]Provided 150 g/ton of apramycin, in phase I and 50 g/ton of carbadox in phase II.

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

Item	Neg. control	Plasma protein	Plasma fraction IgG	Plasma fraction Albumin
Corn	25.147	25.71	25.30	26.22
Spray-dried plasma fraction		10.00	4.00	5.00
Dried whey	25.00	25.00	25.00	25.00
Skim milk	24.00		14.50	10.14
Soybean meal, 46.5%	12.96	13.00	13.00	13.00
Lactose		12.00	4.75	6.93
Soybean oil	5.00	5.00	5.00	5.00
Fish meal	6.00	6.00	6.00	6.00
Antibiotic[b]	1.00	1.00	1.00	1.00
Monocalcium phosphate	.18	1.28	.638	.838
Vitamin/mineral premix	.40	.40	.40	.40
Limestone	.028	.27	.125	.174
L-lysine	.15	.15	.15	.15
Copper sulfate	.08	.08	.08	.08
Cystine	.07		.053	.011
Methionine		.13	.014	.068

[a]All segregated early-weaned diets were formulated to contain 1.7% lysine, at least .46% methionine, .95% Ca, and .80% P. The common phase II diet was identical to that listed in Table 1.
[b]Provided 150 g/ton of apramycin in phase I and 50 g/ton of carbadox in phase II.

Table 3. The Effect of Various Plasma Fractions on Growth Performance of the Early-Weaned Pig (Exp. 1.)[a]

			Plasma fraction			
Item	Neg. control	Plasma protein	Low MW	IgG	Albumin	CV
d 0 to 14						
ADG, lb	.52[b]	.61[c,d]	.55[b]	.66[c]	.58[b,d]	10.0
ADFI, lb	.54[b]	.70[c]	.56[b]	.70[c]	.62[d]	8.9
F/G	1.03[b]	1.15[e]	1.01[b]	1.06[b,c]	1.09[c,d]	4.9
d 14 to 35						
ADG, lb	1.04	1.00	1.00	.99	1.00	7.1
ADFI, lb	1.74	1.65	1.66	1.70	1.66	6.9
F/G	1.67	1.66	1.66	1.71	1.66	4.8
d 0 to 35						
ADG, lb	.83	.84	.82	.86	.83	6.6
ADFI, lb	1.26	1.27	1.22	1.30	1.24	6.8
F/G	1.51	1.51	1.48	1.51	1.50	3.8

[a]Two hundred and sixteen weanling pigs were used (initially 9.9 lbs and 21 d of age), 6 pigs/pen with 6 pens per treatment.
[bcde]Rows with different superscript differ (P<.10).

Table 4. The Effect of Various Plasma Fractions on Growth Performance of the Early-Weaned Pig (Exp. 2.)[a]

			Plasma fraction		
Item	Neg. control	Plasma protein	IgG	Albumin	CV
d 0 to 21					
ADG, lb	.45[b]	.50[b,c]	.56[c]	.51[b,c]	13.3
ADFI, lb	.54[b]	.61[b,c]	.63[c]	.58[b,c]	12.9
F/G	1.23	1.19	1.13	1.15	10.9
d 21 to 35					
ADG, lb	.84	.83	.82	.88	12.2
ADFI, lb	1.34	1.37	1.39	1.37	8.7
F/G	1.60[b,c]	1.65[b,c]	1.72[b]	1.56[c]	9.3
d 0 to 35					
ADG, lb	.60[b]	.63[b,c]	.67[c]	.65[c]	7.6
ADFI, lb	.86[b]	.91[b,c]	.94[c]	.90[b,c]	7.8
F/G	1.42	1.44	1.41	1.37	5.4

[a]One hundred and sixty eight weanling pigs were used (initially 7.0 lbs and 10 d of age), 6 pigs/pen with 7 pens per treatment.
[bc]Rows with different superscript differ (P<.10).

THE EFFECTS OF SUBSTITUTING SPRAY-DRIED WHOLE EGG FROM EGG GRADING PLANTS FOR SPRAY-DRIED PLASMA PROTEIN IN PHASE I DIETS [1]

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Summary

A study was conducted to evaluate the effects of replacing spray-dried plasma protein with spray-dried whole egg from egg grading plants on starter pig performance. Up to 50% (3.5% of the diet) of spray-dried plasma protein can be replaced with spray-dried whole egg (6% of the diet) without influencing performance of starter pigs.

(Key Words: Starter, Plasma Protein, Egg Protein.)

Introduction

Research at Kansas State University has evaluated several protein sources in diets for early-weaned pigs. These protein sources include spray-dried plasma protein, spray-dried blood meal, skim milk, and various soy protein concentrates. Spray-dried whole egg has an excellent amino acid profile; however, there are few data evaluating the use of spray-dried whole egg in starter pig diets. A study conducted at Kansas State University (Swine Day Report, 1993) indicated that spray-dried egg protein reduced feed intake when added to the diet at high levels (>6%). Additional research was needed to determine the influence of spray-dried whole eggs on starter pig performance. Therefore, the goal of this experiment was to determine the maximum level of spray-dried whole egg from egg grading plants that could replace plasma protein in the phase I diet without negatively affecting performance of starter pigs.

Procedures

A total of 270 pigs (initially 9.5 lb and 14 d of age) was used in this 28 d growth trial. Pigs were blocked by weight and allotted to one of five dietary treatments with a total of seven to 10 pigs/pen and six pens/treatment. Dietary treatments were based on level of spray-dried whole egg (0, 3, 6, 9, or 12%) substituted on a lysine basis for spray-dried plasma protein in the phase I diet. Chemical compositions of the spray-dried whole egg and plasma are presented in Table 1. The spray-dried egg protein used in this study was obtained from plants where eggs are graded and packaged.

The trial was divided into two phases, with the pelleted, experimental diets fed during phase I (d 0 to 14 postweaning). All experimental diets were formulated to 1.5% lysine, .9% Ca, .8% P, and at least .42% methionine. The control diet contained 7.0% spray-dried plasma protein, 1.75% spray dried blood meal, and 20% dried whey. Spray-dried whole egg replaced spray-dried plasma protein on an equal lysine basis, while corn and soybean meal were maintained at 36 and 16% in all diets, respectively. Therefore, diets containing 0, 3, 6, 9, or 12% spray-dried whole egg contained 7, 5.25, 3.5, 1.75, or 0%

[1]The authors would like to thank California Spray Dry Inc. for providing the spray-dried whole egg and for partial funding of the experiment. The authors also wish to thank Steve Eichman and Eichman Farms, St. George, KS for the use of facilities and animals used in this experiment.

[2]Food Animal Health and Management Center.

Table 1. Compositions of Spray-Dried Whole Egg and Plasma Protein

Item, %	Whole egg	Plasma protein
Protein	49.00	70.00
Fat	40.10	2.00
Ash	5.20	13.00
Lysine	3.55	6.10
Methionine	1.58	.53
Tryptophan	.83	1.33
Isoleucine	2.50	1.96
Leucine	4.19	5.56
Valine	3.09	4.12
Threonine	2.31	4.13

plasma protein, respectively. Soybean oil was maintained at 5% in all diets. In phase II (d 14 to 28), a common corn-soybean meal diet containing 2.5% spray-dried blood meal and 10% dried whey was fed in a meal form. This common diet was formulated to 1.35% lysine, .9% Ca, and .8% P. Complete compositions of diets are shown in Table 2.

Pigs were housed in an environmentally controlled nursery in 5 × 5 ft pens. Pigs were provided ad libitum access to feed and water. Average daily gain, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance on d 7, 14, 21, and 28 postweaning.

Data were analyzed as a randomized complete block design. General linear model procedures were used with initial weight to establish the blocks. Linear and quadratic polynomials were used to detect the response of replacing spray-dried plasma protein with spray-dried whole egg.

Results and Discussion

From d 0 to 7 postweaning, ADG and F/G became poorer as spray-dried whole egg increased (linear, P<.05) (Table 3). These linear decreases were most evident in pigs fed 9 and 12% spray-dried whole egg.

In phase I (d 0 to 14), no differences in ADG occurred among those fed the control diet and pigs fed diets containing 3 and 6% spray-dried whole egg. However, ADG was reduced as higher levels of spray-dried whole egg were added to the diet (linear, P<.05). As the level of spray-dried whole egg increased, F/G became poorer (quadratic, P<.05). However, F/G of pigs fed diets with either 3 or 6% spray-dried whole egg was not different than that of pigs fed spray-dried plasma protein.

When all pigs were fed a common diet during phase II, F/G improved as a result of increasing spray-dried whole egg in the phase I diet (linear, P<.05). This response in F/G was due to a tendency for decreased phase II ADFI in pigs fed the higher spray-dried whole egg levels in phase I. However, ADG was not influenced by dietary treatment fed during phase I. For the overall trial (d 0 to 28 postweaning), no differences occurred in ADG or F/G.

This research indicates that spray-dried whole egg can replace a portion of plasma protein in the phase I diet. However, further research is needed to answer these additional questions:

1) Would responses differ with various sources of spray-dried whole egg?

2) Why were the differences in performance at the end of phase I lost during phase II?

3) As the total fat level in the diet increased with higher levels of spray-dried whole egg, why did F/G become poorer in phase I?

In conclusion, based on these results, up to 50% of spray-dried plasma protein can be replaced with spray-dried whole egg without influencing ADG or F/G in phase I. A positive F/G response in phase II is related to the higher spray-dried whole egg levels in phase I. For the overall trial, the level of spray-dried whole egg in the phase I diet caused no differences in pig performance.

Table 2. Composition of Experimental Diets[a]

	Spray-dried whole egg, %					
Ingredients, %	0	3	6	9	12	Phase II[b]
Corn	35.83	35.83	35.83	35.83	35.83	56.81
Soybean meal (48% CP)	16.40	16.40	16.40	16.40	16.40	25.86
Plasma protein	7.00	5.25	3.5	1.75	--	--
Whole egg	--	3.00	6.00	9.00	12.00	--
Soybean oil	5.00	5.00	5.00	5.00	5.00	--
Dried whey	25.00	25.00	25.00	25.00	25.00	10.00
Spray dried blood meal	1.75	1.75	1.75	1.75	1.75	2.50
Monocalcium phosphate	1.85	1.75	1.66	1.56	1.46	1.85
Corn starch	4.38	3.29	2.19	1.09	--	--
Limestone	.63	.61	.60	.58	.57	.85
Antibiotic	1.00	1.00	1.00	1.00	1.00	1.00
L-lysine ·HCl	.13	.13	.13	.13	.13	.15
DL methionine	.15	.11	.07	.03	--	.075
Vitamin premix	.25	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15	.15
Zinc oxide	.38	.38	.38	.38	.38	.25
Salt	.10	.10	.10	.10	.10	.25
Total	100	100	100	100	100	100

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

Table 3. Effects on Pig Performance of Substituting Spray-Dried Whole Egg for Spray-Dried Plasma Protein[a]

	Whole egg, %							
Item	0	3	6	9	12	CV	Linear	Quadratic
D 0 to 7								
ADG, lb	.27	.27	.27	.24	.23	12.3	.03	.45
ADFI, lb	.35	.36	.38	.33	.34	8.9	.39	.16
F/G	1.32	1.35	1.49	1.46	1.54	12.7	.03	.79
D 0 to 14								
ADG, lb	.46	.45	.46	.41	.42	6.1	.004	.72
ADFI, lb	.55	.53	.57	.54	.55	7.8	.96	.87
F/G	1.20	1.20	1.25	1.30	1.30	6.2	.007	.007
D 14 to 28								
ADG, lb	.87	.85	.90	.88	.89	6.8	.32	.96
ADFI, lb	1.49	1.37	1.44	1.42	1.40	5.2	.18	.34
F/G	1.74	1.63	1.62	1.62	1.58	5.0	.006	.23
D 0 to 28								
ADG, lb	.66	.64	.68	.65	.66	5.3	.76	.96
ADFI, lb	1.02	.95	1.01	.98	.97	5.4	.37	.51
F/G	1.55	1.47	1.49	1.52	1.49	4.3	.36	.32

[a]Means represent a total of 270 weanling pigs (initially 9.46 lb and 14 d of age) with 7 to 10 pigs per pen and 6 replicate pens per treatment.
[b,c,d]Means on the same row with different subscripts differ by ($P<.05$).

Swine Day 1995

EFFECTS OF DISTILLERS GRAINS ON GROWTH PERFORMANCE IN NURSERY AND FINISHING PIGS

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Summary

Rate and efficiency of gain were not affected by adding as much as 20% distillers dried grains in isocaloric diets for nursery pigs or 30% in isocaloric diets for finishing pigs. These results demonstrate that the previously suggested maximums of 5% distillers dried grains in nursery diets and 10% distillers dried grains in finishing diets are too conservative. Finally, because the 20% (nursery) and 30% (finishing) treatments were the greatest concentrations used in our experiments, additional growth assays are needed to determine the maximum limits for distillers dried grains in diets for pigs.

(Key Words: Distillers Grains, Nursery, Finishing, Sorghum.)

Introduction

Distillers dried grains with solubles (DDGS) result from the fermentation of cereal grains to produce ethyl alcohol. After the alcohol has been removed, the residue is dried to yield DDGS as a source of energy and protein for animal diets.

With the current interest in production of ethanol for fuel/industrial uses, it seems likely that greater quantities will soon become available. However, little information is available about use of DDGS in pig diets, and most of that information was generated 15 to 25 years ago with corn used in the distillation process. Thus, we designed experiments to evaluate sorghum-based DDGS in diets for nursery and finishing pigs.

Procedures

A total of 72 nursery pigs (average initial wt of 15 lb) was used in the first experiment. There were six pigs per pen and four pens per treatment (two pens of barrows and two pens of gilts per treatment). For 7 d post-weaning, all pigs were fed the same complex starter diet (pelleted form) to allow time for adjustment to the nursery environment. On d 7, the pigs were changed to the experimental diets: 1) corn-soybean meal-based control; 2) 10% DDGS; and 3) 20% DDGS. All diets were formulated to 1.4% lysine, .9% Ca, and .8% P and fed in meal form (Table 1). The ME in the diets was adjusted to the same concentration by adding soybean oil.

The experiment was conducted in an environmentally controlled nursery room equipped with 4-ft × 5-ft pens. Each pen had a self-feeder and nipple waterer to provide ad libitum access to feed and water. The pigs and feeders were weighed on d 7 and 29 to determine ADG, ADFI, and F/G. The data were analyzed as a randomized complete block design with initial weight as the blocking criterion. Day 7 was used as a covariable for analysis of the d 7 to 29 growth data. Polynomial regression was used to characterize the shape of the response to increased concentration of DDGS in the diets.

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In the second experiment, 192 hybrid (PIC line 326 boars × C15 sows) barrows and gilts were used. The average initial weight was 94 lb, and the average final weight was 192 lb. The pigs were allotted by weight into 16 pens (6 ft × 16 ft) with 12 pigs per pen and four pens per treatment. Treatments were: 1) corn-soybean meal-based control; 2) 10% DDGS; 3) 20% DDGS; and 4) 30% DDGS. All diets were formulated to .9% lysine, .65% Ca, and .55% P and fed in meal form (Table 2). As in the nursery experiment, soybean oil was used to ensure that all diets had the same concentration of ME.

Weights were taken at the beginning and end of the 49-d experiment to determine ADG, ADF, and F/G.

The data were analyzed as a randomized complete block design with initial weight as the blocking criterion. Polynomial regression was used to describe the shape of the response to increasing concentration of DDGS in the diets.

Results and Discussion

Chemical analysis of ingredients (Table 3) indicated that the compositions of corn and sorghum were similar to one another and published values (e.g., NRC, 1988). However, the fermentation of starch to ethanol greatly concentrated the nonstarch components (e.g., protein, fat, fiber, ash, and amino acids) in the DDGS. Thus, we might anticipate a lower energy value in DDGS (from less starch) despite the high gross energy (i.e., 4.47 for DDGS versus 4.09 and 4.00 for the sorghum and corn, respectively).

For the experiment with nursery pigs (Table 4), ADG, ADFI, and F/G were not affected by increasing the concentration of DDGS up to 20% of the diet (P>.17). This observation is in sharp contrast with the generally accepted maximum inclusion of only 5% DDGS in diets for nursery pigs. The chemical changes during the distillation process did yield a product with lower energy value. Previous results from a chick assay conducted in our laboratory suggested that the published ME value for DDGS (1,513 kcal/lb) in the NRC (1988) are too high. Our chick assay suggested that a more realistic ME value would be 1,176 kcal/lb. Thus, the discrepancies among our results (with soy oil used to equalize ME) and other reports are likely due to no attempt to equalize ME or use of excessively high values for the ME concentration in DDGS when the diets for the earlier experiments were formulated.

For the experiment with finishing pigs (Table 5), ADG, ADFI, and F/G were not affected by increasing the concentration of DDGS up to 30% of the diet (P>.13). Like the nursery experiment, diets for the finishing experiment were adjusted to the same ME concentration by adding soybean oil. The similar ADFI and F/G for all diets suggested similar ME concentrations, and although pig experiments are needed to determine the actual ME concentration of sorghum-based DDGS, the values we used for our experiments (determined in a chick assay) were fairly accurate. Finally, our results suggested that concerns about palatability of diets with DDGS are unwarranted.

In conclusion, DDGS can be used at concentrations of at least three to four times greater than previously suggested without adversely affecting growth performance of nursery and finishing pigs when ME is equalized with fat. Although additional experiments are needed to determine the maximum amount that can be added to diets for pigs, nutritionists certainly should not feel constrained to less than 20% DDGS for nursery diets and 30% DDGS in diets for finishing pigs.

Table 1. Diet Composition for the Nursery Experiment, %[a]

		Dried distillers grains with solubles	
Ingredient	Control	10%	20%
Corn	47.06	36.20	25.33
Soybean meal (46.5% CP)	30.84	29.78	28.73
Dried whey	15.00	15.00	15.00
Dried distillers grains	—	10.00	20.00
Lysine -HCl	.15	.15	.15
Methionine	.04	0.03	.01
Fish meal	2.00	2.00	2.00
Soybean oil	1.00	3.03	5.05
Monocalcium phosphate	1.41	1.27	1.14
Limestone	.65	.70	.75
Vitamin premix	.25	.25	.25
Trace mineral premix	.15	.15	.15
Salt	.20	.20	.20
Zinc oxide	.25	.25	.25
Antibiotic[b]	1.00	1.00	1.00

[a]All diets were formulated to 1.4% lysine, .9% Ca, .8% P, and 1,476 kcal ME/lb of diet. [b]Supplied 50 g/ton of carbadox.

Table 2. Diet Composition for the Finishing Experiment, %[a]

		Dried distillers grains with solubles		
Ingredient	Control	10%	20%	30%
Corn	77.68	66.82	55.95	45.08
Soybean meal (46.5%)	19.52	18.46	17.41	16.35
Dried distillers grains	—	10.00	20.00	30.00
Lysine -HCl	.15	.15	.15	.15
Soybean oil	—	2.01	4.02	6.04
Monocalcium phosphate	.97	.84	.70	.56
Limestone	1.03	1.07	1.12	1.17
Salt	.30	.30	.30	.30
Vitamin premix	.15	.15	.15	.15
Trace mineral premix	.10	.10	.10	.10
Antibiotic[b]	.10	.10	.10	.10

[a]All diets were formulated to .9% lysine, .65% Ca, .55% P, and 1,496 kcal/lb of ME.
[b]Supplied 50 g/ton of carbadox.

Table 3. Composition of Corn, Sorghum, and Sorghum-Based Distillers Dried Grains with Solubles

Ingredient	Corn	Sorghum	DDGS
DM, %	91.9	91.9	89.8
CP, %[a]	8.0	9.5	25.3
Ether extract, %[a]	3.9	3.0	8.1
Crude fiber, %[a]	3.2	2.5	9.6
Ash, %[a]	1.3	1.3	4.5
GE, Mcal/kg[a]	4.00	4.09	4.47
ME, Kcal/lb	1,551[b]	1,488[b]	1,176[c]
Amino acids, %[a]			
Arginine	.42	.32	.94
Histidine	.26	.21	.56
Isoleucine	.30	.34	.94
Leucine	.97	1.03	2.41
Lysine	.29	.23	.58
Methionine + cystine	.42	.34	.97
Phenylalanine + tyrosine	.66	.68	1.87
Threonine	.28	.26	.81
Tryptophan	.06	.08	.20
Valine	.41	.43	1.21

[a]Dry matter basis.
[b]From NRC (1988).
[c]Determined in our laboratory via chick bioassays.

Table 4. Effects of Sorghum-Based Dried Distillers Grains with Solubles on Growth Performance of Nursery Pigs[a,b]

		Dried distillers grains with solubles			Contrasts[c]	
Item	Control	10%	20%	CV	Linear	Quadratic
ADG, lb	1.02	1.06	1.01	5.4	--	--
ADFI, lb	1.64	1.71	1.76	6.5	--	--
F/G	1.61	1.61	1.74	6.9	--	--

[a]A total of 72 weanling pigs (six pigs per pen and four pens per treatment) with an avg initial wt of 15 lb and an avg final wt of 40 lb.
[b]The experimental diets were fed from d 7 to 29 of the nursery phase.
[c]Dashes indicate P>.15.

Table 5. Effects of Sorghum-Based Dried Distillers Grains with Solubles on Growth Performance of Finishing Pigs[a,b]

		Dried distillers grains with solubles				Contrasts[c]		
Item	Control	10%	20%	30%	CV	Linear	Quadratic	Cubic
ADG, lb	1.97	1.98	1.93	1.93	2.6	--	--	--
ADFI, lb	5.22	5.19	4.98	5.08	3.4	.14	--	--
F/G	2.64	2.62	2.58	2.63	3.9	--	.13	--

[a]A total of 192 pigs (12 pigs per pen and four pens per treatment) with an avg initial wt of 94 lb and avg final wt of 192 lb.
[b]The experimental diets were fed for 49 d.
[c]Dashes indicate P>.15.

THE EFFECTS OF SUBSTITUTING DEPROTEINIZED WHEY OR PURE LACTOSE FOR DRIED WHEY ON STARTER PIG PERFORMANCE [1]

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Summary

A study was conducted to evaluate the effects of replacing all or half of spray-dried, edible-grade whey with deproteinized whey or pure lactose on starter pig performance. No differences in pig performance were observed. Therefore, high quality deproteinized whey and lactose are effective replacements for the lactose provided by dried whey in starter pig diets.

(Key Words: Starter, Whey, Lactose, Performance.)

Introduction

Research reported in the 1993 Kansas State Swine Day report (pg. 46) demonstrated the need for lactose in starter pig diets. This trial showed a linear improvement in pig performance in phase I with increasing lactose (7 to 23%). With the importance of lactose as a nutrient in starter pig diets, the next question to evaluate is alternative lactose sources. Dried whey (edible grade) has become a standard in the swine industry. One of the lactose-containing by-products developed recently is deproteinized whey. Therefore, the objective of this experiment was to compare performance of pigs fed diets containing edible-grade dried whey, pure lactose, and deproteinized whey.

Procedures

A total of 180 weanling pigs (initially 9.1 lb and 22.1 d of age) was used in a 35-d growth assay to evaluate the effects of lactose source on starter pig performance. Allotted by initial weight as well as sex, pigs were fed one of five dietary treatments.

The experiment was divided into two phases. In the first phase (d 0 to 14 post-weaning), experimental diets were fed. The experimental diets were formulated to contain 1.6% lysine, .44% methionine, .9% Ca, and .8% P. The control diet contained 6.7% spray-dried plasma protein, 1.75% spray-dried blood meal, and 25% dried whey. Additional diets were based on lactose source replacing half or all the lactose provided by dried whey in the control diet. Therefore, experimental diets used the following ingredients or combinations to provide 18% total lactose: 25% dried whey, 12.5% dried whey and 9% pure lactose, 18% pure lactose, 12.5% dried whey and 10.9% deproteinized whey, and 21.7% deproteinized whey. Dried whey, lactose, and deproteinized whey were assumed to contain 72, 100, and 83% lactose, respectfully. Pure lactose and deproteinized whey contain no amino acids. Therefore, casein was used to replace the protein fraction of dried whey on an equal lysine basis in diets containing pure lactose and deproteinized whey. The experimental diets were fed in a pelleted form.

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[1]The authors would like to thank Land O' Lakes Inc. for providing the whey and lactose products, as well as partial funding of this experiment.

[2]Northeast Area Extension Office.

During phase II (d 14 to 35 postweaning) of the trial, a common diet was fed to all pigs. Formulated to contain 1.3% lysine, .36% methionine, .9% Ca, and .8%, the phase II diet contained 10% dried whey and 2.5% spray-dried blood meal. This diet was fed in a meal form.

Pigs were housed in an environmentally controlled nursery with six pigs per pen (4 × 5 ft) and six pens per treatment. Pigs had ad libitum access to fed and water. Feed disappearance was measured and pigs were weighed on d 7, 14, 21, 28, and 35 to calculate ADG, ADFI, and F/G.

Results and Discussion

From d 0 to 7 postweaning, lactose source had no effect on ADG, ADFI, or F/G. However, from d 7 to 14 postweaning, pigs fed the diet containing 12.5% dried whey and 9% pure lactose had decreased ADG compared with pigs fed any other lactose source. Average daily feed intake was increased from d 7 to 14 for pigs fed the diet containing of 25% dried whey compared to those fed any other lactose source. Pigs fed diets containing 25% dried whey or 12.5% dried whey in combination with 9% pure lactose had improved F/G compared to pigs fed any other lactose source. From d 0 to 14 postweaning, no difference in ADG or ADFI were observed. However, F/G was improved for pigs fed diets containing 25% dried whey or 12.5% dried whey and 9% pure lactose compared to pigs fed diets containing 18% pure lactose or 12.5% dried whey and 10.85% deproteinized whey.

During phase II (d 14 to 35 postweaning), when pigs were fed a common diet, no differences were observed from dietary treatment fed during phase I**.** Moreover, no differences were shown for the overall trial (d 0 to 35) as a result of dietary lactose source fed in phase I.

In conclusion, deproteinized whey and pure lactose are effective replacements for the lactose in dried whey in the phase 1 diet. However, further research is needed to evaluate the effects of replacing the protein fraction of dried whey. In addition, research is needed to determine the effects of substituting deproteinized whey in phase 2 diets.

Table 1. Composition of Experimental Diets[a]

Ingredients, %[c]	Lactose sources, phase I: 25% Dried whey	12.5% Dried whey + 9% lactose	18% Lactose	12.5% Dried whey + 10.9% deproteinized whey	21.7% Deproteinized whey	Phase II[b]
Corn	37.30	38.47	39.68	36.64	36.01	54.47
Soybean meal (48 % CP)	19.85	19.85	19.85	19.85	19.85	24.97
Porcine plasma	6.70	6.70	6.70	6.70	6.70	-
Casein	--	1.78	3.55	1.85	3.70	-
Soybean oil	5.00	5.00	5.00	5.00	5.00	3.00
Dried whey	25.00	12.50	--	12.50	--	10.00
Pure lactose	--	9.00	18.00	--	--	-
Deproteinized whey	--	--	--	10.85	21.70	-
Spray-dried blood meal	1.75	1.75	1.75	1.75	1.75	2.50
Monocalcium phosphate	1.31	1.67	2.03	1.69	2.04	1.91
Limestone	.98	1.05	1.13	1.04	1.13	1.00
Antibiotic	1.00	1.00	1.00	1.00	10.00	1.00
L-lysine ·HCl	.10	.10	.10	.10	.10	.15
DL-methionine	.14	.14	.14	.15	--	.10
Vitamin premix	.25	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15	.15
Zinc oxide	.38	.38	.38	.38	.38	.25
Salt	.10	.20	.30	.10	.10	.25
Total	100.00	100.00	100.00	100.00	100.00	100.00

[a]Phase I diets were formulated to contain 1.6% lysine, .44% methionine, .9% calcium, and .8% phosphorus.
[b]Phase II diet was formulated to contain 1.30% lysine, .36% methionine, .9% calcium, and .8% phosphorus.

Table 2. Effects of Lactose Ingredient Source on Starter Pig Performance[a]

	Lactose source					
Item	25% Dried whey	12.5% Dried whey 9% lactose	18% Lactose	12.5% Dried whey 10.9% deproteinized whey	21.7% Deproteinized whey	CV
D 0 to 7						
ADG, lb	.59	.54	.57	.48	.58	21.3
ADFI, lb	.55	.49	.49	.44	.47	17.1
F/G	.95	.90	.87	.97	.81	15.8
D 7 to 14						
ADG, lb	.93[c]	.82[b]	.92[c]	.91[c]	.98[c]	7.5
ADFI, lb	1.13[b]	1.00[c]	1.00[c]	1.00[c]	1.01[c]	8.3
F/G	1.21[b]	1.22[b]	1.09[c]	1.09[c]	1.03[c]	5.3
D 0 to 14						
ADG, lb	.76	.68	.75	.70	.78	11.1
ADFI, lb	.84	.75	.75	.72	.74	10.0
F/G	1.11[c]	1.09[c]	1.00[bd]	1.04[cd]	.95[b]	6.1
D 14 to 35						
ADG, lb	1.09	1.05	1.09	1.10	1.07	5.9
ADFI, lb	1.86	1.71	1.82	1.82	1.81	6.5
F/G	1.70	1.63	1.68	1.66	1.70	5.1
D 0 to 35						
ADG, lb	.96	.90	.95	.94	.95	5.7
ADFI, lb	1.45	1.32	1.39	1.38	1.38	6.0
F/G	1.51	1.46	1.46	1.47	1.45	4.0

[a]Means represent a total of 180 pigs (initially 9.05 lb and 22.1 d of age) with 6 pigs per pen and 6 replicate pens per treatment.
[b,c,d]Means on the same row with different subscripts differ (P<.05).

EFFECTS OF LACTOSE SOURCES ON NURSERY PIG GROWTH PERFORMANCE [1]

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Summary

A study was conducted to evaluate different sources of pure lactose as a substitute for spray-dried, edible-grade whey in starter diets. Results suggest that pure lactose can replace the lactose provided by dried whey in phase I starter diets. However, numerical differences in growth performance occurred among the lactose sources used.

(Key Words: Starter, Lactose, Performance.)

Introduction

Recent research at Kansas State University has shown that increasing lactose from 7 to 23% in a spray-dried plasma protein-based diet resulted in a linear improvement in pig performance. Pure lactose has been shown to be an effective replacement for dried whey in diets for the early-weaned pig. With increasing availability of lactose, we wanted to know if differences in nutritional value existed among different lactose sources. Therefore, the objective of this experiment was to compare growth performance of pigs fed different lactose sources as well as pigs fed a diet containing spray-dried, edible-grade whey.

Procedures

A total of 344 pigs (initially 9.6 lb and 13.97 d) was used in this 28 d growth trial. Pigs were blocked by weight and allotted to one of six dietary treatments with a total of seven to 11 pigs/pen and five to six pens/treatment. Treatments were based on lactose sources used to replace the lactose (14.4%) provided by dried whey in the phase I diet, as well as positive (20% dried whey) and negative control (7.2% lactose) diets.

The trial was divided into two phases with the pelleted, experimental diets fed during phase I (d 0 to 14 postweaning). All experimental diets were formulated to 1.6% lysine, .9% Ca, .8% P, and at least .44% methionine. The positive control diet contained 6.7% plasma protein, 1.75% spray dried blood meal, and 20% dried whey. Soybean oil was maintained at 5% in all diets. In the lactose-source diets, pure lactose was used to replace the lactose fraction of dried whey (14.4% lactose). Additionally, casein replaced the protein fraction contributed by dried whey, on an equal lysine basis. The negative control diet was formulated to contain only 7.2% lactose and no dried whey. The protein fraction provided by dried whey again was replaced by casein on a lysine basis.

In phase II (d 14 to 28), a common corn-soybean meal diet containing 2.5% spray-dried blood meal and 10% dried whey was fed in a meal form. This common diet was formulated to 1.35% lysine, .9% Ca, and .8% P.

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[1]The authors would like to thank First District Association and Mid American Dairymen for providing lactose products. The authors also wish to thank Steve Eichman and Eichman Farms, St. George, KS for the use of facilities and animals in this experiment.

[2]Northeast Area Extension Office.

Pigs were housed in an environmentally controlled nursery in 5 x 5 ft pens. Pigs were provided ad libitum access to feed and water. Average daily gain, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance on d 7, 14, 21, and 28 postweaning.

Data were analyzed as a randomized complete block design. General linear model procedures were used with blocks based on initial weight.

Results and Discussion

From d 0 to 7 and d 7 to 14 postweaning, lactose source had no effect on ADG, ADFI, and F/G. Additionally, lactose source had no effect on growth performance in phase I (d 0 to 14 postweaning).

When all pigs were fed a common diet during phase II (d 14 to 28), ADG was not affected by the diet fed during phase I. However, pigs fed the negative control or lactose source 2 in phase I had decreased ($P<.05$) ADFI in phase II compared to those fed all other diets. No differences were observed in F/G during phase II.

Although not significant, pigs fed lactose source 4 during phase I had 12.5% poorer ADG than pigs fed lactose source 3 or the diet containing 20% dried whey, for the overall trial (d 0 to 28). Pigs fed the positive control diet or lactose source 1 during phase I had higher ADFI than pigs fed the negative control. In addition, pigs fed the positive control had higher ADFI than pigs fed lactose source 2. Intermediate ADFI was observed for pigs fed diets with lactose sources 3 and 4. Feed efficiency was not affected by phase I lactose source.

In conclusion, only numerical differences in performance were observed among the lactose sources used. Moreover, pure lactose is an effective replacement for the lactose provided by dried whey in starter pig diets. However, further research is needed to determine the specific chemical characteristics of lactose from different sources and their effects on growth performance.

Table 1. Composition of Experimental Diets[a]

Ingredients, %	Positive control	Lactose source[b]	Negative control	Phase II[c]
Corn	41.60	43.70	51.30	56.80
Soybean meal, 48 % CP	20.50	20.50	20.50	25.90
Dried whey	20.00	--	--	10.00
Lactose	--	14.40	7.20	--
Casein	--	2.80	2.50	--
Plasma protein	6.70	6.70	6.70	--
Spray dried blood meal	1.75	1.75	1.75	2.50
Soybean oil	5.00	5.00	5.00	--
Monocalcium phosphate	1.40	2.00	1.90	1.90
Limestone	.90	1.00	1.10	.85
Antibiotic	1.00	1.00	1.00	1.00
L-lysine ‑HCl	.10	.10	.10	.125
DL-methionine	.14	.10	.10	--
Vitamin premix	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15
Zinc oxide	.38	.38	.38	.25
Salt	.10	.10	.10	.25
Total	100.00	100.00	100.00	100.00

[a]Phase I diets were formulated to contain 1.6% lysine, .44% methionine, .9% Ca, and .8% P.
[b]All four lactose sources were replaced at equal levels.
[c]Phase II diet was formulated to contain 1.35% lysine, .37% methionine, .9% Ca, and .8% P.

Table 2. Effects of Lactose Source on Starter Pig Performance[a]

	25% Dried whey	Lactose source, 14.4%				7.2% Lactose	
Item	Positive control	1	2	3	4	Negative control	CV
Day 0 to 7							
ADG, lb	.30	.27	.27	.28	.24	.24	24.1
ADFI, lb	.45	.42	.40	.40	.38	.40	13.7
F/G	1.62	1.67	1.64	1.48	1.73	1.52	24.9
D 7 to 14							
ADG, lb	.65	.63	.66	.69	.61	.60	12.2
ADFI, lb	.80	.73	.73	.73	.70	.67	11.7
F/G	1.24	1.17	1.11	1.05	1.16	1.12	12.5
D 0 to 14							
ADG, lb	.48	.45	.46	.48	.42	.44	10.2
ADFI, lb	.62	.57	.56	.56	.54	.54	9.9
F/G	1.32	1.29	1.23	1.16	1.30	1.24	10.0
D 14 to 28							
ADG, lb	.93	.88	.88	.92	.91	.83	7.6
ADFI, lb	1.49[b]	1.46[b]	1.40[bc]	1.42[b]	1.44[b]	1.31[c]	6.6
F/G	1.61	1.67	1.58	1.54	1.59	1.59	7.0
D 0 to 28							
ADG, lb	.70	.67	.67	.70	.66	.63	7.1
ADFI, lb	1.10[b]	1.00[bd]	.98[cd]	.99[bc]	.99[bc]	.92[c]	6.4
F/G	1.51	.154	.146	1.41	1.49	1.47	5.9

[a]Means represent a total of 344 weanling pigs (initially 9.63 lb and 13.97 d of age) with 7 to 11 pigs per pen and 5 to 6 replicate pens per treatment.
[b,c,d]Means on the same row with different subscripts differ (P<.05).

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EFFECTS OF DRY-EXTRUDED WHOLE SOYBEANS ON GROWTH PERFORMANCE OF NURSERY PIGS AND GROWTH PERFORMANCE, CARCASS CHARACTERISTICS, AND STOMACH MORPHOLOGY OF FINISHING PIGS

I. H. Kim, J. D. Hancock, R. H. Hines, L. L. Burnham, and T. L. Gugle

Summary

In a 31-d nursery experiment, replacing soybean meal (SBM) with dry-extruded whole soybeans (DEWS) tended to improve F/G (6% overall difference), but ADG was not affected. Ajusting the diet with DEWS to the nutrient:calorie ratio of the diet with SBM did not greatly improve growth performance compared to the diet that was simply formulated to the same concentration of lysine as the diet with SBM. In a second experiment (with finishing pigs), 50 and 100% of the SBM in a corn-based diet was replaced with DEWS. Replacement resulted in 2% greater ADG and 8% better F/G, without significantly increasing carcass fatness or the incidence of stomach ulcers. Our data suggest that DEWS are an acceptable (if not superior) alternative to SBM in diets for nursery and finishing pigs.

(Key Words: Soybeans, Extrusion, Ulcers, Backfat.)

Introduction

In the past several KSU Swine Day Reports, we shared data suggesting equal or greater growth performance in nursery pigs when soybean meal (SBM) and soybean oil were replaced with dry-extruded whole soybeans (DEWS). However, we still are asked frequently if the fat in extruded soybeans is adequately utilized by weanling piglets and if lysine and other nutrients should be increased to keep the same nutrient:calorie ratios in DEWS-based diets.

In contrast, it is generally agreed that fat in diets for growing/finishing pigs improves efficiency and sometimes rate of gain. However, the inclusion of only 5% added fat has been blamed for increased average backfat thickness (as much as .05 to .1 in). Therefore, the objectives of the experiments reported herein were to determine the effects of DEWS (with or without adjustment for nutrient:calorie ratios) on growth performance of nursery pigs. Also of interest was to determine the effects of increased percentage of DEWS in diets (in place of SBM) on growth performance, carcass characteristics, cost of gain, and stomach lesions in finishing pigs.

Procedures

In the first experiment, a total of 72 weanling pigs (initial wt of 10.6 lb) was used in a 31-d growth assay. The pigs (PIC Line 326 boars × C15 sows) were blocked by weight and assigned to treatment based on sex and ancestry. There were six pigs per pen and four pens per treatment. The experimental diets (Tables 1, 2, and 3) were fed in three phase (d 0 to 7, 7 to 17, and 17 to 31). Treatments were: 1) SBM-based control; 2) DEWS without nutrient:calorie ratios adjusted; and 3) DEWS with nutrient:calorie ratios adjusted. Diets with SBM and the DEWS treatment that was not adjusted for nutrient:calorie ratios were formulated to 1.6% lysine for d 0 to 7, 1.45% lysine for d 7 to17, and 1.3% lysine for d 17 to 31. The diets with adjustment for nutrient:calorie ratios were formulated to 1.67% lysine for d 0 to 7, 1.53% lysine for d 7 to 17, and 1.38% lysine for d 17 to 31. The soybeans were mill-run and processed in an Insta-Pro® extruder with a barrell temperature of 298°F and throughput of 1,500 lb/h.

The pigs were housed in an environmentally controlled nursery room with the tem-

perature at 90°F for wk 1 and reduced by 5°F per week thereafter. The pigs had ad libitum access to feed and water. Pigs and feeders were weighed on d 0, 7, 17, and 31 to allow calculation of ADG, ADFI, and F/G.

The data were analyzed as a radomized complete block design with orthogonal contrasts used to separate treatment means. Pen was the experiment unit.

In a second experiment, 150 crossbred (Duroc × Yorkshire × Hampshire × Chester White) finishing pigs (112 lb initial wt) were used. The pigs were housed in a modified open-front buildings (five barrows and five gilts per pen), with 50% solid concrete and 50% concrete slat flooring. Each pen (6 ft × 16 ft) had a two-hole self feeder and a nipple waterer to allow ad libitum consumption of feed and water. There were five pens per treatment. Treatments were: 1) SBM, 2) 50:50 blend (protein basis) of SBM and DEWS, and 3) 100% replacement of SBM with DEWS. The SBM (control) diet was corn-based and formulated to .7% lysine, .65% Ca, and .55% P (Table 4). All diets were formulated to the same lysine:DE ratio (i.e., 2.1 g lysine/Mcal of DE).

The pigs and feeders were weighed at initiation and conclusion of the experiment to allow calculation of ADG, ADFI, and F/G. When pigs in the heaviest pen of a weight block averaged 250 lb, the entire group was removed from the growth assay. The pigs were killed at a commercial slaughter facility, and hot carcass weight was recorded to allow calculation of dressing percentage. Last rib backfat thickness was measured with a ruler on both sides of the split carcass. Stomachs were collected and scored for severity of ulcers and keratinization. The scoring system for ulcers was: 0 = normal; 1 = erosions; 2 = ulcers; and 3 = severe ulcers. The scoring system for keratinization was: 0 = normal; 1 = mild keratosis; 2 = moderate keratosis; and 3 = severe keratosis.

All data were analyzed as a randomized complete block design with pen as the experimental unit. Polynomial regression was used to determine linear and quadratic effects of DEWS concentration.

Results and Discussion

For d 0 to 7 of the nursery experiment, pigs fed diets with DEWS tended to have better F/G ($P<.09$) than those fed diets with SBM (Table 5). For d 0 to 17, pigs fed DEWS had lower ADFI ($P<.04$) and a trend for better F/G ($P<.07$) than pigs fed SBM. Overall (d 0 to 31), no differences in ADG or F/G occurred among pigs fed SBM vs DEWS ($P>.22$), but pigs fed DEWS had a 6% numerical advantage in F/G. Although few statistically significant differences occurred in this experiment, the trends in the responses were consistent to other data generated at KSU during the past 7 yr. The general trend was for better ADG and F/G immediately after weaning, and an F/G effect in the late nursery phase. These responses suggest that the protein and fat in DEWS were utilized well by nursery pigs.

For the finishing experiment, ADG (linear effect, $P<.06$) and F/G (linear effect, $P<.001$) were improved as the concentration of DEWS in the diets was increased (Table 6).

No differences in slaughter weight ($P>.23$) occurred among pigs fed the soybean treatments. However, hot carcass weight and, thus, dressing percentage increased (linear effects, $P<.01$) as the concentration of DEWS was increased. Backfat thickness and fat free lean index were not affected as DEWS concentration was increased ($P>.26$).

The number of stomachs given each score for keratinization and ulceration and a mean score for each treatment are provided in Table 7. As concentration of DEWS was increased, stomach keratinization score increased (row mean scores differ test, $P<.005$). However, severity of ulceration was not affected (row mean scores differ test, $P>.52$) by DEWS concentration in the diet. Furthermore, of the 146 stomachs collected, none had a severe ulcer, and only one had severe keratinization. Therefore, no symptoms of reduced animal health were noted in

our experiment that could be related to dietary treatment.

In conclusion, our data suggest that DEWS provide an excellent protein source for weanling pigs and can be used to replace 100% of the SBM in nursery diets. Finally, finishing pigs fed diets with DEWS in place of SBM had improved rates and efficiencies of gain without negative effects on stomach morphology or carcass fatness.

Table 1. Diet Composition for d 0 to 7 of the Nursery Experiment, %

		DEWS[a]	
Ingredient	SBM[a]	Unadjusted	Adjusted[b]
Corn	31.81	25.04	24.75
Soybean product	21.43	30.17	30.17
Dried whey	20.00	20.00	20.00
Lactose	10.00	10.00	10.00
Plasma protein	4.00	4.00	4.00
Wheat gluten	4.00	4.00	4.00
Blood meal	2.00	2.00	2.00
Soybean oil	2.00	--	--
Dicalcium phosphate	1.90	1.77	1.93
Limestone	.67	.80	.83
Salt	.10	.10	.10
Vitamin premix	.25	.25	.25
Trace mineral premix	.15	.15	.15
L-lysine HCl	.25	.25	.33
DL-methionine	.07	.10	.11
Zinc oxide	.37	.37	.38
Antibiotic[c]	1.00	1.00	1.00
Total	100.00	100.00	100.00
Calculated analysis			
DE, kcal/kg	3,489	3,683	3,672
ME, kcal/kg	3,273	3,419	3,408
Lysine:ME, g/Mcal	4.9	4.7	4.9
CP, %	21.5	21.7	23.7
Lysine, %	1.60	1.60	1.67
Ca, %	.90	.90	.94
P, %	.80	.80	.83
Ether extract, %	3.7	7.4	7.4

[a]SBM=soybean meal and DEWS=dry-extruded whole soybeans.
[b]Adjusted to the same nutrient:calorie ratio as the SBM (control) diet.
[c]Provided 150 g/ton of apramycin.

Table 2. Diet Composition for d 7 to 17 of the Nursery Experiment, %

		DEWS[a]	
Ingredient	SBM[a]	Unadjusted	Adjusted[b]
Corn	43.78	34.36	33.92
Dried whey	20.00	20.00	20.00
Soybean product	27.67	39.02	39.02
Soybean oil	2.00	--	--
Blood meal	2.00	2.00	2.00
Dicalcium phosphate	1.62	1.47	1.69
Limestone	.73	.91	.94
Vitamin premix	.25	.25	.27
Trace mineral premix	.15	.15	.16
L-lysine ·HCl	.15	.15	.26
DL-methionine	.09	.12	.14
Zinc oxide	.36	.37	.39
Salt	.20	.20	.21
Antibiotic[c]	1.00	1.00	1.00
Total	100.00	100.00	100.00
Calculated analysis			
DE, kcal/kg	3,490	3,764	3,748
ME, kcal/kg	3,294	3,506	3,491
Lysine:ME, g/Mcal	4.4	4.1	4.4
CP, %	21.67	21.93	21.91
Lysine, %	1.45	1.45	1.53
Ca, %	.90	.90	.95
P, %	.80	80	.85
Ether extract, %	4.2	9.5	9.5

[a]SBM=soybean meal and DEWS=dry-extruded whole soybeans.
[b]Adjusted to the same nutrient:calorie ratio as the SBM (control) diet.
[c]Provided 150 g/ton of apramycin.

Table 3. Diet Composition for d 17 to 31 of the Nursery Experiment, %

		DEWS[a]	
Ingredient	SBM[a]	Unadjusted	Adjusted[b]
Corn	59.15	48.43	47.99
Soybean product	33.48	47.14	47.14
Soybean oil	3.00	--	--
Monocalcium phosphate	1.51	1.32	1.53
Limestone	.90	1.12	1.15
Vitamin premix	.25	.25	.26
Tracer mineral premix	.15	.15	.16
L-lysine ·HCl	.15	.15	.26
DL-methionine	.02	.05	.09
Copper sulfate	.09	.09	.10
Salt	.30	.30	.32
Antibiotic[c]	1.00	1.00	1.00
Total	100.00	100.00	100.00
Calculated analysis			
DE, kcal/kg	3,634	3,943	3,927
ME, kcal/kg	3,435	3,669	3,654
Lysine:ME, g/Mcal	3.8	3.5	3.8
CP, %	21.24	21.57	21.56
Lysine, %	1.30	1.30	1.38
Ca, %	.80	.80	.85
P, %	.70	.70	.74
Ether extract, %	5.6	11.5	11.4

[a]SBM=soybean meal and DEWS=dry-extruded whole soybeans.
[b]Adjusted to the same nutrient:calorie ratio as the SBM (control) diet.
[c]Provided 50 g/ton of mecadox.

Table 4. Diet Composition for the Finishing Experiment, %

		Replacement of SBM	
Ingredient	SBM[a]	50% DEWS[a]	100% DEWS
Sorghum	81.62	78.50	75.34
Soybean meal	15.71	7.86	--
Extruded soybeans	--	10.81	21.64
Moncalcium phosphate	1.04	1.11	1.18
Limestone	.93	.98	1.04
Salt	.30	.31	.32
Vitamin premix	.15	.15	.16
Tracer mineral premix	.10	.10	.11
Antibiotic[b]	.10	.10	.11
L-lysine -HCl	.05	.08	.10
Total	100.00	100.00	100.00
Calculated analysis			
DE, kcal/kg	3,365	3,405	3,446
ME, kcal/kg	3,208	3,293	3,378
Lysine:DE, g/Mcal	2.2	2.2	2.2
CP, %	14.57	14.61	14.65
Lysine, %	.70	.72	.74
Ether extract, %	2.5	4.5	6.6

[a]SBM=soybean meal and DEWS=dry-extruded whole soybeans.
[b]Provided 40g/ton of tylosin.

Table 5. Effects of Dry-Extruded Whole Soybeans with or without Adjustment for Nutrient:Calorie Ratios in Weaned Pigs[a]

		DEWS[b]			Contrasts[c]	
Item	SBM[b]	Unadjusted	Adjusted	CV	1	2
d 0 to 7						
ADG, lb	.74	.83	.79	9.0	.15	--[d]
ADFI, lb	.73	.74	.68	5.9	--	.12
F/G	.99	.89	.86	9.9	.09	--
d 0 to 17						
ADG, lb	.91	.90	.90	8.2	--	--
ADFI, lb	1.04	.97	.94	5.6	.04	--
F/G	1.14	1.08	1.04	5.8	.07	--
d 0 to 31						
ADG, lb	.99	.96	.99	6.8	--	--
ADFI, lb	1.35	1.26	1.24	4.9	.04	--
F/G	1.36	1.31	1.25	7.5	--	--

[a]Seventy two weanling pigs were used (initial wt of 10.6 lb) with six pigs per pen and four pens per treatment.
[b]SBM=soybean meal and DEWS=dry-extruded whole soybeans.
[c]Contrasts were: 1) SBM vs DEWS; and 2) unadjusted vs adjusted.
[d]Dashes indicate P>.15.

Table 6. Effects of Dry-Extuded Whole Soybeans on Growth Performance in Finishing Pigs[a]

		Replacement of SBM			Contrast	
Item	SBM[b]	50% DEWS[b]	100% DEWS	CV	Linear	Quadratic
ADG, lb	1.82	1.81	1.91	3.9	.06	--[d]
ADFI, lb	6.01	5.74	5.53	4.5	.01	--
F/G	3.30	3.17	2.89	4.8	.001	--
Slaughter wt, lb	251	251	258	3.6	--	--
Hot carcass wt, lb	187	189	190	3.6	.01	--
Dressing percentage	73.7	74.5	74.8	.7	.01	--
Last rib backfat thickness, in	1.13	1.15	1.19	0.6	--	--
FFLI, %[c]	47.1	47.0	46.9	4.5	--	--

[a]A total of 150 finishing pigs were used (initial body wt of 112 lb) with 10 pigs per pen and five pens per treatment.
[b]SBM=soybean meal and DEWS=dry-extruded whole soybeans.
[c]Equation (NPPC, 1991) was: Fat Free Lean Index=51.537 + (.035 × hot carcass wt) - (12.26 × off-midline backfat thickness).
[d]Dashes indicate P>.15.

Table 7. Effects of Dry-Extruded Whole Soybeans on Stomach Morphology in Finishing Pigs[a]

		Replacement of SBM			Contrasts	
Item	SBM[b]	50% DEWS[b]	100% DEWS	CV	1[e]	2[f]
Stomach keratinization						
Total observation	47	50	49	--	--	--
Normal	32	26	18	--	--	--
Mild	11	20	25	--	--	--
Moderate	4	4	5	--	--	--
Severe	0	0	1	--	--	--
Mean score[c]	.58	.78	.93	79.0	.005	.02
Stomach ulceration						
Total observations	47	50	49	--	--	--
Normal	45	50	47	--	--	--
Erosions	1	0	0	--	--	--
Ulcers	1	0	2	--	--	--
Severe ulcer	0	0	0	--	--	--
Mean score[d]	.06	.00	.10	546.0	.52	.23

[a]A total of 146 stomachs were collected (47 to 50/treatment).
[b]SBM=soybean meal and DEWS=dry-extruded whole soybeans.
[c]Scoring system was: 0 = normal; 1 = mild keratinization; 2 = moderate keratinization; and 3 = severe keratinization.
[d]Scoring system was: 0 = normal; 1 = erosions; 2 = ulcers; and 3 = severe ulcers.
[e]Cochran-Mantel-Haenszel statistic, row mean scores differ test.
[f]Cochran-Mantel-Haenszel statistic, nonzero correlation test.

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SODIUM SULFITE AND EXTRUSION AFFECT THE NUTRITIONAL VALUE OF SOYBEAN PRODUCTS FOR NURSERY PIGS

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Summary

Extruded soybeans improved rates and efficiencies of gain when fed to nursery pigs in place of soybean meal (SBM). Sodium sulfite (an extrusion aid) increased extruder throughput and improved d 13 to 35 and overall efficiency of growth in pigs fed extruded soybeans and unextruded SBM. Further research is needed to determine if greater sodium sulfite concentrations will continue to increase extruder throughput and to elucidate the mechanism for improved growth performance of pigs fed sodium sulfite with unextruded SBM.

(Key Words: Nursery, Soybeans, Processing.)

Introduction

Feeding whole soybeans to swine offers soybean producers an alternative to selling their crop, especially in years when poor growing conditions result in green soybeans with poor market value. On-farm or small-scale processing technologies available to producers include roasting and extruding. Roasting involves direct or indirect exposure of the soybeans to dry heat and has given mixed results in swine feeding experiments. Alternatively, extrusion consistently has been demonstrated to yield soybean products with equal or greater nutritional value than SBM, but the cost for processing soybeans can negate much of the benefit in pig performance. Thus, an extrusion aid (sodium sulfite) has been developed to increase extruder throughput and, thereby, decrease the cost per ton of extruded soybeans. Little is known about the effects of sodium sulfite (Na_2SO_3) on nutritional value of extruded soybeans, and in last year's KSU Swine Day Report, we suggested improved nutritional value of diets when Na_2SO_3 was added even with no extrusion treatment. Thus, the experiment reported herein was designed to determine the optimum concentration of Na_2SO_3 for use when extruding soybeans. Also of interest was to verify the response we reported last year, that Na_2SO_3 may be of benefit in diets for weanling pigs even if not used as an extrusion aid.

Procedures

The experiment was arranged in a 2 × 3 factorial with main effects of soybean product (SBM or extruded soybeans) and Na_2SO_3 (0, 15, or 30 lb/ton of soybean product). The dry-extruded whole soybeans (DEWS) treatments were processed in an Insta-Pro® dry extruder, with barrel temperatures of 298°F for the DEWS, 298°F for the DEWS + 15 lbs Na_2SO_3/ton of soy product, and 300°F for the DEWS + 30 lbs Na_2SO_3/ton of soy product.

Six pigs were allotted per pen and five pens per treatment. All diets were formulated to .92% lysine, .8% Ca, and .7% P for d 0 to 13 and .76% lysine, .8% Ca, and .7% P for d 13 to 35 (Table 1). The diets were formulated to be slightly deficient in lysine to emphasize differences in protein utilization among pigs fed the various treatments. Also, soybean oil was added to the diets with soybean meal, so that all diets had the same lysine:DE ratio.

The pigs were housed in an environmentally controlled nursery room with ad libitum access to feed and water. The pigs and feeders were weighed at d 0, 13, and 35 to allow calculation of ADG, ADFI, and F/G. Feces were collected from four pigs in each pen on

d 12 and pooled for determination of apparent digestibilities of DM and N. The data were analyzed as a 2 × 3 factorial using the GLM procedure of SAS. Polynomial regression was used to determine linear and quadratic effects of Na_2SO_3 concentration.

Results and Discussion

Chemical compositions of the soy products were similar to expected values, with slightly more than 48% CP in the SBM and 35 to 37% CP in the soybeans (Table 2). Likewise, crude fat, crude fiber, and amino acid concentrations were within normal ranges, with no marked effects of extruding on the chemical compositions of the soybean preparations.

As the concentration of Na_2SO_3 was increased to 30 lb/ton of soy product, extruder throughput was increased by 4% (Table 3). The improved extruder throughput probably resulted from the granular nature of the sulfite premix. That granular nature would contribute friction, thereby increasing mechanical energy and barrel temperature. Alternatively, we opened the annular gap die on the extruder barrel to maintain a constant processing temperature and increase extruded throughput.

For d 0 to 13 of the growth assay, treatment had no effect on ADG or ADFI (P>.16). Feed/gain became poorer as the concentration of Na_2SO_3 was increased for pigs fed SBM, with little response to increased concentrations of Na_2SO_3 when the pigs were fed DEWS (SBM vs DEWS × Na_2SO_3 quadratic interaction, P<.03). For d 13 to 35, pigs fed DEWS had better rates and efficiencies of gain than pigs fed SBM (P<.001). Also, F/G was improved (P<.01) with increasing concentration of Na_2SO_3.

The improved growth performance from use of DEWS in place of SBM is consistent with results we have published in previous KSU Swine Day Reports. However, Na_2SO_3 is marketed as an extrusion aid, and there is no obvious reason for the improved efficiency of gain with its addition to diets without extrusion.

For the entire experiment (d 0 to 35), pigs fed diets with DEWS had better ADG (P<.003) and F/G (P<.002) than pigs fed SBM. Addition of Na_2SO_3 did not affect ADG for the overall growth period, but increasing the concentration of Na_2SO_3 tended to improve F/G (linear effect, P<.06), especially when used for processing DEWS.

Digestibility of DM in SBM and DEWS tended to increase as concentration of Na_2SO_3 was increased, although maximum DM digestibility was observed with 15 lb Na_2SO_3/ton of soy product (quadratic effect, P<.007). Nitrogen digestibility also increased as Na_2SO_3 concentration was increased.

In conclusion, DEWS were superior to SBM as a protein source for nursery-age pigs. Also, adding Na_2SO_3 improved extruder throughput and efficiency of growth. However, the improvements with use of Na_2SO_3 were linear up to our greatest addition (i.e., 30 lb Na_2SO_3/ton of soy product), and additional research is needed to determine the greatest concentration that should be used.

Table 1. Composition of Diets[a]

	d 0 to 13		d 13 to 35	
Item, %	SBM[b]	DEWS[c]	SBM	DEWS
Corn	48.67	48.67	63.53	63.53
Soy product	19.82	25.97	16.47	21.58
Dried whey	20.00	20.00	10.00	10.00
Soybean oil	1.98	-	1.66	-
Cornstarch	4.84	.67	4.01	.55
Monocalcium phosphate	1.83	1.68	1.62	1.50
Limestone	.73	.89	.82	.95
Salt	.20	.20	.40	.40
Vitamin premix	.25	.25	.25	.25
Mineral premix	.15	.15	.15	.15
Zinc oxide	.35	.35	-	-
Copper sulfate	-	-	.09	.09
Antibiotic[d]	1.00	1.00	1.00	1.00
Sodium sulfite[e]	-	-	-	-
DL-methionine	.03	.021	-	-
Chromic oxide[f]	.15	.15	-	-
Total	100.00	100.00	100.00	100.00

[a]The diets were formulated to .92% lysine, .9% Ca, .8% P, and 1.56 Mcal DE/lb of diet from d 0 to 13 and .76% lysine, .8% Ca, .7% P, and 1.56 Mcal of DE/lb of diet from d 13 to 35.
[b]SBM = soybean meal.
[c]DEWS = dry-extruded whole soybeans.
[d]Provided 150 g of apramycin per ton of diet for d 0 to 13 and 50 g of carbadox per ton of diet for d 13 to 35.
[e]Sodium sulfite was added at the expense of cornstarch to give the 0, 15, and 30 lb/ton of soy product treatments.
[f]Used as an indigestible marker.

Table 2. Characteristics of Soy Products

Item	SBM	Soybeans	DEWS	DEWS + 15 lb/ton of Na_2SO_3	DEWS + 30 lb/ton of Na_2SO_3
Extruder throughput, lb/h	-	-	1,275	1,311	1,328
Crude protein, %	48.33	35.82	35.99	37.09	35.46
Crude fat, %	.86	17.80	19.76	20.35	19.95
Crude fiber, %	3.96	9.18	9.54	9.92	9.43
Amino acids, % of sample					
Arginine	3.42	2.39	2.60	2.78	2.46
Histidine	1.28	.96	1.01	1.06	.97
Isoleucine	2.14	1.52	1.74	1.79	1.66
Leucine	3.75	2.71	2.92	3.05	2.79
Lysine	3.09	2.26	2.39	2.50	2.29
Methionine	.70	.53	.56	.59	.53
Phenylalanine	2.47	1.77	1.89	1.97	1.81
Threonine	1.92	1.41	1.45	1.56	1.40
Tryptophan	.62	.42	.48	.49	.45
Valine	2.34	1.69	1.83	1.85	1.78
Trypsin inhibitor, mg/g	2.05	12.98	1.66	2.09	1.49

Table 3. Effects of Sodium Sulfite on the Nutritional Value of Soybean Products for Nursery Pigs[a]

	SBM[b]			DEWS[c]				Contrasts[e]				
Item	0[d]	15	30	0	15	30	SE	1	2	3	4	5
d 0 to 13												
ADG, lb	.65	.57	.57	.62	.63	.63	.07	-[f]	-	-	-	-
ADFI, lb	1.06	1.06	1.00	1.05	1.07	1.07	.04	-	-	-	-	-
F/G	1.63	1.86	1.75	1.69	1.70	1.70	.03	-	-	.09	.01	.03
d 13 to 35												
ADG, lb	1.00	1.01	1.01	1.10	1.09	1.11	.03	.001	-	-	-	-
ADFI, lb	2.16	2.05	2.01	2.17	2.10	2.08	.05	-	.04	-	-	-
F/G	2.16	2.03	1.99	1.97	1.93	1.87	.02	.001	.01	-	-	-
d 0 to 35								.				
ADG, lb	.87	.84	.84	.92	.92	.93	.02	.003	-	-	-	-
ADFI, lb	1.75	1.68	1.64	1.76	1.72	1.71	.04	-	.07	-	-	-
F/G	2.01	2.00	2.00	1.91	1.87	1.84	.02	.002	.06	-	-	-
Digestibilities (d 12), %												
DM	82.4	86.2	84.8	82.0	84.7	83.1	.9	.11	.07	-	.007	-
N	74.4	82.3	78.6	77.6	76.6	78.9	.3	-	.05	-	.09	.004

[a]A total of 150 weanling pigs (avg initial wt of 13.2 lb) were allotted with six pigs per pen and five pens per treatment.
[b]SBM=soybean meal.
[c]DEWS=dry-extruded whole soybeans.
[d]Pounds of Na_2SO_3 per ton of soy product.
[e]Contrasts were: 1) SBM vs DEWS; 2) linear effect of Na_2SO_3; 3) SBM vs DEWS × linear effect of Na_2SO_3: 4) quadratic effect of Na_2SO_3; and 5) SBM vs DEWS × quadratic effect of Na_2SO_3.
[f]Dashes indicate P>.15.

PARTICLE SIZE (1,000 vs 500 µm) AFFECTS NUTRITIONAL VALUE OF SIMPLE AND COMPLEX DIETS FOR WEANLING PIGS AND BROILER CHICKS

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Summary

Nursery pigs fed complex diets had greater ADG than those fed simple diets, and as particle size was reduced, ADG and F/G tended to improve. There was a trend for reducing particle size to increase ADG more for pigs fed simple versus complex diets, but the response in efficiency of gain was of similar magnitude regardless of diet complexity. A second experiment was designed to determine if broiler chicks were an acceptable model for predicting the effects of feed processing procedures on nursery pigs. Chicks responded somewhat differently than pigs to the diet complexity × particle size treatments, with reduction of particle size having an effect only in simple diets.

(Key Words: Nursery, Diet Complexity, Particle Size.)

Introduction

Cereal grains typically are processed before incorporation into diets for pigs. This processing nearly always involves grinding in a hammermill or roller mill to reduce particle size and, thus, improve nutrient digestibility. In the past several KSU Swine Day Reports, we have given much attention to the positive effects of reducing mean particle size of cereal grains. From those experiments, we emphasized that reducing mean particle size of cereal grains to <600 µm resulted in greater nutrient digestibility, efficiency of growth, lactation performance, and decreased fecal excretion of nutrients compared to the coarser sizes of 900 to 1,000 µm. However, these marked benefits were observed in pigs fed relatively simple diets with high proportions as cereal grain. With only 30 to 40% of a complex starter diet as cereal, the benefits of reducing particle size conceivably could be reduced greatly. The experiment reported herein was designed to determine the effects of reducing particle size of corn from 1,000 to 500 µm in simple and complex diets for weanling pigs. Also, a chick bioassay was conducted to determine the merits of using broiler chicks as a quick and inexpensive model for the response of nursery pigs to feed-processing technologies.

Procedures

A total of 192 weanling pigs (initial wt of 11.7 lb and 21 d of age) was used in a 24-day growth assay. The pigs were blocked by weight and allotted (based on sex and ancestry) with eight pigs per pen and six pens per treatment. Treatments were: 1) 1,000 µm corn in a simple diet; 2) 500 µm corn in a simple diet; 3) 1,000 µm corn in a complex diet; and 4) 500 µm corn in a complex diet. The corn (mill-run) was ground in a hammermill through screens with openings of 1/2 in and 1/16 in to yield the 1,000 and 500 µm particle size treatments. The simple diet regimen was corn-soybean meal-whey-based for d 0 to 10 and 10 to 24 (Table 1). The complex diet regimen had dried whey, lactose, spray-dried plasma protein, spray-dried vital wheat gluten, and spray-dried blood meal for d 0 to 10 and dried whey and spray-dried blood meal for d 10 to 24. All diets had 1.6% lysine, .45% methionine, .9% Ca, and .8% P for d 0 to 10 and 1.3% lysine, .36% methionine, .8%

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Ca, and .7% P for d 10 to 24. The diets were fed in pelleted form.

The pigs were housed in an environmentally controlled nursery room. The temperature was maintained at 90°F during wk 1 and decreased 5°F each week thereafter. Each pen had a self-feeder and nipple water to allow ad libitum consumption of feed and water. Pigs and feeders were weighed on d 0, 10, and 24 to allow calculation of ADG, ADFI, and F/G. Chromic oxide (.15%) was included in the diets as an indigestible marker and fecal samples were collected on d 9 and 23 from four pigs per pen by rectal massage. The samples were dried, ground, and analyzed for DM, N, GE, and Cr concentrations to allow calculation of apparent nutrient digestibilities using the indirect ratio method.

The data were analyzed as a randomized complete block design (initial wt as the blocking criterion) with pen as the experimental unit. Treatment comparisons were : 1) simple vs complex diet formulation; 2) 1,000 vs 500 µm mean particle size; and 3) the simple vs complex × 1,000 vs 500 µm interaction.

In a second experiment, 480 broiler chicks (4 d old and 94 g average wt) were used to determine the effects of simple (cereal grain-soybean meal-based) vs complex (cereal grain-soybean meal-based with 6% tallow, 4% meat and bone meal, and 1% feather meal) diet formulation; diet form (meal vs crumble); and corn particle size (1,000 vs 500 µm) in a 2 × 2 × 2 factorial arrangement of treatments. The diets were formulated to 1.32% lysine, .61% methionine, 1.1% Ca, and .5% available P (Table 2). The chicks were allotted by weight into battery brooders (five chicks per cage and 12 cages per treatment), and given ad libitum access to feed and water during the 14-d experiment. Weights were collected at the beginning and end of the experiment to determine ADG, ADFI, and F/G. The data were analyzed as a randomized complete block design with pen as the experimental unit.

Results and Discussion

For the pig experiment, particle sizes of the milled corn were close to those desired (Table 3). As geometric mean particle size was decreased, log normal standard deviation of particle size decreased (from 2.4 to 1.9) and surface area of the milled corn increased (from 70.7 to 97.2 cm^2/g). Pellet durabilities were similar among all treatments (i.e., PDI values of 97.7 to 99.1%). Reducing particle size of the cereals in a diet typically improves PDI. However, with all of our diets above 97% PDI (very high by industry standards), it was not surprising that reducing particle size had little effect on pellet quality.

For d 0 to 10, pigs fed complex diets had 9% greater ADG (P<.04) than pigs fed simple diets (Table 4). Pigs fed the 500 µm treatments tended to have greater ADG than those fed the 1,000 µm treatments (P<.06), but no differences occurred in F/G (P>.11). Overall (d 0 to 24 postweanling), pigs fed complex diets had 8% greater ADG (P<.005) and 3% better F/G (P<.01) compared to pigs fed simple diets. Also, pigs fed the 500 µm treatments had 5% better overall F/G than those fed the 1,000 µm treatments (P<.007). When this experiment was designed, we anticipated that the response to reduction of particle size might be greater in simple diets (with their greater proportion as cereal grain) than in complex diets. There was a trend (P<.07) in the overall data for ADG of pigs fed simple diets to be improved more than ADG of pigs fed complex diets as particle size was reduced from 1,000 to 500 µm. However, the improvements in F/G with decreased particle size were similar in simple and complex diets. Finally, the ADG and F/G values for pigs fed simple diets with corn ground to 500 µm were essentially the same as those for pigs fed complex diets with corn ground to 1,000 µm. Thus, the added cost of complex diet formulations is wasted if proper attention is not given to particle size of the cereal grain in the diet.

At d 9, apparent digestibilities of DM, N, and GE were greater for pigs fed complex diets and diets with smaller particle size (P<.02). At d 23, there was a trend (P<.06) for greater DM digestibility with greater diet complexity, and pigs fed diets with corn

ground to 500 µm had greater digestibility of DM (P<.02) and GE (P<.003) than pigs fed diets with corn ground to 1,000 µm.

For the chick experiment (Table 5), no 3-way interactions occurred among diet complexity, diet form, and particle size (P>.2). However, 2-way interactions were observed. Reducing particle size of corn from 1,000 to 500 µm increased rate of gain in chicks fed complex diets but had little effect on rate of gain in chicks fed simple diets (diet complexity × particle size, P<.02). This response was not consistent with the diet complexity × particle size effect in nursery pigs (i.e., a trend for greater response to decreased particle size in simple diets). Also, F/G was improved when particle size was reduced in meal diets but not in diets fed as crumbles (diet form × particle size interaction, P<.005). Thus, noteworthy differences occurred between nursery pigs and broiler chicks for response to diet complexity and reduction of particle size, and caution should be used when extrapolating results from chick assays to expected responses in nursery pigs.

In conclusion, our data suggest that reducing particle size of corn is important for simple and complex diets fed to nursery pigs. Also, complex diets with 1,000 µm corn gave no better performance than simple diets with 500 µm corn.

Table 1. Diet Composition for the Pig Experiment, %

	Diets for d 0 to 10[a]		Diets for d 10 to 24[b]	
Ingredient	Simple	Complex	Simple	Complex
Corn	40.25	25.26	56.72	45.35
Soybean meal (46.5% CP)	21.93	23.84	31.68	24.58
Dried whey	20.00	20.00	5.00	20.00
Lactose	--	10.00	--	--
Soy isolate	10.00	--	--	--
Spray-dried plasma protein	--	4.00	--	--
Spray-dried wheat gluten	--	4.00	--	--
Spray-dried blood meal	--	2.00	--	2.00
Soybean oil	3.00	6.00	2.00	4.00
Lysine-HCl	.15	.20	.20	.10
DL-methionine	.07	.08	.04	.07
Monocalcium phosphate (21% P)	1.52	1.91	1.42	1.22
Limestone	.83	.61	.84	.68
Salt	.30	.15	.40	.30
Vitamin premix	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15
Selenium premix	.05	.05	.05	.05
Zinc oxide	.35	.35	--	--
Copper sulfate	--	--	.10	.10
Antibiotic[c]	1.00	1.00	1.00	1.00
Chromic oxide	.15	.15	.15	.15
Total	100.00	100.00	100.00	100.00

[a]Diets for d 0 to 10 were formulated to 1.6% lysine, .45% methionine, .9% Ca, and .8% P.
[b]Diets for d 10 to 24 were formulated to 1.3% lysine, .36% methionine, .8% Ca, and .7% P.
[c]Provided 150 g/ton of apramycin in diets for d 0 to 10 and 50 g/ton of carbadox in diets for d 10 to 24.

Table 2. Diet Composition for the Chick Experiment, %[a]

Ingredient	Simple	Complex
Corn	54.94	48.28
Soybean meal (46.5% CP)	39.30	35.90
Meat and bone meal	--	4.00
Feather meal	--	1.00
Tallow	1.00	6.00
DL-methionine	.30	.30
Monocalcium phosphate	2.02	2.05
Limestone	1.14	1.17
Salt	.40	.40
Vitamin and mineral premixes	.75	.75
Copper sulfate	.05	.05
Antibiotic[b]	.10	.10
Total	100.00	100.00

[a]Diets were formulated to 1.32% lysine, .61% methionine, 1.1% Ca, and .5% available P.
[b]Provided 110 g/ton of chlortetracycline.

Table 3. Characteristics of Corn and Diets for the Pig Experiment

	Simple		Complex	
Item	1,000	500	1,000	500
Grain characteristics				
Geometric mean particle size, µm	938	565	--[a]	--
Standard deviation of the particle size	2.4	1.9	--	--
Surface area, cm^2/g	70.7	97.2	--	--
Diet characteristics				
Pellet durability index				
d 0 to 10	98.9	99.1	98.8	98.9
d 10 to 24	97.7	98.4	98.8	98.8

[a]The same corn was used for simple and complex diets.

Table 4. Growth Performance of Weanling Pigs Fed Simple and Complex Diets with Corn Milled to 1,000 and 500 µm[a]

	Simple		Complex			Contrasts[b]		
Item	1,000	500	1,000	500	CV	1	2	3
d 0 to 10								
ADG, lb	.61	.70	.71	.72	9.7	.04	.06	--[c]
ADFI, lb	.64	.72	.77	.73	7.6	.006	--	.02
F/G	1.05	1.03	1.09	1.01	7.0	--	.11	--
d 10 to 24								
ADG, lb	1.07	1.14	1.18	1.18	5.4	.01	--	.12
ADFI, lb	1.53	1.58	1.61	1.57	6.5	--	--	--
F/G	1.43	1.39	1.36	1.33	3.4	.006	.09	--
d 0 to 24								
ADG, lb	.87	.96	.98	.99	5.5	.005	.04	.07
ADFI, lb	1.16	1.22	1.26	1.22	6.2	.15	--	.14
F/G	1.33	1.27	1.29	1.23	3.1	.01	.007	--
Apparent digestibility, %								
d 9								
DM	85.2	87.3	86.7	88.6	1.3	.01	.001	--
N	80.2	83.7	84.1	84.9	2.4	.01	.02	.13
GE	85.0	87.1	86.7	88.4	1.4	.01	.001	--
d 23								
DM	87.4	88.0	87.9	88.8	.8	.06	.02	--
N	83.8	84.8	84.5	84.6	1.5	--	--	--
GE	88.1	89.0	88.1	89.5	.9	--	.003	--

[a]One hundred ninety-two weanling pigs (initially 11.7 lb and 21 d of age, with eight pigs per pen and six pens per treatment) were used.
[b]Contrasts were:1) simple vs complex diet formulation; 2) 1,000 vs 500 µm particle size; 3) simple vs complex × 1,000 vs 500 µm.
[c]Dashes indicate P>.15.

Table 5. Effects of Diet Complexity, Physical Form, and Particle Size on Growth Performance of Broiler Chicks[a]

	Simple				Complex					Contrasts[b]						
	Meal		Crumble		Meal		Crumble									
Item	1,000	500	1,000	500	1,000	500	1,000	500	CV	1	2	3	4	5	6	7
Gain, lb	1.05	1.06	1.14	1.11	1.09	1.14	1.09	1.12	5.2	.12	.007	--[c]	--	.02	.001	--
Feed intake, lb	1.50	1.45	1.57	1.54	1.49	1.53	1.45	1.50	3.9	.11	.03	--	--	.001	.001	--
F/G	1.43	1.37	1.38	1.39	1.37	1.34	1.33	1.34	3.6	.001	.09	.14	.005	--	--	--

[a]A total of 480 broiler chicks (initially 94 g initial wt, with five birds per cage and 12 cages per treatment) were used in a 14-d growth assay.
[b]Contrasts were:1) simple vs complex; 2) meal vs crumble; 3) 1,000 vs 500 µm; 4) complexity × form; 5) complexity × particle size; 6) form × particle size; 7) complexity × form × particle size.
[c]Dashes indicate P>.15.

THE INTERACTIVE EFFECTS OF TURBOZYME 160 AND DIET COMPLEXITY ON STARTER PIG GROWTH PERFORMANCE

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Summary

These results suggest that feeding a complex starter diet improves initial (d 0 to 7 postweaning) growth performance of segregated early-weaned pigs. Feeding either a simple or complex diet with added Turbozyme 160 improves feed efficiency from day 0 to 14 postweaning. However, for the overall experimental period, neither a complex diet nor added Turbozyme 160 had any effect on growth performance.

(Key Words: Starter, Performance, Diet Complexity, Enzyme.)

Introduction

Technology for the feeding and care of the early-weaned pig has improved immensely in the last 10 years. As producers have moved to weaning at a younger age, the industry has evolved from feeding simple corn-soybean meal diets from weaning to market to a phase feeding system using numerous diets tailored to the changing needs of the pig. However, because of the high cost of these diets, feed additives that could reduce the need for complex protein and(or) carbohydrate sources would have a substantial economic impact on the swine industry. Recently, Oklahoma State University found one such feed additive, Turbozyme 160, to produce promising improvements in swine growth and feed efficiency. Research at the University of Illinois with 21-d-old pigs suggested that Turbozyme 160 addition enhanced performance of pigs fed a simple diet so it was comparable to that of pigs fed a more complex diet. If including Turbozyme 160 in the diet would allow for similar pig performance on a less complex diet formulation, this additive would be adopted widely in commercial swine production. Therefore, the objective of this experiment was to evaluate the effects of Turbozyme in complex (industry standard) and simple (low cost) starter diet programs for pigs weaned at 13 to 14 days of age.

Procedures

Two hundred and thirteen weanling crossbred pigs (PIC C15 × L 326) with an average initial weight of 7.9 lb and 13 +/- 2 days of age were used in a 28-day growth assay to determine the interactive effects of diet complexity (complex vs simple) and enzyme addition (control or .10% Turbozyme 160) on starter pig growth performance. Pigs were blocked by initial weight, randomized across treatments by sex, and allotted to each of four dietary treatments. Treatments were arranged in a 2 × 2 factorial with main effects including diet complexity (complex or simple) and the addition of an enzyme to the diet (control or Turbozyme 160). There were eight to 10 pigs/pen in a block and six pens/treatment.

From d 0 to 14 postweaning, pigs were fed either a typical diet formulated for pigs weaned at 10 to 14 days of age or a less complex diet (Table 1). The complex diet contained 25% dried whey, 5% lactose, 7.5% spray-dried plasma protein, 4% select menhaden fish meal, and 1.75% spray-dried blood meal and was formulated to contain

[1]Northeast Area Extension Office.

1.6% lysine, .44% methionine, and 1.08% threonine. The simple diet contained 20% dried whey, 2.5% spray-dried plasma protein, 2.5% select menhaden fish meal, and 2.5% spray-dried blood meal. It also was formulated to contain 1.6% lysine, .44% methionine, and 1.08% threonine. Turbozyme 160 (.10%) replaced corn in the control diets to provide the additional dietary treatments, and all diets were pelleted through a pellet mill equipped with a 3/32" die.

From d 14 to 28 (phase II), all pigs were fed a diet containing 10% dried whey and 2.5% spray-dried blood meal and formulated to 1.35% lysine and .37% methionine with or without Turbozyme 160. Pigs continued to be fed their respective control or added Turbozyme 160 (.10%) diet as previously fed from d 0 to 14 postweaning.

Pigs were weighed and feed disappearance was determined on d 0, 7, 14, 21, and 28 postweaning to determine ADG, ADFI, and feed efficiency (F/G). Statistical analysis was conducted as a 2 × 2 factorial with evaluation of main effects of diet complexity and enzyme addition and their interactions.

Results and Discussion

No diet complexity by enzyme interactions were observed for d 0 to 14 or cumulative (d 0 to 28) growth performance (P>.10), suggesting that Turbozyme 160 addition did not differentially improve performance of pigs fed the simple diet vs those fed the complex diet. Main effect means are presented in Table 2, and interactive treatment means are presented in Table 3. Unlike previous research at the University of Illinois, pigs fed the simple diet with added Turbozyme 160 did not have a greater response to Turbozyme 160 than pigs fed the complex diets, i.e., pigs fed either complex or simple diets responded identically to the added Turbozyme 160. In fact, the greatest response to added Turbozyme 160 was observed in ADG from d 7 to 14 postweaning in pigs fed the complex diets. Perhaps differences in weaning age, Turbozyme 160 level, or diet formulation account for the differences observed between the two studies.

From d 0 to 7 postweaning, Turbozyme 160 addition had no effect on ADG, ADFI, or F/G (Table 2). However, from d 0 to 14 postweaning, addition of Turbozyme 160 tended (P<.12) to numerically improve ADG by approximately 8%. During the same period, a 6% improvement occurred in feed efficiency (P<.05) for pigs fed diet with added Turbozyme 160. From d 7 to 14 postweaning, a diet complexity by enzyme interaction was observed (P<.08) for ADG. Although pigs fed Turbozyme 160 had greater (P<.02) ADG than those fed the control diets, the improvement in ADG was greater in those pigs fed the complex diets (18%) compared with pigs fed the simple diets (2%). In addition, pigs fed the diets with added Turbozyme 160 had better F/G (P<.07) than those fed the control diets. From d 14 to 28, addition of Turbozyme 160 had no effect on growth performance. Studies at Oklahoma State University have shown a more consistent response to added Turbozyme 160 in that the improvements were observed throughout the entire trial. Possible reasons for differences between the two studies are mentioned above.

Feeding pigs a complex, segregated early weaning diet compared with a simple, transition diet improved ADG, ADFI, and F/G during the first week of the trial. Average daily gain and ADFI also were improved (P<.05) for pigs fed the complex diet from d 0 to 14 postweaning, but no differences occurred for the overall trial. This response suggests that, for very young pigs (13 to 17 days of age), a complex starter diet is necessary to stimulate feed intake and ADG. As indicated by the similar growth performance between pigs fed complex or simple diets from d 7 to 14 postweaning, diet complexity can be decreased quickly. As the pig becomes older and its digestive system is better developed, the pig can be switched to a simpler diet to lower feed cost per lb of gain without adversely affecting performance.

In conclusion, these results suggest that feeding either a simple or complex diet with added Turbozyme 160 improves feed efficiency from day 0 to 14 postweaning. Feeding a complex starter diet improves initial (d 0 to 7 postweaning) growth performance of segregated early-weaned pigs.

Table 1. Diet Composition

	Phase I[a]		
Ingredient, %	Complex[b]	Simple[b]	Phase II[bc]
Corn	35.65	37.97	53.78
Dried whey	25.00	20.00	10.00
Soybean meal (46.5% CP)	12.52	27.52	25.87
Plasma protein	7.50	2.50	--
Lactose	5.00	--	--
Soy oil	5.00	5.00	3.00
Fish meal, select menhaden	4.00	--	--
Blood meal, spray-dried	1.75	2.50	2.5
Medication[d]	1.00	1.00	1.00
Monocalcium phosphate	.95	1.52	1.89
Limestone	.56	.75	.84
Zinc oxide	.38	.38	.25
Vitamin premix	.25	.25	.25
Trace mineral premix	.15	.15	.15
DL-methionine	.125	.15	.075
L-lysine ·HCl	.075	.15	.15
L threonine	--	.07	--
Salt	.10	.10	.25
Total	l00.00	100.00	100.00

[a]Phase I diets were fed from d 0 to 14 postweaning and formulated to contain 1.60% lysine, .44% methionine, 1.08% threonine, .90% Ca, and .80% P.
[b]Turbozyme replaced corn (.10%) in each of the diets to provide the additional treatments
[c]Phase II diets were fed from d 14 to 28 postweaning and formulated to contain 1.35% lysine, .37% methionine, .90% Ca, and .80% P.
[d]Provided 55 g/ton carbadox.

Table 2. Main Effects of Turbozyme and Diet Complexity on Starter Pig Performance[ab]

	Diet complexity		Enzyme			Probability value		
Item	Control	Simple	Control	Turbozyme	CV	Enzyme	Diet	Enzyme × diet
D 0 to 7								
ADG, lb	.33	.24	.28	.29	21.9	.63	.01	.69
ADFI, lb	.43	.36	.39	.40	14.4	.55	.01	.69
F/G	1.30	1.52	1.39	1.39	13.4	.89	.02	.85
D 7 to 14								
ADG, lb	.53	.55	.51	.57	9.5	.02	.57	.08
ADFI, lb	.67	.63	.65	.66	13.4	.83	.28	.53
F/G	1.25	1.14	1.25	1.14	10.8	.07	.06	.66
D 0 to 14								
ADG, lb	.43	.38	.39	.42	11.7	.12	.05	.40
ADFI, lb	.54	.48	.51	.52	12.2	.60	.04	.88
F/G	1.27	1.25	1.30	1.22	6.9	.05	.77	.51
D 14 to 28								
ADG, lb	.79	.79	.81	.78	8.3	.26	.93	.57
ADFI, lb	1.14	1.17	1.19	1.12	8.7	.13	.57	.83
F/G	1.43	1.47	1.47	1.43	7.5	.53	.47	.33
D 0 to 28								
ADG, lb	.61	.59	.60	.60	7.5	1.0	.26	.40
ADFI, lb	.84	.82	.85	.82	8.0	.33	.56	.93
F/G	1.36	1.41	1.41	1.36	6.0	.19	.50	.25

[a]A total of 213 pigs with an average age of 13 ± 2 d and average initial weight of 7.9 lb.
[b]Pigs were fed either a complex (SEW) or simple (transition) diet with or without Turbozyme from d 0 to 14 postweaning. From d 14 to 28, pigs were fed a phase II diet (2.5% spray-dried blood meal, 10% dried whey) with or without Turbozyme.

Table 3. Interactive Effects of Turbozyme and Diet Complexity on Starter Pig Performance[ab]

	Complex		Simple			Probability value		
Item	Control	Turbozyme	Control	Turbozyme	CV	Enzyme	Diet	Enzyme × diet
D 0 to 7								
ADG, lb	.32	.34	.23	.25	21.9	.63	.01	.99
ADFI, lb	.43	.43	.34	.37	14.4	.55	.01	.69
F/G	1.30	1.28	1.52	1.52	13.4	.89	.02	.85
D 7 to 14								
ADG, lb	.49	.58	.54	.55	9.5	.02	.57	.08
ADFI, lb	.65	.69	.64	.62	13.4	.83	.28	.53
F/G	1.33	1.18	1.18	1.10	10.8	.07	.06	.66
D 0 to 14								
ADG, lb	.40	.45	.37	.39	11.7	.12	.05	.40
ADFI, lb	.53	.55	.48	.49	12.2	.60	.04	.88
F/G	1.32	1.22	1.28	1.23	6.9	.05	.77	.51
D 14 to 28								
ADG, lb	.80	.79	.82	.77	8.3	.26	.93	.57
ADFI, lb	1.18	1.10	1.20	1.14	8.7	.13	.57	.83
F/G	1.47	1.39	1.45	1.47	7.5	.53	.47	.33
D 0 to 28								
ADG, lb	.60	.62	.60	.58	7.5	1.0	.26	.40
ADFI, lb	.86	.83	.84	.81	8.0	.33	.56	.93
F/G	1.43	1.33	1.41	1.39	6.0	.19	.50	.25

[a]A total of 213 pigs with an average age of 13 ± 2 d and average initial weight of 7.9 lb.
[b]Pigs were fed either a complex (SEW) or simple (transition) diet with or without Turbozyme from d 0 to 14 postweaning. From d 14 to 28, pigs were fed a phase II diet (2.5% spray-dried blood meal, 10% dried whey) with or without Turbozyme.

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OMITTING VITAMIN AND TRACE MINERAL PREMIXES FROM DIETS DURING LATE FINISHING (190 TO 250 LB) DID NOT REDUCE GROWTH PERFORMANCE, CARCASS LEANNESS, OR MUSCLE QUALITY

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Summary

Average daily gain; F/G; dressing percentage; tenth rib fat thickness; and depth, marbling, color, and firmness of the longissimus muscle were not influenced by omitting the vitamin and(or) trace mineral premixes from diets during late finishing (190 to 250 lb). Thus, our data suggest that the KSU vitamin and trace mineral premixes can be omitted during late finishing to reduce cost of gain without decreasing growth performance, carcass merit, or muscle quality.

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

Introduction

Diet costs represents 55-65% of the total cost of producing a market hog. Nutrient concentrations in diets for pigs typically are based on the minimum standards set by the National Research Council (NRC, 1988) with sometimes generous safety margins to ensure against deficiencies. However, as pigs increase in age and size their nutrient needs as a percentage of the diet decrease, and with the current trend toward heavier slaughter weights, dietary excesses of most nutrients are common in late finishing. These excess nutrients are excreted as waste; thus, lower nutrient concentrations in diets for late finishing could help make livestock operations more environmentally friendly.

Many poultry producers are drastically reducing, and sometimes completely omitting, vitamin and trace mineral premixes just prior to slaughter to reduce cost of gain. This approach is based on the hypothesis that a short period exists during which deletion of vitamins and minerals would have no effect on performance and carcass characteristics, because body stores would last until slaughter.

Therefore, the objective of the experiment reported herein was to determine if short-term deletion of vitamin and(or) trace mineral premixes affects growth performance, carcass leanness, or muscle quality in finishing pigs.

Procedures

A total of 128 finishing pigs (initial wt of 189 lb) were blocked by weight and allocated to pens based on sex and ancestry. There were eight pigs (PIC Line 326 boars × C15 sows) per pen and four pens per treatment. Treatments were: 1) corn-soybean meal-based control with the KSU vitamin and trace mineral premixes; 2) diet 1 with the vitamin premix omitted; 3) diet 1 with the trace mineral premix omitted; and 4) diet 1 with the vitamin and trace mineral premixes omitted. The diets were corn-soybean meal-based

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and formulated to .7% lysine, .65% Ca, and .55% P (Table 1). The pigs were housed in a modified open-front building with 50% solid concrete and 50% concrete slat flooring. Each pen (6 ft × 16 ft) had a self-feeder and nipple waterer to allow ad libitum consumption of feed and water. Pigs and feeders were weighed at initiation and conclusion of the growth assay to allow calculation of ADG, ADFI, and F/G.

When pigs in the heaviest pen of a weight block reached an average wt of 250 lb, the entire block was removed from the growth assay. Two blocks reached the ending weight on d 27 and two blocks on d 29 of the experiment. The pigs were killed at a commercial slaughtered plant to collect carcass measurements. Tenth rib fat thickness was measured 2 in from the midline using a Fat-O-Meter™ probe and adjusted to skin-on fat thickness by adding .1 to the probe reading. Dressing percentage was calculated with hot carcass weight as a percentage of slaughter weight. Color, firmness, and marbling of the longissimus muscle were determined according to NPPC (1991) guidelines. Additionally, chops from the 10th rib location were cut 1 in thick, placed on an absorbent pad in a styrofoam tray, and overwrapped with polyvinylchloride film. Measurements of longissimus muscle color were determined at d 0 (before display) and after 3 and 5 d of continuous (24 h/d) display at 36°F under 150 foot candle deluxe warm white fluorescent lighting. A Minolta CR-200 spectrocolorimeter (1 cm diameter aperture) was used to measure meat lightness and intensity of red, yellow, and pink color at d 0, 3, and 5.

All data were analyzed as a randomized complete block design with orthogonal contrasts used to separate treatment means. Pen was the experimental unit.

Results and Discussion

From 190 to 250 lb, ADG and F/G were not influenced (P>.22) by dietary treatment (Table 2). Dressing percentage; 10th rib fat thickness; fat free lean index; and subjective scores for marbling, color, and firmness of the longissimus muscle also were not affected by dietary treatment (P>.11).

Objective color determinations (Table 3) at d 0 (before display) suggested that pigs fed diets without the vitamin and(or) mineral premixes had redder meat and more vivid or intense pink color compared to pigs fed the control diet (P<.06). Meat color for pigs fed the diet without mineral premix was lighter and more yellow than that for pigs fed the diet without vitamin premix (P<.05). However, the color determinations for all treatments were considered to be well within normal ranges. Also, the rate of change for meat color to d 3 and 5 was similar for all treatments. Thus, withdrawal of the vitamin and(or) mineral premixes had no effect on pork muscle color stability during display.

In conclusion, cost of gain was decreased by omitting the vitamin and(or) trace mineral premixes during the late finishing phase. Also, concerns that omitting these premixes would result in fatter carcasses with poor meat color/quality were unwarranted.

Table 1. Diet Composition, %[a]

		Premix omitted		
Ingredient	Control	Vitamin	Mineral	Vitamin+ mineral
Corn	83.83	83.99	83.94	84.10
Soybean meal (46.5% CP)	12.37	12.35	12.36	12.34
Soybean oil	1.00	1.00	1.00	1.00
Monocalcium phosphate (21% P)	1.12	1.12	1.12	1.12
Limestone	.94	.94	.94	.94
Salt	.30	.30	.30	.30
Vitamin premix	.15	--	.15	--
Trace mineral premix	.10	.10	--	--
L-Lysine ·HCl	.15	.15	.15	.15
Antibiotic[b]	.05	.05	.05	.05
Total	100.00	100.00	100.00	100.00

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

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

		Premix omitted				Contrasts[b]		
Item	Control	Vitamin	Mineral	Vitamin+ mineral	CV	1	2	3
ADG, lb	2.42	2.31	2.43	2.32	5.6	--[g]	--	--
ADFI, lb	7.81	7.12	7.35	7.28	3.5	.005	--	--
F/G	3.23	3.08	3.03	3.14	5.3	--	--	--
Dressing percentage	74.1	74.4	74.3	74.5	.7	--	--	--
Backfat thickness, in	.75	.72	.73	.74	6.4	--	--	--
Fat free lean index, %[c]	50.2	50.5	50.4	50.3	1.3	--	--	--
Meat Quality								
Color[d]	2.6	2.5	2.5	2.5	1.9	.12	--	.11
Firmness[e]	2.5	2.5	2.5	2.6	5.1	--	--	--
Marbling[f]	1.9	1.9	1.8	1.9	14.5	--	--	--

[a]A total of 128 pigs (eight pigs/pen and four pens/treatment) with an avg initial wt of 189 lb and an avg final wt of 254 lb.
[b]Contrasts were: 1) control vs other treatments; 2) omitting vitamins or minerals vs omitting both; 3) omitting vitamins vs minerals.
[c]Equation (NPPC, 1991) was: Fat free lean index=51.537 + (.035 × hot carcass wt) - (12.26 × off-midline backfat thickness).
[d]Scored on a scale of 1=pale pinkish-gray to 5=dark purplish-red (NPPC, 1991).
[e]Scored on a scale of 1=very soft and watery to 5=very firm and dry (NPPC, 1991).
[f]Scored on a scale of 1=practically devoid to 5=moderately abundant (NPPC, 1991).
[g]Dashes indicate P>.15.

Table 3. Objective Measurements of Longissimus Muscle Color[a]

		Premix omitted				Contrasts[c]		
Item[b]	Control	Vitamin	Mineral	Vitamin+ mineral	CV	1	2	3
Day 0								
Lightness	51.5	51.6	52.7	51.9	1.4	--[d]	--	.05
Redness	10.8	11.1	11.4	11.6	4.0	.06	--	--
Yellowness	7.4	7.4	7.9	7.7	4.1	.14	--	.05
Pink color intensity	13.1	13.3	13.9	13.9	3.7	.06	--	.14
Day 3								
Lightness	53.8	54.1	54.4	53.9	1.9	--	--	--
Redness	9.5	9.7	9.9	10.1	5.1	--	--	--
Yellowness	7.8	7.8	8.3	8.1	3.5	--	--	.02
Pink color intensity	12.3	12.4	12.9	12.8	3.9	--	--	--
Day 5								
Lightness	54.3	54.3	54.7	54.2	3.1	--	--	--
Redness	8.5	8.5	8.8	9.0	4.5	--	--	--
Yellowness	7.9	7.9	8.4	8.0	4.0	--	--	.07
Pink color intensity	11.7	11.6	12.2	12.1	3.2	--	--	.09

[a]A total of 128 pigs (eight pigs/pen and four pens/treatment) with an avg initial wt of 189 lb and an avg final wt of 254 lb.
[b]Minolta CR-200 spectrocolorimeter values (lightness is Hunter 'L' value; redness is Hunter 'a' value; yellowness is Hunter 'b' value; pink color intensity is saturation index).
[c]Contrasts were: 1) control vs other treatments; 2) omitting vitamins or minerals vs omitting both; 3) omitting vitamins vs minerals.
[d]Dashes indicate P>.15.

LOW-PHOSPHORUS DIETS DURING LATE-FINISHING DECREASE COST OF GAIN WITH MINIMAL EFFECT ON GROWTH PERFORMANCE, CARCASS CHARACTERISTICS, AND MEAT QUALITY

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Summary

Partially omitting (up to 66%) the supplemental inorganic phosphorus (P) source from a late-finishing (190 to 250 lb) diet resulted in slightly greater ADG and backfat thickness, which probably resulted from the greater feed (energy) intake. Meat quality was unaffected by treatment. Thus, during late-finishing, a total P concentration of .40% can be used to decrease diet cost without decreasing performance or meat quality of high-lean pigs.

(Key Words: Phosphorus, Performance, Carcass, Meat.)

Introduction

Phosphorus (P) typically is the third most expensive nutrient in swine diets, following energy and protein. Excess dietary P is excreted in urine and feces as an environmental pollutant, and some European countries already have limited expansion of swine production units based on the amount of P that would be excreted. Thus, some nutritionists are considering reduced P in diets to decrease feed costs and excretion in swine waste products.

Today, many researchers believe that diets for late-finishing (over 200 lb) are often overfortified with nutrients (e.g., protein, vitamins, and minerals). This is because diet specifications are derived mostly from experiments with lighter pigs. It is also hypothesized that body stores of many minerals and vitamins may be sufficient to maintain normal growth during the late-finishing period. The experiment reported herein was conducted to determine the effects of removing supplemental P during late-finishing on growth performance, carcass characteristics, and meat quality of high-lean pigs.

Procedures

A total of 128 pigs, with an average initial body wt of 190 lb, was used in the 31-d experiment. Crossbred pigs of PIC origin (line 326 boars × C15 sows) were blocked by weight and sex and allocated to dietary treatments based on ancestry. There were eight pigs per pen and four pens per treatment.

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

The control diet was corn-soybean meal-based and formulated to .70% lysine, .65% Ca, and .55% P with all other nutrients in excess of NRC recommendations (Table 1). The other diets were achieved by incrementally removing monocalcium phosphate (the source of inorganic phosphorus) from the control such that treatments were: 1) control diet; 2) 33% of the monocalcium phosphate omitted; 3) 66% of the monocalcium phosphate omitted; and 4) all of the monocalcium phosphate omitted. Calcium concentrations were decreased (by omitting limestone) to keep the Ca:P ratio constant at

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1.2:1 in all diets. The diets were fed in meal form.

Pigs and feeders were weighed at the beginning and end of the experiment to allow calculation of ADG, ADFI, and F/G. When pigs in the heaviest pen of a weight block averaged 250 lb, the entire block was slaughtered in a commercial plant. Hot carcass weight, last rib backfat thickness, and longissimus muscle depth were recorded immediately following slaughter. After chilling, the carcasses were fabricated, and the longissimus muscle was scored for color, firmness, and marbling according to NPPC (1991) guidelines. Also, chops from the 10th rib location were cut 1 in thick, placed on an absorbent pad in a styrofoam tray, wrapped with polyvinylchloride film (standard retail film with high oxygen permeability), and displayed for 5 d (36°F with 150 foot candles deluxe warm white fluorescent lighting). A Minolta CR-200 spectrocolorimeter was used to measure meat lightness and intensity of red, yellow, and pink color at d 0, 3, and 5.

Prior to statistical analyses, hot carcass weight, dressing percentage, last rib backfat thickness, and longissimus muscle depth were adjusted by using slaughter weight as a covariable. All data were analyzed for linear, quadratic, and cubic effects of omitting P using the GLM procedure of SAS.

Results and Discussion

Average daily feed intake and F/G were not influenced by treatment (P>.15), but ADG increased and days from 190 to 250 lb decreased (quadratic effects, P<.03) when 66% of the inorganic P source was omitted (Table 2). Although it is difficult to explain why decreasing P additions would actually increase ADG, the improvements probably were an artifact (chance effect) resulting from the greater feed intake for pigs fed the diet with 66% of the inorganic P source omitted. Thus, omitting up to 66% of the inorganic P source certainly had no negative effect on growth performance. Totally omitting the inorganic P source, however, resulted in reduced ADG and increased days to market.

Carcass characteristics were not influenced apart from a slight increase (.05 and .06 in) in last rib backfat thickness and a slight decrease in NPPC lean index (.6%) when 33% and 66% of the inorganic P source was omitted. Again, these effects were likely artifacts of the greater feed intake for pigs fed the diet with 66% of the inorganic P source omitted. Subjective scores for color, marbling, and firmness of the longissimus muscle were not affected by treatment (P>.12).

Omitting the inorganic P source did not have a consistent effect on objective measurements (Hunter values) of color stability (Table 3). The muscle was lighter in color for all treatments before display, but with the inorganic P source omitted, the meat became less red and yellow and total lightness and pink color intensity decreased (P<.07). These trends were still present at d 3 and d 5, but omitting P did not cause greater rates of changes in any color determinations. Furthermore, all measurements were considered normal and in acceptable ranges. Thus, omitting the inorganic P source had minimal influence on pork muscle color and (or) color stability during display.

In conclusion, omitting up to 66% of the inorganic P source (i.e., down to .40% total P) from diets in late-finishing can improve profitability of swine operations feeding high-lean pigs to heavy slaughter weights.

Table 1. Diet Composition, %[a]

		Inorganic P omitted		
Ingredients	Control	33%	66%	100%
Corn	83.82	84.30	84.77	85.24
Soybean meal (46.5% CP)	12.37	12.33	12.29	12.25
Soybean oil	1.00	1.00	1.00	1.00
Monocalcium phosphate (21% P)	1.12	.75	.37	-
Limestone	.94	.87	.82	.76
Salt	.30	.30	.30	.30
Vitamin premix	.15	.15	.15	.15
Trace mineral premix	.10	.10	.10	.10
Lysine-HCl	.15	.15	.15	.15
Antibiotic	.05	.05	.05	.05
Total	100.00	100.00	100.00	100.00
Calculated analysis				
Lysine, %	.70	.70	.70	.70
Ca, %	.65	.56	.47	.37
Total P, %	.55	.47	.40	.32
Available P, %	.29	.22	.14	.06

[a]All diets were formulated to a Ca:P ratio of 1.2 with other nutrients in excess of NRC (1988) recommendations.
[b]Provided 40 g/ton Tylosin.

Table 2. Effects of Omitting the Inorganic Phosphorus Source during Late-Finishing on Growth Performance, Carcass Characteristics, and Meat Quality[a,b]

	Total phosphorus %					Probability, P <		
Item	.55	.47	.40	.32	CV	Lin	Quad	Cub
ADG, lb	1.84	1.89	1.92	1.73	5.0	-[g]	.03	-
ADFI, lb	6.72	6.71	6.81	6.36	4.7	-	-	-
F/G	3.66	3.56	3.55	3.69	4.5	-	-	-
Total P intake, g/d	16.8	14.3	12.4	9.2	NA[h]	NA	NA	NA
Available P intake, g/d	8.8	6.7	4.3	1.7	NA	NA	NA	NA
Days to market (190-260 lb)	32.8	31.8	31.3	34.8	5.2	-	.03	-
Dressing percentage	65.7	65.7	66.0	65.6	1.1	-	-	-
Last rib backfat thickness, in	.63	.68	.69	.64	5.1	-	.02	-
Longissimus muscle depth, in	2.19	2.16	2.26	2.26	6.4	-	-	-
NPPC lean index, %[c]	49.4	48.8	48.8	49.4	.9	-	.02	-
Meat color[d]	2.5	2.4	2.5	2.5	6.7	-	-	-
Meat firmness[e]	2.3	2.4	2.5	2.6	15.1	0.12	-	-
Meat marbling[f]	2.1	2.1	2.0	2.6	9.8	-	-	-

[a]A total of 128 pigs with an average initial body wt of 190 lb (8 pigs/pen and 4 pens/treatment).
[b]Carcass measurements were adjusted for final live weight.
[c]Equation used was: Index=51.537 + (.035 × hot carcass wt) – (12.26 × off-midline backfat thickness) (NPPC, 1991).
[d]Scored on a scale of 1=pale, pinkish gray to 5=dark, purplish red (NPPC, 1991).
[e]Scored on a scale of 1=very soft and watery to 5=very firm and dry (NPPC, 1991).
[f]Scored on a scale of 1=practically devoid to 5=moderately abundant (NPPC, 1991).
[g]Dashes indicate P>.15.

[h]Not applicable means no statistical treatment of data.

Table 3. Measurements of Meat Color[a]

	Total phosphorus %					Probability, P<		
Item[b]	.55	.47	.40	.32	CV	Lin	Quad	Cub
Day 0								
Lightness	50.8	50.9	51.4	52.4	4.7	-[c]	-	-
Redness	13.3	11.8	12.9	11.7	11.7	-	-	.04
Yellowness	8.5	7.5	8.4	7.9	13.0	-	-	.07
Pink color intensity	15.8	14.0	15.4	14.1	11.5	-	-	.04
Day 3								
Lightness	51.4	51.3	52.8	53.5	4.3	.06	-	-
Redness	10.1	9.7	9.6	8.8	13.1	.07	-	-
Yellowness	8.0	7.7	8.2	7.4	9.7	-	-	.12
Pink color intensity	13.0	12.4	12.6	11.6	9.3	.05	-	-
Day 5								
Lightness	52.6	52.6	54.1	54.0	4.1	.13	-	-
Redness	8.5	8.3	7.6	7.7	15.3	-	-	-
Yellowness	8.3	7.7	8.2	7.6	10.8	-	-	.10
Pink color intensity	12.0	11.4	11.2	10.9	8.8	.06	-	-

[a]A total of 8 loins per treatment.
[b]MINOLTA CR-200 spectrocolorimeter values (lightness is Hunter 'L' value; redness is Hunter 'a' value; yellowness is Hunter 'b' value; pink color intensity is saturation index)
[c]Dashes indicate P>.15.

DIETARY LYSINE AND SLAUGHTER WEIGHT AFFECT GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS IN BOARS AND BARROWS

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Summary

During the growing and finishing period, the boars ate less, had better F/G, and were less fat than barrows. A high plane of nutrition (high vs moderate lysine concentrations for the growing-finishing phases) and decreasing slaughter weight from 260 to 220 lb also improved efficiency of gain and carcass leanness. However, many notable interactions occurred among the gender × lysine × slaughter weight treatments. Also, year (rotational-cross of average health status and lean growth potential vs a terminal-cross of high lean growth potential after repopulation of the farm) had pronounced effects on growth performance and carcass merits such that the combination of lean genotype-boars-high lysine-220 lb had advantages of 15, 20, 39, 49, and 15% for ADG, ADFI, and F/G, avg backfat thickness, and fat-free lean index, respectively, compared to the control (i.e., the avg lean growth-barrows-moderate lysine-260 lb treatment).

(Key Words: Barrows, Boars, Genotype, Slaughter Weight.)

Introduction

In countries such as Denmark, Britain, Spain, and Australia, boars are routinely fed for meat production. The reported advantages to feeding boars include greater carcass leanness, greater ADG, greater efficiency of gain, and reduced concern about animal discomfort (caused by the castration process) with modern swine production practices. However, the potential for boar odor, especially with current trends for slaughter weights in excess of 250 lb, is a serious concern in the U.S. fresh-meat market. Therefore, we designed an experiment to determine the merits of a high plane of nutrition (to accelerate the growth curve) and decreased slaughter weight to allow capture of the greater growth performance of boars and yet avoid the potential for boar odor in fresh meat products.

Procedures

Two groups (group one in 1994 and group two in 1995) of pigs (avg initial wt of 11.7 lb and avg age of 18 d) were allotted by weight and ancestry (five pigs per pen and 20 pens per treatment) and used in a 38-d growth assay to determine the effects of gender (barrows vs boars) on growth performance of nursery pigs. The first group of pigs (Yorkshire × Hampshire × Chester White × Duroc rotational-cross) had medium-lean growth potential and average health status. The second group of pigs (PIC line 326 boars × C15 sows terminal-cross) had high-lean growth potential and health status (i.e., the first group of pigs through the facilities after the depopulation-repopulation). All pigs were fed the same diets (Table 1) for d 0 to 10 (1.6% lysine), 10 to 24 (1.4% lysine), and 24 to 38 (1.35% lysine) post-weaning. The pigs were housed in 4 ft × 5 ft pens with woven wire flooring. Room temperatures were 90, 87, 84, 80, and 75°F for wk 1, 2, 3, 4, and 5, respectively. Each pen had a self-feeder and nipple waterer to allow ad libitum consumption of feed and water. The pigs and feeders were weighed on d 0, 10, 24, and 38 to allow calculation of ADG, ADFI, and F/G.

For the growing-finishing phase, the pigs were reallotted (two pigs per pen) and housed in an environmentally controlled finishing

barn with totally slatted floors. Eighty of the Year 1 pigs (medium-lean growth with an initial wt of 69 lb) and 80 of the year 2 pigs (high-lean growth with an initial wt of 74 lb) were used. The experiment was conducted in a 2 × 2 × 2 factorial with main effects of gender (barrows vs boars), lysine concentration regimen (moderate, .9 and .7% vs high, 1.3 and 1.1% for the growing-finishing phases, respectively), and slaughter weight (220 vs 260 lb). The grower (Table 1) diets were fed to a pen mean weight of 150 lb. At 150 lb, the pigs were switched to finishing diets that were fed until slaughter. The lysine concentrations for the moderate vs high treatments were selected by review of recommendations from the Agriculture Research Council in England, the National Research Council in the U.S., the Commonwealth Scientific and Industrial Research Organization of Australia, the Rowett Institute of Scotland, the University of Kentucky, and the University of Illinois. All vitamin and mineral concentrations were in excess of NRC (1988) recommendations. Slaughter weight treatments were 220 lb (typical for countries that produce boars for meat) and 260 lb (typical for packing plants in the U.S.).

The pigs and feeders were weighed every 7 d to allow calculation of ADG, ADFI, and F/G. Hot carcass weight was recorded at slaughter and all other carcass measurements were collected 24 h later. Dressing percentage was calculated with hot carcass weight as a percentage of live weight. Backfat thickness was measured at the first rib, last rib, and last lumbar vertebra from both sides of the carcass and used to calculate average backfat thickness. Tenth-rib fat depth was measured at 3/4 the distance across the longissimus muscle. The longissimus muscle was traced and the area measured using a planimeter. Fat free lean index (FFLI) was calculated from hot carcass weight and last rib fat depth, using the NPPC equation.

All data were analyzed using the GLM procedure of SAS, with year (genotype) as the unreplicated whole plot and a 2 × 2 × 2 (gender × lysine regimen × slaughter weight) factorial arrangement of treatments in the subplot. Before statistical treatment, carcass measurements were adjusted to the targeted endpoint weights of 220 and 260 lb by using slaughter weight as a covariable. The two-, three-, and four-way interactions among the whole plot and subplot effects were tested, but only those with probability values of .10 or less are included in the tables of this report.

Results and Discussion

Differences for year (genotype) were apparent for most of the response criteria during the nursery experiments (Table 2). However, the effects of year cannot be credited completely to the change in genotype because of depopulation/repopulation (i.e., improved health status) when the farm was stocked with the high-lean growth genotype. Indeed, one might expect differences because of lean growth potential to be expressed as improved efficiency of gain during the growing-finishing phases and greater carcass leanness at market weight. Barrows and boars did not differ in growth performance up to d 24 of the experiment. However, from d 24 to 38, the boars ate less feed ($P<.05$) and were more efficient than barrows ($P<.02$). Although differences in F/G are anticipated for barrows vs boars during the growing-finishing phase, the differences during wk 4 and 5 of our nursery experiment were unexpected. Nonetheless, advantages in growth performance for boars apparently begin at or near 42 d of age.

During the growing period and overall (Tables 3 and 4), year had significant effects on ADG ($P<.001$) and F/G ($P<.06$), with greater growth performance during year 2 (after the repopulation). As noted for the nursery data, the year effect is probably a combination of influence from the change in genotype and improved health status immediately after a depopulation/repopulation. Nonetheless, the year 2 (terminal-cross) pigs reached slaughter weight 12 days sooner that the rotational-cross pigs ($P<.001$).

Barrows and boars had similar ADG to 150 lb; however, boars consumed less feed and had better F/G ($P<.01$). These same

effects were noted during the finishing phase for the overall experiment.

Lysine concentration (high vs moderate) had no effect on ADG, ADFI, or F/G during the growing period (P>.26). However, from 150 lb to slaughter weight and overall, pigs consuming the high lysine regimen ate less feed and had better F/G compared to pigs fed moderate lysine concentrations (P<.06).

As for the slaughter weight treatments, pigs slaughtered at 220 lb had greater ADG and better F/G than those slaughtered at 260 lb (P<.01). Boars had lower dressing percentages and greater FFLI's than barrows, and pigs slaughtered at 260 lb had larger LEA and greater dressing percentages than pigs slaughtered at 220 lb (P<.001). However, as for the growth data, notable interactions occurred among the treatments for carcass data. Pigs from year 1 (medium-lean growth) accumulated more 10th rib backfat thickness with the greater slaughter weight than did the year 2 (high-lean growth) pigs (year × slaughter wt interaction, P<.01). The LEA of boars was greater than that of barrows in year 1; however, little difference in LEA occurred between boars and barrows in year 2 (year × gender interaction, P<.01). Finally, LEA was increased more for boars than barrows when lysine concentration of the diet was increased (gender × lysine regimen interaction, P<.06).

Despite the mentioned trends for improved rate and (or) efficiency of gain for the main effects of barrows vs boars, moderate vs high lysine concentrations, and the 220 vs 260 lb slaughter weight, many noteworthy interactions occurred. For example, the pigs in year 1 (medium-lean growth) had greater overall ADG when left as boars with no change in ADG for year 2 (high-lean growth) pigs left as boars (year × gender interaction, P<.03). Also, the F/G of pigs from year 2 (high-lean growth) responded more to the high lysine regimen than did the F/G of pigs from year 1 (year × lysine regimen interaction, P<.03). Finally, F/G for year 2 boars was improved with the high lysine regimen, whereas barrows from year 2 and barrows from year 1 responded little to the high lysine regimen (year × gender × lysine interactions, P<.01 and .09, respectively for the finishing period and overall F/G data). The response seems logical because the amino acid demands would be greater for high-lean growth (year 2) boars than for barrows or the boars of a medium-lean growth (year 1) potential.

In conclusion, the year 2 (high-lean growth) boars fed a high lysine regimen and slaughtered at 220 lb were 39% more efficient, had 49% less avg backfat thickness, and went to market 35 days sooner than the control barrows (medium-lean gain, fed moderate lysine regimen, and slaughtered at 260 lb). Thus, it seems likely that use of boars of a high-lean growth genotype will help the swine industry offer an extremely lean product to consumers with minimum cost of production. Also, the young age (130 d old) when these pigs were slaughtered would be likely to minimize concerns about development of boar odor. Alternatively, boars could be fed to heavier weights and their carcasses used for processed meat products, with gilt carcasses used to meet the lower demand for the fresh-meat trade.

Table 1. Diet Composition, %

	Nursery[a]			Grower[b]		Finisher[c]	
Ingredient	PH 1	PH 2	PH 3	Moderate[d]	High[d]	Moderate	High
Corn	40.07	56.54	54.28	67.72	52.99	77.85	63.12
Soybean meal	17.21	16.78	37.80	25.20	40.26	17.43	32.49
Dried whey	20.00	15.00	--	--	--	--	--
Dried-skim milk	5.00	--	--	--	--	--	--
SD plasma	10.00	--	--	--	--	--	--
SD blood meal	--	1.50	--	--	--	--	--
Fishmeal	1.00	3.00	--	--	--	--	--
Soybean oil	3.00	3.00	3.00	4.00	4.00	2.00	2.00
Dicalcium phosphate	1.58	1.56	2.24	1.65	1.33	1.22	.90
Limestone	.55	.58	.59	.68	.67	.75	.74
Salt	--	--	.35	.35	.35	.35	.35
Vit/Min/AA/Ab[e]	1.59	2.04	1.74	.40	.40	.40	.40

[a]The nursery pigs were fed the same diets for d 0 to 10 (1.6% lysine), 10 to 24 (1.4% lysine), and 24 to 38 (1.35% lysine).
[b]The grower diets were fed from 72 to 150 lb.
[c]The finisher diets were fed from 150 lb to the targeted slaughter weights of 220 or 260 lb.
[d]Moderate diets were formulated to .9 and .7% lysine and high diets were formulated to 1.3 and 1.1% lysine.
[e]Supplied 150 g/ton of apramycin for d 0 to 24 and 50 g/ton of carbadox for d 24 to 38, and 40 g/ton of tylosin for the growing and finishing phases [synthetic amino acids (AA) were not included in the growing/finishing phases].

Table 2. Growth Performance of Nursery Pigs[a]

	Year 1		Year 2			Contrasts[b]		
Item	Barrow	Boar	Barrow	Boar	CV	1	2	3
d 0 to 10								
ADG, lb	.69	.67	.78	.81	10.7	.02	--[c]	--
ADFI, lb	.61	.63	.80	.86	8.8	.001	.09	--
F/G	.88	.94	1.03	1.06	12.9	.01	--	--
d 10 to 24								
ADG, lb	.80	.79	1.16	1.12	10.3	.001	--	--
ADFI, lb	1.13	1.11	1.51	1.50	7.4	.001	--	--
F/G	1.41	1.41	1.30	1.34	6.4	.001	--	--
d 24 to 38								
ADG, lb	1.40	1.36	1.53	1.50	9.4	.001	--	--
ADFI, lb	2.12	1.98	2.30	2.16	9.6	.003	.05	--
F/G	1.51	1.46	1.51	1.45	4.6	--	.02	--
d 0 to 38								
ADG, lb	.99	.97	1.20	1.18	7.6	.001	--	--
ADFI, lb	1.36	1.30	1.61	1.58	7.3	.001	--	--
F/G	1.37	1.34	1.34	1.34	3.2	--	--	--

[a]A total of 200 weanling pigs (five pigs/pen and 20 pens per treatment) with an average initial wt of 11.7 lb and an average final wt of 52.8 lb.
[b]Contrasts were: 1) year; 2) barrows vs boars; 3) year by gender interaction.
[c]Dashes = P>.10.

Table 3. Growth Performance of Barrows and Boars during the Growing-Finishing Phase[a]

	Barrows				Boars				
	Moderate		High[b]		Moderate		High		
Item	220	260	220	260	220	260	220	260	CV
Grower									
ADG, lb									
Year 1[c]	1.91	2.00	1.83	2.00	1.95	1.96	1.96	1.92	
Year 2[d]	2.13	2.23	2.27	2.44	2.28	2.20	2.29	2.28	
Average	2.02	2.12	2.05	2.22	2.12	2.08	2.13	2.10	7.2
ADFI, lb									
Year 1	4.30	4.75	4.54	4.88	4.35	4.39	4.38	4.49	
Year 2	5.07	4.92	4.70	5.20	4.85	4.80	4.12	4.53	
Average	4.69	4.84	4.62	5.04	4.60	4.60	4.25	4.51	8.8
F/G									
Year 1	2.25	2.38	2.48	2.44	2.23	2.24	2.23	2.34	
Year 2	2.38	2.21	2.07	2.13	2.13	2.18	1.80	1.99	
Average	2.32	2.28	2.25	2.27	2.17	2.21	2.00	2.15	10.5
Finisher									
ADG, lb									
Year 1	2.03	1.85	2.17	1.98	2.14	2.08	2.21	1.99	
Year 2	2.38	2.16	2.20	2.07	1.96	1.99	2.16	2.07	
Average	2.21	2.01	2.19	2.03	2.05	2.04	2.19	2.03	10.3
ADFI, lb									
Year 1	6.33	5.82	5.85	6.17	5.83	5.64	5.52	5.44	
Year 2	6.19	6.31	5.85	6.33	5.37	5.23	4.87	5.10	
Average	6.26	6.07	5.85	6.25	5.60	5.44	5.20	5.27	8.7
F/G									
Year 1	3.12	3.15	2.77	3.12	2.72	2.71	2.50	2.75	
Year 2	2.60	2.92	2.66	3.06	2.74	2.63	2.25	2.48	
Average	2.83	3.02	2.67	3.08	2.73	2.67	2.37	2.62	10.0
Overall									
ADG, lb									
Year 1	1.96	1.93	1.95	1.99	2.04	2.03	2.08	1.93	
Year 2	2.25	2.19	2.26	2.22	2.15	2.08	2.22	2.16	
Average	2.11	2.06	2.11	2.11	2.10	2.06	2.15	2.05	6.8
ADFI, lb									
Year 1	5.19	5.34	5.07	5.60	5.04	5.12	4.93	5.00	
Year 2	5.51	5.74	5.23	5.88	5.10	5.24	4.45	4.88	
Average	5.35	5.54	5.15	5.74	5.07	5.18	4.69	4.94	7.0
F/G									
Year 1	2.65	2.77	2.60	2.81	2.47	2.52	2.37	2.59	
Year 2	2.45	2.62	2.31	2.65	2.37	2.52	2.00	2.26	
Average	2.54	2.69	2.44	2.72	2.41	2.51	2.18	2.41	7.2
Age, days[e]									
Year 1	147	165	148	167	145	163	145	164	
Year 2	128	155	130	156	129	156	130	156	
Average	138	160	139	162	137	160	138	160	1.4

[a]A total of 160 barrows and boars (initial weight of 71 lb) was used.

[b]Moderate (.9 and .7% lysine) vs high (1.3 and 1.1% lysine).

[c]Rotational cross (Yorkshire × Chester White × Duroc × Hampshire) before repopulation.

[d]Terminal cross (PIC line 326 boars × C15 sows) after repopulation.

[e]Age = days from birth to slaughter weight.

Table 4. Probability Values for the Growth Performance Data[ab]

Item	Year (1)	Gender (2)	Lys (3)	Swt (4)	1×2	1×3	1×4	2×3	1×2×3
Grower									
ADG	.001	--[c]	--	NA[d]	--	.05	NA	--	--
ADFI	.09	.01	--	NA	--	.03	NA	--	--
F/G	.02	.01	--	NA	--	.01	NA	--	--
Finisher									
ADG	--	--	--	.01	.01	--	--	--	.03
ADFI	--	.001	.04	--	.03	--	--	--	--
F/G	.01	.001	.02	.01	--	--	--	--	.01
Overall									
ADG	.001	--	--	--	.03	--	--	--	--
ADFI	--	.001	.06	.001	.02	.10	--	.06	--
F/G	.06	.001	.02	.001	--	.03	--	--	.09
Age	.001	.01	.10	.001	.01	--	.001	--	--

[a]Contrasts were: 1) year; 2) gender (barrows vs boars); 3) lysine regimen (moderate vs high) and; 4) slaughter weight (220 vs 260 lb).
[b]All two-, three-, and four-way interactions were tested, but only those with response criteria having a probability value of .10 or less are included in this table.
[c]Dashes = P>.10.
[d]Not applicable (i.e., slaughter wt treatments were applied at the end of the finishing phase).

Table 5. Carcass Characteristics of Barrows and Boars[a]

	Barrows				Boars				
	Moderate[b]		High[b]		Moderate		High		
Item	220	260	220	260	220	260	220	260	CV
Carcass									
Dressing, %									
Year 1[c]	72.9	75.6	74.4	75.2	72.8	73.7	72.3	73.4	
Year 2[d]	73.8	74.9	73.7	73.9	72.8	73.1	72.7	72.7	
Average	73.4	75.3	74.1	74.6	72.8	73.4	72.5	73.1	1.4
Average BF, in									
Year 1	1.31	1.56	1.32	1.47	1.14	1.31	1.03	1.22	
Year 2	.98	1.15	.99	1.08	.89	.97	.76	.87	
Average	1.15	1.36	1.16	1.28	1.02	1.14	.90	1.05	11.1
10th rib BF, in									
Year 1	1.29	1.64	1.31	1.52	1.19	1.35	.96	1.20	
Year 2	.85	.87	.67	.79	.67	.74	.56	.56	
Average	1.07	1.26	.99	1.16	.93	1.05	.76	.88	14.4
Loin eye area, sq in									
Year 1	5.49	5.88	5.32	5.59	5.42	6.16	6.01	6.35	
Year 2	6.08	6.87	6.54	7.15	5.90	6.37	6.57	7.00	
Average	5.79	6.38	5.93	6.37	5.66	6.27	6.29	6.68	8.4
FFLI, %									
Year 1	45.4	44.1	45.7	45.4	47.1	46.3	47.4	47.1	
Year 2	48.8	48.1	48.7	49.2	49.8	49.9	50.5	50.8	
Average	47.1	46.1	47.2	47.3	48.5	48.1	49.0	49.0	2.5

[a]A total of 160 barrows and boars (initial weight of 71 lb) was used.
[b]Moderate (.9 and .7% lysine) vs high (1.3 and 1.1% lysine).
[c]Rotational cross (Yorkshire × Chester White × Duroc × Hampshire)
[d]Terminal cross (PIC line 326 boars × C15 sows).

Table 6. Probability Values for the Carcass Data[a]

Item	Year (1)	Gender (2)	Lys (3)	Swt (4)	1×2	1×3	1×4	2×3	1×2×3
Dressing %	--[b]	.001	--	.001	--	--	.05	--	--
Average BF	.001	.001	.01	.001	--	--	--	--	--
10th rib BF	.001	.001	.01	.001	--	--	.01	--	--
LEA	.01	--	.02	.001	.01	.08	--	.06	--
FFLI	.001	.001	.02	--	--	--	--	--	--

[a]Contrasts were: 1) year; 2) gender (barrows vs boars); 3) lysine regimen (moderate vs high); 4) slaughter weight (220 vs 260 lb).
[b]All two-, three-, and four-way interactions were tested, but only those with response criteria having a probability value of .10 or less are included in this table.
[c]Dashes = P>.10.

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THE EFFECTS OF INCREASING DIETARY ENERGY DENSITY ON GROWING-FINISHING PIG GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS

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Summary

Eighty crossbred gilts were used in a growth trial to evaluate the effects of increasing dietary energy density on growing-finishing pig growth performance and carcass characteristics. In this trial, adding fat to corn-soybean meal diets with a constant calorie:lysine ratio to increase the energy density during the growing phase (98 to 160 lb) improved feed efficiency with no influence on growth rate. However, increasing the energy content of the diet by adding fat had no benefit during the finishing phase (160 to 233 lb).

(Key Words: Growing-Finishing, Fat, Performance.)

Introduction

Research has shown that the addition of dietary fat improves growth and efficiency of growing-finishing swine. However, these improvements are coupled with an increase in backfat thickness and a decrease in carcass lean. Swine producers must address the paradox of growth performance increasing while the leanness of their animals decreases. Therefore, our objective was to determine the effects of increasing energy density of growing-finishing swine diets on growth performance and carcass characteristics.

Procedures

Eighty crossbred gilts (initially 98 lb) were used in a growth assay to evaluate the effects of increasing energy density in growing-finishing swine diets on growth performance and carcass characteristics. Choice white grease (CWG) was added at 1.5, 3, 4.5, and 6% to a corn-soybean meal-based control diet (Table 1). Pigs were blocked by weight and ancestry and allotted to one of the five dietary treatments. The experimental diets were fed in two phases: growing (98 to 160 lb) and finishing (160 to 233 lb). A constant lysine:calorie ratio of 3.2 g lysine/Mcal ME was maintained during the growing phase. During the finishing phase, a lysine:calorie ratio of 2.47 g lysine/Mcal ME was maintained.

The pigs were housed two per pen in an environmentally controlled finishing barn with 4 ft × 4 ft totally slatted pens. The pens contained a single-hole feeder and a nipple waterer to allow pigs ad libitum access to feed and water. Drip coolers were activated when temperatures exceeded 80°F, cycling on 3 out of every 15 min. Pigs and feeders were weighed every 14 days to calculate ADG, ADFI, and F/G. Pigs were scanned ultrasonically to determine body composition when they were weighed. When mean pig weight reached 230 lb, pigs were slaughtered at a commercial slaughter facility to collect carcass data.

The data from this trial were analyzed with the GLM procedure of SAS. The statistical model included linear and quadratic effects of increasing energy density of the diet.

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Results and Discussion

During the growing phase (98 to 160 lb), increasing energy density in the diet decreased ADFI and improved F/G (linear, P<.01; Table 2). However, ADG was not affected by energy density. Total energy and lysine intake were not affected by dietary energy density. This is in agreement with previous research showing that increasing the energy level will improve efficiency but decrease feed intake. This also indicates that the pig adjusts its daily feed intake to maintain a constant caloric intake.

Increasing the energy density of the diet during the finishing phase (161 to 233 lb) decreased ADG (quadratic, P<.05); pigs fed the diet with no added dietary fat had the greatest gain. Feed efficiency became poorer and then improved as energy density of the diet increased (quadratic, P<.05); pigs consuming the diet with 6% added fat had the best F/G. Similar to the growing phase, total energy and lysine intakes were not affected by the energy content of the diet.

For the entire trial (98 to 233 lb), ADG was decreased (quadratic, P<.10) as energy density increased. Feed efficiency improved and intake decreased (linear, P<.01) with increasing energy density. This suggests that increasing energy density in growing pigs diets (< 161 lb) has a positive effect on growth performance but increasing energy density in the late finishing phase has a detrimental effect on growth performance of this genetic line of high-lean growth pigs.

Before pigs were sent to the commercial slaughter plant, they were scanned ultrasonically at the tenth rib. Ultrasonic images were interpreted to determine tenth rib backfat (TRFD) depth and loin muscle area (LMA, Table 3). Increasing dietary energy density decreased TRFD (P<.05). Pigs fed the diet containing 6% CWG had the least tenth rib fat depth at .84 in, whereas the pigs fed the diet with 1.5% CWG had the highest TRFD, .94 in. Loin muscle area was not affected by increasing dietary energy density.

When the pigs were slaughtered at 233 lb, carcass data were collected from carcass performance sheets provided by the packer. Pigs were skinned prior to evaluation by an optical probe (Fat-O-Meater). Increasing dietary energy density decreased backfat depth (BF; quadratic, P<.05). Pigs fed the diet with the highest and second highest energy densities (6% added CWG) had the lowest BF of .56 in. Loin muscle depth (LMD), similar to the ultrasound data, was not affected by increasing energy density of the diet. Percentage lean, collected from the optical probe data, was variable in response to dietary energy density. Percentage lean decreased through 3 % CWG and then increased with 6% CWG. Increasing energy density in the diet also affected the percentage carcass yield. Increasing the energy density of the diet through 6% added CWG improved carcass yield (linear, P<.01). The premium paid by the packer was not affected by dietary treatment. The average premium was $2.44/carcass cwt.

These data indicate that dietary fat can be added to the growing diet to improve F/G without affecting ADG. However, during the finishing phase, the addition of CWG to the basal diet decreased ADG. During the entire trial, pigs adjusted ADFI so that energy intake across treatments was equal. Increasing the level of CWG had no significant impact on BF or LMA. A consistent linear response was detected for carcass yield, which must be investigated further. Overall, adding fat to the growing diet may be justified, depending on the cost of fat, to improve feed efficiency without affecting subsequent carcass characteristics.

Table 1. Basal Diet Composition[a]

Item, %	Growing (100 to 160 lb)	Finishing (160 to 230 lb)
Corn	67.39	76.41
Soybean meal, 46.5%	29.62	20.89
Monocalcium phosphate	1.30	1.04
Limestone	1.09	.96
Salt	.35	.35
Vitamin premix	.20	.20
Trace mineral premix	.15	.15
Choice white grease	--	--
Total	100.00	100.00

[a]Grower diets were formulated to 3.2 g lysine / Mcal ME, .75% Ca, and .65% P. Finisher diets were formulated to 2.47 g lysine/Mcal ME, .65% Ca, and .55% P. Dietary lysine levels range from 1.06 to 1.14% in the grower phase and .82 to.88% in the finishing phase.

Table 2. The Effects of Increasing Energy Level Growing-Finishing Pig Growth Performance[a]

	Choice white grease, %					
Item	0	1.5	3.0	4.5	6.0	CV
Growing						
ADG, lb	1.96	2.01	1.97	1.94	2.04	7.5
ADFI, lb[b]	4.33	4.23	4.10	3.90	4.06	6.6
F/G[b]	2.23	2.11	2.08	2.02	1.99	7.9
Energy intake, Mcal	6.49	6.44	6.38	6.17	6.55	6.5
Lysine intake, g	20.85	20.74	20.48	19.81	21.00	6.5
Finishing						
ADG, lb[f]	2.11	1.91	1.94	1.94	1.97	7.9
ADFI, lb[b]	7.82	7.57	7.36	7.39	7.05	6.5
F/G[f]	3.74	3.94	3.81	3.81	3.58	6.0
Energy intake, Mcal	11.78	11.62	11.52	11.78	11.44	6.5
Lysine intake, g	29.13	28.71	28.41	29.03	28.15	6.5
Overall						
ADG, lb[g]	2.03	1.95	1.95	1.94	2.00	6.0
ADFI, lb[b]	6.18	5.99	5.82	5.75	5.64	5.4
F/G[b]	3.04	3.01	2.99	2.97	2.81	4.8

[a]Means derived from 80 pigs housed at two per pen with eight replicate pens per treatment.
[bcd]Linear effect of energy (P<.01, .05, and .10).
[efg]Quadratic effect of energy (P<.01, .05, and .10, respectively).

Table 3. The Effects of Increasing Energy on Carcass Characteristics

	Level of choice white grease, %					
Item	0	1.5	3	4.5	6	CV
Real time ultrasound[a]						
Tenth rib fat depth, in	.87	.94	.93	.86	.84	16.9
Tenth rib LMA, in^2	5.26	5.32	5.18	5.35	5.33	11.7
Percent lean[b]	49.81	49.47	49.11	50.39	50.45	5.1
Fat-O-Meater[c]						
Backfat depth. in[f]	.60	.66	.68	.58	.56	22.1
Loin muscle depth, in	2.17	2.24	2.09	2.18	2.18	9.7
Percentage lean%[dg]	56.18	55.45	54.76	56.48	56.75	4.2
Carcass yield, %[de]	63.91	64.58	64.73	65.12	65.30	2.3

[a]Means derived from 80 pigs scanned at 232 lb with 16 pigs per treatment.
[b]Percent lean was derived from NPPC equations for carcasses with 5% fat utilizing real time ultrasound measurements.
[c]Means derived from 79 pigs slaughtered at 232 lb with 15 or 16 pigs per treatment.
[d]Percent lean and carcass yield derived form plant carcass performance data sheet.
[e]Linear effect of energy ($P<.01$)
[fg]Quadratic effect of energy ($P<.05$ and .10, respectively).

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EFFECTS OF FEEDER DESIGN AND PELLETING ON GROWTH PERFORMANCE AND WATER USE IN FINISHING PIGS

M. M. Rantanen, J. D. Hancock, R. H. Hines, and I. H. Kim

Summary

Pigs fed from wet-dry feeders had 4% greater ADG with 50% less water usage than those consuming feed from dry feeders. Pelleting diets improved F/G by 4% compared to meal diets. However, the benefits of pelleting were primarily when a dry feeder was used, with little evidence to support use of both pelleting and wet/dry feeders for finishing pigs.

(Key Words: Finishing, Pigs, Feeders, Pellet.)

Introduction

Feed costs represent 60 to 70% of the total cost of production for a farrow to finish swine operation. The growing-finishing phase will account for the majority of those diet costs. Therefore, reducing cost of gain would greatly affect the overall profitability of a swine operation. We have reported previously that pelleting improved feed efficiency (and in some cases ADG) and reduced the amount of nutrients excreted as feces. Regulating water usage is also of great concern to many producers. Data given in the 1994 KSU Swine Day Report (p 168) suggested that a wet/dry feeder design decreased water disappearance and improved efficiency of gain in finishing pigs. Thus, we conducted an experiment to determine if the beneficial effects of pelleting and wet/dry feeder design are additive.

Procedures

A total of 288 finishing pigs (initial wt of 104.5 lb) was used in a 35-d growth assay. The pigs were allotted by initial weight, gender, and ancestry to the treatments: 1) dry feeder with meal diet, 2) dry feeder with pelleted diet, 3) wet/dry feeder with meal diet, 4) wet/dry feeder with pelleted diet. The experiment was conducted as a 2 × 2 factorial with eight to 10 pigs per pen and eight pens per treatment. Diets were ground through a 1/16-in screen with approximate particle size of 600 microns and pelleted through a 3/16-in die. Feeder designs were a simple two-hole, dry feeder (Pride of the Farm®) and a single-hole, wet/dry shelf feeder with a nipple waterer located at the base of the trough (Crystal Spring®). The pens with dry feeders were equipped with one nipple waterer mounted against the wall. Each pen was equipped with a water meter to measure water disappearance. The pens were 10 × 16 ft with concrete (50% solid and 50% slat) flooring. All data were analyzed using the GLM procedure of SAS. Pen was the experimental unit.

Results and Discussion

Pigs fed from the wet/dry feeders had 4% greater ADG than those fed from the dry feeders ($P<.04$). Feeder design had no effect on ADFI or F/G ($P>.24$). Pigs fed the pelleted diet consumed less feed and had better F/G ($P<.02$ and $P<.01$, respectively) than pigs fed the diet in meal form. However, an interaction was noted among feeder type and diet form. In dry feeders, pelleting improved efficiency of gain by 7%, but with the wet/dry feeders, pelleting improved efficiency of gain by only 1% (feeder type × diet form interaction, $P<.04$). Thus, there would be little reason to install a pellet mill if wet/dry feeders were used or to purchase wet/dry feeders if pellets are being fed. We should note, however, that water disappearance was 50% less ($P<.001$) when pigs fed

from the wet feeders. Thus, even when pelletized feed is used to maximize efficiency of gain, wet/dry feeders could help to reduce water wastage and waste management concerns.

Table 1. Diet Composition[a]

Ingredient	Percent
Corn	77.97
Soybean meal (46.5% CP)	17.84
Soybean oil	1.50
Monocalcium-phosphate	1.03
Limestone	.91
Salt	.30
Vitamin and mineral premixes	.25
Lysine-HCl	.15
Antibiotic[b]	.05

[a]Diets were formulated to .85% lysine, .65% Ca, and .55% P. Diets were ground through a 1/16-in screen with approximate particle size of 600 microns and pelleted through a 3/16-in die or fed in meal form.
[b]Provide 40 g/ton tylosin.

Table 2. Effect of Feeder Design and Pelleting on Growth Performance and Water Disappearance in Finishing Pigs

	Dry		Wet/dry			Contrasts[b]		
Item	Meal	Pellet	Meal	Pellet	CV	1	2	3
ADG, lb	2.26	2.16	2.30	2.30	5.0	.04	--[c]	--
ADFI, lb	5.98	5.30	5.78	5.73	7.1	--	.02	.04
F/G	2.65	2.45	2.51	2.49	3.9	--	.01	.04
Water, g/d	1.6	1.7	1.1	1.1	13.7	.001	--	--

[a]A total of 288 finishing pigs (8 to 10 pigs/pen and 8 pens/treatment) with an average initial wt of 104.5 lb and an average final wt of 183.5 lb.
[b]Contrasts were: 1) wet/dry versus dry, 2) meal versus pelleted, and 3) the interaction of feeder type and diet form.
[c]Dashes = P>.15.

Swine Day 1995

CAN AUGERS BE USED TO BLEND DIETS ON THE FARM?

S. L. Johnston, R. H. Hines, J. D. Hancock, K. C. Behnke [1], and S. L. Traylor [1]

Summary

Growing/finishing gilts were fed two-, three-, four-, or five-phase diet regimens from 77 to 276 lb. The diets were mixed in either a conventional, horizontal ribbon mixer or a 9 ft auger. No interactions occurred among the mixer type and phase-feeding treatments. Pigs fed diets blended with the auger had similar ADG but slightly (4%) worse F/G compared to those fed diets mixed in the mixer. Finally, the three-phase regimen gave the lowest F/G and the lowest cost of gain.

(Key Words: Phase-Feeding, Finishing, Mixing.)

Introduction

Phase feeding of growing/finishing pigs is recommended to meet nutrient requirements, while minimizing nutrient excesses. This should decrease costs of gain and the excretion of nutrients into the environment. Some poultry producers are experimenting with use of two bins, with a common boot and auger, to blend diets as they are passed into the grower building and to the feeders. With this system, an infinite number of diet changes becomes possible using feed bins containing only two diets. The obvious advantage to this technology is the flexibility in potential number of diet formulations at the farm with the greatly simplified request for number of diets (i.e., two) to be prepared at the feed plant. However, in last year's KSU Swine Days Report, we (Traylor et al.) suggested that improper mixing may decrease growth performance in nursery and finishing pigs. Thus, the objective of the experiment reported herein was to compare growth performance between gilts fed diets blended in an auger or mixed in a mixer. Also of interest were the effects of 2-, 3-, 4-, and 5-phase feeding programs during the growing/ finishing period on growth performance and backfat thickness.

Procedures

A total of 80 gilts (average initial wt of 77 lb) was used in a 105-d growth assay (average final wt of 276 lb). The pigs (Hampshire × Chester White × Duroc × Yorkshire rotational cross) were allocated by weight and ancestry, with two per pen (5 ft by 5 ft), in an environmentally controlled building. Two diets (1.0 and .6% lysine) were formulated using sorghum grain and soybean meal (48% CP) as the primary ingredients (Table 1). Appropriate ratios of these diets were mixed for 3 min in a 1.5-ton capacity, horizontal ribbon mixer (Davis®) or by dropping the two diets simultaneously into the hopper of a 9-foot, 4-in diameter (Allied®) auger to give intermediate diets with .9, .8, and .7% lysine. The diets were fed in four combinations to give a 2 × 4 factorial arrangement of treatments (Table 2).

Each pen had a self-feeder and nipple waterer to allow ad libitum consumption of food and water. The pigs and feeders were weighed at initiation and conclusion of the growth assay to allow calculation of ADG, ADFI, and F/G. Last rib backfat thickness measurements were taken at the end of the growth assay using a Scanoprobe® ultrasonic fat meter. The fat thickness measurements

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were adjusted to the same endpoint using final weight as a covariate. All data were analyzed using the GLM procedure of SAS with pen as the experimental unit.

Results and Discussion

Average daily gain for pigs fed auger-blended feed was not different (P >.21) from that of pigs fed diets mixed in the mixer (Table 3). However, pigs given the auger-blended feed had greater ADFI (P<.02) and worse F/G (P<.01) than pigs fed mixed diets. These results suggest that lack of mix uniformity with our auger-blending treatment was sufficient to cause differences in growth performance. However, we used only a 9-ft solid shaft auger. Better results might be obtained when using longer, hollow core (e.g., Flex Auger®) systems that are commonly found at swine operations.

When comparing the phase-feeding regimens, F/G and cost of gain were lowest for pigs fed the three-phase treatment. These results were consistent for both the auger-blended and the mixed treatments, suggesting that the added time and trouble of using four or more diet changes during the growing/finishing phase was not warranted. We should note, however, that our lowest lysine concentration was .6%. More than three phases might be of benefit (i.e., lower cost of gain) if the additional diets were added to minimize nutrient excesses (e.g., reduce lysine to .5% for the last phase). Of course, additional experiments would be needed to ensure that the lower nutrient concentrations would not adversely affect performance or carcass leanness.

No differences for last rib backfat thickness occurred among pigs fed the auger-blended vs mixed diets (P>.62). Also, the number of diet changes had no effect (P>.32) on backfat thickness.

In conclusion, our results suggest that using an auger system to blend multiple diets in a production swine unit is likely to give satisfactory growth performance with no increase in fat deposition. But, regardless of mixing protocol, the three-phase feeding program gave the best growth performance with minimal nutrient excesses in the diets.

Table 1. Composition of the Basal Diets[a]

Ingredient	1.0% lysine	.6% lysine
Sorghum grain	70.06	83.58
Soybean meal (48% CP)	26.89	13.07
Monocalcium phosphate	1.33	1.58
Limestone	.92	.97
Salt	.35	.35
Vitamins	.20	.20
Trace minerals	.15	.15
Antibiotic[b]	.10	.10

[a]Diets with .9, .8, and .7% lysine were made by mixing the 1.0 and .6% lysine basal diets.
[b]Provided 100 grams of aureomycin per ton of feed.

Table 2. Weeks at Each Lysine Concentration for the Phase Treatments

No of phases	Lysine concentration 1.0%	.9%	.8%	.7%	.6%
2	-	-	8 wk	-	7 wk
3	5 wk	-	5 wk	-	5 wk
4	4 wk	4 wk	-	4 wk	3 wk
5	3 wk	3 wk	3 wk	3 wk	3 wk

Table 3. Effects of Auger-Blending and Phase-Feeding on Growth Performance, Fat Thickness, and Cost of Gain in Growing-Finishing Pigs[a]

	Mixer phase regimens				Auger phase regimens				
Trait	2	3	4	5	2	3	4	5	CV
ADG,lb[b]	1.88	1.89	1.92	1.84	1.85	1.90	1.93	1.90	5.5
ADFI, lb[c]	6.29	5.97	6.18	6.09	6.40	6.26	6.56	6.51	5.7
F/G[d]	3.35	3.16	3.22	3.31	3.46	3.30	3.40	3.43	4.8
LRFD, in[e]	1.33	1.29	1.35	1.29	1.30	1.30	1.31	1.30	5.7
Cost of gain, $/lb[f]	.214	.208	.216	.217	.221	.210	.223	.224	--
Cost/ pig, $	42.58	41.44	43.08	43.24	43.91	41.73	44.45	44.66	--

[a]A total of 80 pigs (with an avg initial wt of 77 lb and an avg final wt of 276 lb were used in a 105-d growth assay.
[b]No effect of treatment (P>.21).
[c]Mixer vs auger (P<.02).
[d]Mixer vs auger (P<.01) and quadratic effect of phases (P<.04).
[e]No effect of treatment (P>.32).
[f]Feed cost was based on grain sorghum at $5.02/cwt and soybean meal at $205/ton.

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EFFECTS OF CROWDING AND INTERMITTENT FEED INTAKE ON GROWTH PERFORMANCE AND DEVELOPMENT OF STOMACH LESIONS IN FINISHING PIGS

P. Sorrell, J. D. Hancock, L. L. Burnham, I. H. Kim, G. A. Kennedy[1], and R. H. Hines

Summary

Pigs in uncrowded pens (12 ft^2/pig) consumed more feed, gained at a greater rate, and tended to develop fewer stomach lesions than pigs in crowded pens (6 ft^2/pig). Pigs with ad libitum access to feed consumed more feed and gained at a greater rate than pigs deprived of feed for 24-h periods twice each week. The resulting intermittent feed intake increased the severity of stomach lesions but only for uncrowded pigs. In conclusion, crowding slowed growth for all pigs and increased the severity of stomach lesions. Intermittent feed intake also slowed growth, but its effects on development of stomach lesions were less consistent.

(Key Words: Finishing, Ulcers, Crowding, Feeding Pattern.)

Introduction

Increased building and equipment costs with small profit margins have influenced swine producers to maximize use of pens and facilities by increasing stocking density. The result is stress from crowding. Additionally, there are anecdotal reports that changes in feed intake resulting from disease, poor feeder management, changes in diet formulation, etc., precipitate death loss from stomach ulcers in pigs. Thus, the experiment reported herein was designed to determine the effects of stocking density and intermittent feed intake on growth performance, carcass measurements, and changes in stomach morphology of finishing pigs.

Procedures

One hundred ninety-two crossbred (Duroc × Yorkshire × Hampshire × Chester White) pigs were allotted with eight pigs per pen (uncrowded) with 6 sq ft/pig or 16 pigs per pen (crowded) with 12 sq ft/pig. These pigs were allowed to consume feed on an ad libitum basis or they were deprived of feed for 24 h on Monday and Thursday of each week. All pigs were fed the same corn-SBM based diet formulated to .65% lysine, .65% calcium. .55% phosphorous, and 1.56 Mcal DE/lb and supplied with 100 g chlortetracycline per ton of diet. The pigs were allotted to treatments on the basis of weight (initial average of 126 lbs), sex (half barrows and half gilts in each pen), and ancestry. The pigs were housed in a modified open-front barn with half slatted concrete and half solid concrete floors. The experiment concluded when the average weight in the heaviest pen group of a weight block was 250 lb. The barrows in each pen were slaughtered for collection of stomachs and carcass measurements.

Response criteria were ADG, ADFI, F/G, last rib backfat thickness, dressing percentage, stomach keratinization score, and stomach ulceration score. The data were analyzed as a randomized complete block design with a 2 × 2 factorial arrangement of treatments. Contrasts were: 1) uncrowded vs crowded; 2) ad libitum vs intermittent feeding; and 3) the interaction between stocking density and feeding regimen. Pen was the experimental unit.

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[1]Department of Diagnostic Medicine/Pathobiology.

Results and Discussion

Pigs in the uncrowded pens consumed more feed (P<.001) and gained at a greater rate (P<.001) (Table 1) than pigs in the crowded pens. Also, pigs given ad libitum access to feed had greater ADG and ADFI than those consuming feed intermittently (P<.001). There were no differences in F/G among the pigs or interactions among the stocking density and feeding regimen treatments. The lack of effect on efficiency of growth was unexpected, because slight reductions in feed consumption often result in improved feed efficiency. Alternatively, severe feed restriction (e.g., 24-h periods twice each week) may have decreased the energy available for growth versus maintenance and, thereby, negated the possible efficiency-boosting effects of lower feed intake.

Dressing percentage (P<.50) and adjusted backfat thickness (P<.80) were not different for uncrowded versus crowded pigs. Pigs allowed to consume feed on an ad libitum basis had greater slaughter weights (P<.01) and dressing percentages (P<.06) and tended to have greater adjusted backfat thickness (P<.06) compared to those fed intermittently.

The numbers of stomachs given each score for keratinization and ulceration are presented in Table 1. Mean scores indicated that intermittent intake decreased keratinization (P<.001). However, intermittent feeding in uncrowded pigs increased ulcers but decreased ulcers in crowded pigs (crowding × feeding regimen interaction, P<.004).

In conclusion, increasing stocking density to minimize housing costs per pen marketed must be balanced with the expected decrease in growth performance. Also, death loss attributed to ulceration was minimal in this experiment, but the increase in keratinization and ulceration score with the stress of overcrowding raises concern about animal husbandry. In contrast, intermittent feed intake had little effect on development of stomach lesions.

Table 1. Effects of Crowding and Intermittent Feed Intake on Growth Performance and Stomach Lesions in Finishing Pigs[a]

	Uncrowded[b]		Crowded[c]			Contrasts[d]		
Item	Ad libitum	Intermittent	Ad libitum	Intermittent	CV	1	2	3
ADG	1.96	1.78	1.79	1.55	5.0	.001	.001	.40
ADFI	6.46	5.87	5.72	5.16	4.3	.01	.001	.80
F/G	3.30	3.30	3.20	3.33	5.4	.09	.70	.30
Slaughter wt, lb	265	243	245	229	5.2	—[e]	.01	—[e]
Adjusted backfat, in	1.15	1.10	1.14	1.10	4.0	.80	.06	.70
Dressing percentage	73.6	72.8	74.72	72.4	1.2	.50	.06	.70
Stomach keratinization								
Total observations	14	15	30	28	—	—	—	—
Normal	1	4	1	16	—	—	—	—
Mild	5	4	6	7	—	—	—	—
Moderate	5	6	14	5	—	—	—	—
Severe	3	1	9	0	—	—	—	—
Mean score[f]	1.93	1.51	2.20	.88	23.8	.30	.001	.04
Stomach ulcerations								
Total observations	14	15	30	28	—	—	—	—
Normal	8	6	13	18	—	—	—	—
Erosions	2	3	2	2	—	—	—	—
Ulcerations	2	5	12	8	—	—	—	—
Meal score[g]	.6	1.15	1.30	.72	41.7	.30	.80	.004

[a]A total of 192 pigs (average initial wt of 126 lb) was used.
[b]Uncrowded pens contained 8 pigs/pen (12 ft^2/pig).
[c]Croweded pens contained 16 pigs/pen (6 ft^2/pig).
[d]Contrasts were 1) crowded vs uncrowded, 2) ad libitum vs intermittent feeding, and 3) interaction vs interaction.
[e]Dashes indicate P>.15.
[f]The scoring system was 0=normal, 1=mild keratinization, 2=moderate keratinization, and 3=severe keratinization.
[c]The scoring system was 0=normal, 1=erosin, 2=ulcers, and 3=severe ulcers.

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MIXING AND CLEAN-OUT PROPERTIES OF SULFAMETHAZINE AND CARBADOX IN SWINE FEED

T. Herrman [1], K. Behnke [1], and T. Loughin [2]

Summary

Results of this study suggest that carbadox was incorporated uniformly in the feed by mixing. However, the two medicated feed additives containing sulfamethazine did not incorporate uniformly in the feed. The causal mechanism for the poor mixing performance of sulfamethazine was not discovered; however, assay variability was eliminated as a primary source of variation. Flushing the feed mixing, conveying, and sack-off systems twice with ground corn did not eliminate drug carryover. Further investigation of the mixing and clean-out properties of medicated feed additives is warranted.

(Key Words: Feed, Mixing, Clean-Out, Drugs.)

Introduction

Concern over the safety of the food supply in the United States is paramount among consumers. The current good manufacturing practices (cGMPs) used to regulate animal feed production outline procedures to help assure that meat, milk, and eggs produced from animals receiving medicated feeds contain no violative drug residues.

Food and Drug Administration (FDA) cGMPs specify that "Equipment shall be capable of producing medicated feed of intended purity and potency"; this includes proper mixer performance. Mixer testing procedures are outlined by the American Society of Agricultural Engineers. This procedure entails describing feed uniformity by calculating the coefficient of variation (CV) using salt assays from 10 feed samples collected from the mixer. The cGMPs also specify that "Adequate procedures shall be established and used for all equipment used in the production and distribution of medicated feeds to avoid unsafe contamination of medicated and non-medicated feeds".

Sulfamethazine and carbadox are two antibacterial drugs widely used in swine production. Residue tolerances for these two products in uncooked tissue are 0.1 ppm and 0.0 ppm, respectively. Both products are classified as category II drugs under the cGMPs; withdrawal times are 15 days for sulfamethazine and 10 weeks for carbadox. Both products are used to improve weight gain and feed efficiency, as well as control or prevent bacterial diseases.

The high rate of violations for tissue residues of sulfamethazine has concerned FDA personnel for years. The FDA has identified that a lack of sequencing, flushing, and cleaning of mixer equipment accounted for 25% of sulfamethazine violations. As little as 1 ppm of sulfamethazine in feed, or 1/4 teaspoon of sulfa in a 1-ton batch of feed, can cause violative sulfa residues. Evaluating the performance of these two medicated feed additives in terms of their flushing and clean-out properties may help explain the cause for cross-contamination of feed.

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[2]Department of Statistics.

Studies examining the cause of cross-contamination in feed manufactured on-farm revealed that powdered sulfamethazine increased this risk compared to the granular form of the drug. The drug manufacturing industry developed granular and pellet forms of sulfamethazine to help reduce cross-contamination. This effort, combined with a strong education campaign by USDA and FDA, reduced the violation rate in pork from 13% prior to 1978 to about 5% from 1980 to 1987. For sulfamethazine in swine, the current residue violation rate is less than 1%.

Improper mixing and incorrect inclusion rates of medicated feed additives create the potential for tissue-residue violations. The FDA has established assay limits of 20% and 25% for complete feed containing sulfamethazine and carbadox, respectively. Exceeding these tolerances presents a potential source of violative tissue residue, whereas inclusion rates below the established tolerance may reduce the efficacy of the drug to control disease and allow development of microbial resistance.

This study was conducted to examine the mixing and clean-out properties of two forms of sulfamethazine and one carbadox product to better understand the role that product form, mixing performance, and flushing/clean-out properties may play in producing quality feed.

Procedures

Medicated swine feed was produced in 1,000 lb batches at the feed mill of the Department of Grain Science and Industry, Kansas State University (Table 1). The study was replicated three times for each of three medicated feed additives:

1) 10 g per lb sulfamethazine in extruded pelleted form (pelleted sulfa),

2) 10 g per lb sulfamethazine in granular form (granular sulfa), and

3) 2.5 g per lb carbadox (carbadox).

Table 1. Swine Grower Ration Used to Test Mixing and Clean-Out Properties of Sulfamethazine and Carbadox

Ingredient	Percent
Corn	73.45
Soybean meal (48% CP)	22.20
Monocalcium phosphate	1.45
Limestone	1.05
L-lysine ·HCl	.10
Vitamin premix	.20
Trace mineral premix	.15
Salt	.30
Drug[1]	1.00

[1]Inclusion rate for sulfamethazine products, only 5 lb of the carbadox product was added to feed and an additional 5 lb of ground corn was used.

Sulfamethazine was included in the feed at a rate of 110 ppm of feed, and carbadox was used at 55 ppm of feed. Treatments were arranged in a completely randomized design with repeated measures taken at three mixing times and after transferring feed to 50 lb sacks.

Corn conforming to U.S. Grain Grading Standards for number 2 yellow corn was ground to a particle size ranging between 550 and 700 microns using a Jacobson hammermill with a 1/8 in diameter screen. A 400 lb ground corn placebo was passed through the mixing and sack-off system, and the mixer, leg, and sack-off bin then were cleaned prior to mixing feed for the study. Feed consisting of corn (73.5% by weight) and soybean meal (22.2% by weight) was batched with a Wisconsin Electric Manufacturing, Inc. system and emptied into a Sprout Waldron horizontal double-ribbon mixer. The micro-ingredients (monocalcium phosphate, limestone, lysine, vitamins, trace minerals, and salt) were added to the mixer by an Able micro-ingredient system.

Mixing properties of the medicated feed additives were evaluated by sampling the

mixer using a Seedburo Grain Probe after 1.5, 2.5, and 4 min of mixing time. In order to reduce costs for incorporating replications, the CVs were computed based on eight rather than 10 samples. Following the mixing treatment, feed was conveyed to the sack-off bin and packaged into 50 lb capacity sacks, of which eight were sampled. Two flush treatments with 200 lb of corn followed each batch of feed. The feed system was cleaned by the same procedures used in mill preparation.

Samples from the mixer, packaging, flush, and clean-out were split using a riffler and analyzed separately for salt and drug content. Salt analyses were performed using Quantab titrators. Assays for sulfamethazine and carbadox were performed by a commercial lab. The lowest detection limits for these assays are 5 ppm and 2 ppm, respectively. Triplicate assays were performed on all samples that were 30% outside the desired medication level following the first assay results.

Coefficient of variation (CV), standard deviation, and mean measurements taken across the locations were calculated for each drug, replication, and mixing time using the Univariate procedure in SAS. Drug levels were analyzed on a proportional basis, because the carbadox inclusion rate was half of the sulfamethazine inclusion rate. The GLM procedure in SAS was used to evaluate treatment effects for both the mixing and clean-out portions of the study. Main effects were separated using Fisher's least significant difference (LSD) technique, and interactions were analyzed using the least significant difference among the least squares means produced by the GLM procedure. Variance components in the general linear model were evaluated using the VARCOMP procedure of SAS. A paired-comparison t-test was performed on the mean difference between drug mixing uniformity and salt mixing uniformity.

Results and Discussion

Mixing Properties. Mixing properties compared among drugs were different ($P<.01$), whereas mixing time did not differ ($P>.05$). Carbadox mixed well, as indicated by an average CV of 11.4% (Table 2). The CV for pelleted sulfa was 30.4%, and the CV for granular sulfa was 25.6%.

Increased mixing time after 1.5 min did not significantly improve the uniformity of drug distribution in the swine feed ($P>.10$). This suggests that some factor other than mixing time hindered sulfamethazine distribution in the feed. Electrostatic properties of feed ingredients are reported to occur; however, a paucity of information is available regarding the influence of static charge on mixing properties. Ingredient carriers, oil, and grounding the mixer are used to reduce static cling. However, ingredients not directly in contact with the mixer may possess electrostatic charge. If static charge was the cause for non-uniform distribution of sulfamethazine in the feed, additional mixing would not rectify this problem. Further investigation to explain the cause for poor mixing performance should include measuring various physical properties of sulfamethazine, salt, and corn, such as density, particle size, hygroscopicity, conductivity, and static charge during mixing or movement.

Mean assay values for each drug × mixing time combination (Table 2) indicate that the pellet form of sulfamethazine was present at a lower concentration (87.1 ppm) than the granular form (108.4 ppm) in the complete feed. Both sulfamethazine products were packaged as a Type-B premix at a concentration of 10 g per lb, and assays of the premixes for drug level indicated that the granular and pellet forms contained 114% and 104% of the label amount, respectively. The higher mean for the granular sulfamethazine explains why its CV was smaller than that of the pellet form. The standard deviations for both products were similar, and the range between assays was about 27 ppm greater for the granular product.

The statistical components of variability for the two sulfamethazine products and carbadox were analyzed using data from samples subjected to triplicate drug assays.

Assay variability was small relative to other components of variability in the experiment. The greatest variability occurred between replications for the same sample site within each drug treatment.

The paired-comparison t-test between salt and drug CVs revealed that carbadox did not differ significantly (P>.05) from salt with respect to distribution uniformity in the feed, whereas both forms of sulfamethazine displayed mixing properties that were significantly different (P<.05) than those of salt.

Clean-out Properties. We observed a drug × location interaction in feed clean-out/flush material (P<.01; Figure 1). Drug concentrations in both the ground-corn flush treatments did not vary (P>.05) among products. A trend for sulfamethazine to be present but carbadox not to be present at detectable concentrations was established for both corn flush treatments.

The mixer clean-out samples displayed a similar trend with respect to drug carryover. Sulfamethazine contents in mixer clean-out samples did not differ (P>.05) between the pellet (8.1 ppm) and granular (12.6 ppm) product, However, carbadox (<2.0 ppm) differed from the granular form of sulfamethazine (P<.05). The highest sulfamethazine concentration (16.2 ppm) found in 1.1 kg of mixer clean-out material could result in a contamination of 32 parts per billion in the subsequent 1,000 lb batch of feed. This is below the 1 ppm level that can lead to violative tissue residues.

The feed collected from the boot of the leg contained significantly (P<.05) higher drug levels than the flush and mixer clean-out material. No significant difference was present between the three drug products. The highest level of sulfamethazine carryover (37.8 ppm pellet and 39.9 ppm granular) occurred in the material collected from the boot of the leg. Because this is a dead spot in the feed conveying system, the only way to remove carryover material is to clean the boot (physical removal). A high concentration of drug at this location is not undesirable, because the pellet and granular products were designed to flush from the system.

The concentrations of drugs in material collected from the sack-off bin varied dramatically between products. The concentration of carbadox in the sack-off bin was approximately 86% of the inclusion rate (43 ppm) compared to the sulfamethazine products, which were present at 7 ppm and 23.5 ppm for the pellet and granular forms, respectively. Clean-out material from the sack-off bin consists of fine, dust-like particles. Perhaps carbadox possesses similar dust-like properties and separates from the feed at the sack-off bin. The presence of a high drug concentration in the sack-off bin appears particularly hazardous, because it relates to product cross-contamination. The high concentration of carbadox in the sack-off bin also may explain why it was not present in the ground corn flush.

Veterinarians, swine producers who manufacture their own feed, and commercial feed processors should be aware of the different properties that medicated feed additives possess with respect to mixing and clean-out performance. In light of these results, it is imperative that the cGMPs are followed to avoid cross-contamination and violative tissue residue. Veterinarians and commercial feed companies who supply producers with premix, basemix, or supplement products containing drugs can play an integral role in educating producers about the importance of good manufacturing practices and how to avoid cross-contamination.

Table 2. Coefficient of Variation (CV) Percentages and Means, Ranges, and Standard Deviations (in ppm) for Two Sulfamethazine Forms and Carbadox at 1.5, 2.5, and 4 Minutes Mixing Time and after Bagging Feed

		Assay results, ppm		
Treatment	CV %	Mean	Range	Std. Dev.
Sulfa pelleted				
1.5 min. mix	28.2	73.6	86.9	20.8
2.5 min. mix	32.4	90.2	126.9	29.2
4.0 min. mix	30.8	98.6	122.6	30.4
bags	30.4	85.9	103.1	26.2
Average	30.4	87.1	109.9	26.6
Sulfa granular				
1.5 min. mix	25.1	109.8	125.0	27.6
2.5 min. mix	25.9	112.7	150.5	29.2
4.0 min. mix	28.2	104.5	149.5	29.5
bags	23.4	106.6	121.8	25.0
Average	25.6	108.4	136.7	27.8
Carbadox				
1.5 min. mix	14.3	48.1	30.5	6.9
2.5 min. mix	5.7	44.5	10.7	2.6
4.0 min. mix	10.6	45.2	18.6	4.8
bags	14.9	44.7	31.0	6.7
Average	11.4	45.6	22.7	5.2

Figure 1. Interactions among Three Medicated Feed Additives and Five Sources of Clean-Out Material.

Swine Day 1995

TEST WEIGHT AFFECTS THE MILLING CHARACTERISTICS OF GRAIN SORGHUM

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Summary

As test weight was reduced from normal to intermediate (i.e., from 58 to 52 lb/bu), little change occurred in milling characteristics of grain sorghum. However, as test weight was decreased from intermediate to light (52 to 39 lb/bu), production rate slowed and cost of grinding increased dramatically. Decreasing screen opening size from 8/64 in to 3/64 in also decreased production rates and increased electrical energy costs, with these effects much more pronounced in light test-weight sorghum.

(Key Words: Sorghum, Test Weight, Grinding.)

Introduction

Grain sorghum production in Kansas during the 1993 crop year was 176.4 million bushels. Thus, grain sorghum is an important crop for both grain farmers and livestock feeders in our state. Data gathered by the Kansas Department of Agriculture suggested that more than 30% of the sorghum produced in Kansas was given a discount because of excessive moisture and nearly 10% was discounted for light test weight during good cropping years. Test weight of sorghum grains is affected by genetics, environment, and cultural practices. In particular, late planting, cool growing season, and early frost result in light test weight, and all three of the factors occurred this year in Kansas.

Data generated at KSU during the past 4 years suggested that the feeding value of sorghum with test weight as low as 35 lb/bu was only 10 to 12% lower than that of normal test-weight sorghum. This reduction in feeding value of light sorghum is in sharp contrast with the 30 to 50% discount in price some farmers have reported. Very little information is available about milling characteristics that might help a producer decide whether or not to use light test-weight sorghum in diets for pigs. Thus, an experiment was conducted to determine the milling characteristics of sorghum grain varying widely in test weight.

Procedures

Grain sorghums with test weights of 58, 52, and 39 lb/bu were obtained from grain producers in the state of Kansas. Three replications (random samples) of each test weight were ground in a 1.5 horsepower Bliss hammermill (Model ELT-9506-TF) equipped with screens having openings of 8/64, 6/64, 4/64, and 3/64 in. The motor load of the hammermill was constant at 75% of capacity during milling, so that production rates and electrical energy consumption could be measured. Net electrical energy was calculated as the difference between total electrical energy used during grinding and electrical energy used to spin the hammer rotor while no sorghum was being ground. Samples were obtained after grinding to allow determination of the geometric mean particle size (Dgw), log normal geometric standard deviation (Sgw), and apparent bulk density (lb/ft^3).

All data were analyzed as a completely randomized design with a 3 × 4 factorial

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arrangement of treatments. Main effects were test weight (58, 52, and 39 lb/bu) and screen size (8/64, 6/64, 4/64, and 3/64 in) used to mill the grain. Polynomial regression was used to characterize the response of milling characteristics as test weight and screen size were decreased and to identify any interactions among the test weight and screen size treatments.

Results and Discussion

Each lot of grain sorghum was characterized with an official grade (Table 1). Minimal differences occurred for dockage, foreign matter, and broken kernels as test weight was decreased from 58 to 52 lb/bu. However, marked differences between the 52 and 39 lb/bu sorghums occurred for dockage, foreign matter, and broken/foreign matter content.

Although the same screens were used to grind all three sorghums, as test weight was decreased, there was a trend for the 39 lb/bu sorghum to have greater particle size than the 58 and 52 lb/bu sorghums (quadratic trend, P<.08). Also, a marked decrease in production rate and increases in total and net energy consumption occurred during grinding, as test weight was decreased from 52 lb/bu to 39 lb/bu (quadratic, P<.01). The decreased desirability for milling the 39 lb/bu test weight sorghum results from its relatively high fiber content (glumes, stalks, etc.) compared to the 52 and 58 lb/bu sorghums. Indeed, the difficulty in grinding the fibrous 39/lb/bu sorghum resulted in a total grinding cost of $2.23/ton compared to values of $.94/ton and $.85/ton for the 58 and 52 lb/bu test-weight sorghums, respectively.

Because feed manufacturers use equipment that is based on volumetric capacity (mixers, bins, etc.), any changes in ground grain bulk density could affect the performance of the mixer (i.e., mix uniformity), storage capacity of bulk bins, and production rate through grinders. Linear decreases in bulk density of the whole and ground grain occurred as test weight was decreased (P<.01), but most of the effect actually occurred as test weight was decreased from 52 to 39 lb/bu (quadratic, P<.01).

As screen size opening was decreased from 8/64 to 3/64 in, geometric mean particle size (Dgw) was decreased from 759 to 366 microns (linear, P<.01) and variation of particle size (Sgw) decreased from 2.11 to 1.97. However, production rate decreased from 535 lb/h to 115 lb/h as screen size was decreased (P<.01), and total electrical cost of grinding was increased by $1.92/ton.

Thus, both decreasing test weight and using screens with smaller openings tend to decrease production rate and increase milling costs. However, the effects of test weight and screen size were not independent, as indicated by several noteworthy interactions. The most important of these interactions indicated that decreased throughput and increased milling costs from using small screen openings were greatly affected by 39 lb/bu sorghum vs the 52 and 58 lb/bu sorghums (test weight by screen size interaction, P<.01).

In conclusion, our data suggest that grain sorghum test weight as low as 52 lb/bu has no effect on mill throughput, energy consumption, or energy costs for grinding when compared to normal test-weight sorghum. In contrast, the use of sorghum with a test weight of 39 lb/bu reduced mill throughput from 297 to 166 lb/h and increased grinding costs from $.41 to $2.33/ton. Thus, increased milling costs should be considered along with potential reductions in growth performance in making a decision about use of low test-weight sorghum.

Table 1. Characteristics of the Whole Grain[a]

	Test weight, lb/bu		
Item	58	52	39
Grade	#1 white	# 4 white	Sample
Test weight, lb/bu	58.0	51.5	38.5
Dockage, %	0.00	0.00	1.00
Foreign matter, %	0.3	0.4	6.5
Broken/foreign matter, %	1.3	1.5	14.5

[a]Official grain grades were determined by an FGIS inspector.

Table 2. Effects of Test Weight and Screen Size on Grain Sorghum Processing Characteristics

	Test weight, lb/bu												
	58				52				39				
Item Screen size, in:	8/64	6/64	4/64	3/64	8/64	6/64	4/64	3/64	8/64	6/64	4/64	3/64	CV
Milled grain characteristics													
Geometric mean particle size, microns	775	536	401	361	739	534	402	321	762	595	430	416	10.6
Log normal standard deviation	2.13	2.17	2.05	2.00	2.12	2.17	2.01	2.00	2.06	2.02	1.98	1.90	3.0
Production characteristics													
Production rate, lb/h	581.0	300.1	165.2	141.5	642.6	360.0	173.0	151.0	383.2	155.6	72.8	53.0	9.8
Electrical energy consumption, kWh/ton													
Total	4.57	8.67	15.4	18.17	4.00	7.33	14.63	16.73	6.70	16.47	35.67	52.60	16.6
Net[a]	1.17	2.06	3.73	4.57	1.03	1.87	3.47	4.00	1.70	4.00	9.23	15.83	27.6
Electrical energy grinding costs, $/ton[b]													
Total	.37	.69	1.23	1.45	.32	.59	1.17	1.34	.54	1.32	2.85	4.21	16.6
Net	.09	.17	.30	.37	.08	.15	.28	.32	.14	.32	.74	1.27	27.6
Apparent bulk density, lb/ft^3													
Whole grain	46.93	48.43	48.42	48.88	42.93	42.27	41.47	42.15	30.03	29.27	31.40	29.23	3.7
Ground grain	41.78	41.45	40.72	39.23	38.63	37.77	36.63	36.38	27.42	28.25	30.33	29.37	2.4
Difference	-5.15	-6.98	-7.70	-9.65	-4.30	-4.50	-4.84	-5.77	-2.62	-1.02	-1.07	0.14	23.5

[a]Difference between total grinding amps and empty amps.
[b]Calculation based on $.08/kWh for electrical energy cost.

Table 3. Probability Table

	Test weight		Screen size			Two-way interactions					
Item	Linear (1)	Quadratic (2)	Linear (3)	Quadratic (4)	Cubic (5)	1 × 3	1 × 4	1 × 5	2 × 3	2 × 4	2 × 5
Geometric mean particle size	-[a]	.08	.01	.01	-	-	-	-	-	-	-
Log normal standard deviation	.01	.11	.01	-	.07	-	-	-	-	-	-
Production rate	.01	.01	.01	.01	-	.01	-	-	-	-	-
Total energy consumption	.01	.01	.01	-	.04	.01	.08	-	.01	-	-
Net energy consumption	.01	.01	.01	-	-	.01	.04	-	.01	-	-
Total grinding cost	.01	.01	.01	-	.04	.01	.08	-	.01	-	-
Net grinding cost	.01	.01	.01	-	-	.01	.04	-	.01	-	-
Whole grain density	.01	.01	-	-	-	-	-	.10	-	-	-
Ground grain density	.01	.01	.05	-	-	.01	-	-	.02	.10	-
Difference in density	.01	-	.03	-	-	.01	-	-	-	-	-

[a]Dash indicates P>.11.

Swine Day 1995

CONSUMER ACCEPTANCE OF LOW-DOSE IRRADIATED, BONELESS, PORK CHOPS

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Summary

Acceptance of irradiated, chilled, boneless, pork chops and nonirradiated controls by consumers was not different. Coupled with consumer concerns about food safety and well-documented improvement in consumer attitudes about irradiated foods, the potential for market acceptance is very promising.

(Key Words: Irradiation, Consumer Acceptance.)

Introduction

Recent events involving food borne infections in meat products have increased consumer awareness of possible food contamination with pathogens, especially *Escherichia coli* O157:H7. Of surveyed consumers, 43% were very concerned with food safety. Irradiation is one possible method to increase meat safety, especially when combined with good manufacturing practices. The World Health Organization stated that no toxicological hazard resulted from consuming food irradiated with up to 10 kilograys (kGy). Historically, consumers have rejected irradiation, but several studies indicate that consumer attitudes toward irradiation are changing. Even though the effects of irradiation on the survival of microorganisms in food have been well studied, little is known about the effects of low-dose irradiation on meat quality. Meat quality ultimately will determine consumer acceptance. The objective of this study was to determine consumer acceptance of chilled, vacuum-packaged, boneless, pork chops exposed to irradiation.

Procedures

Eight center-cut boneless chops from each of seven loins (NAMP #412B) per replication were cut 1.25 in thick. Four chops per loin were assigned randomly to each irradiation treatment (0 and 2.5 kGy). Individual loins and chops were tracked throughout the study. Only chops with NPPC color, firmness/wetness, and marbling scores of 2, 3, or 4; loin eyes of 4.5 to 6.5 in^2; and Minolta L* (lightness) values of 40 to 58 were used. Chops were vacuum-packaged. After packaging, chops were boxed and stored chilled at 37 ± 3°F. Boxed product was stored for about 60 h and shipped with arrival within 24 h at FOOD TECHnology Service, Inc. (Mulberry, FL). After product temperature was stabilized overnight to 37°F, chops were treated with either 0 or 2.5 kGy of radioactive Co^{60}. After irradiation, product was stored overnight, returned to Kansas State University, and stored at 37 ± 3°F for about 60 h.

Consumers (n=108) were chosen from a database of 500. Panelists included only those consumers that ate pork or beef at least three times per week. Twenty-eight chops for each treatment for each replicate were broiled to 165°F internally, as measured by thermocouples attached to a temperature recorder. To avoid animal differences, each panelist evaluated treatment samples from the same loin. Each chop was sliced into equal

[1]Cryovac North America, Mount Prospect, IL.
[2]National Live Stock and Meat Board, Chicago, IL.

portions and tested by four panelists. Overall acceptance, meatiness, freshness, tenderness, and juiciness were evaluated using a 9-point scale (1=dislike to 9=like extremely).

Results and Discussion

Approximately 84% of the panelists were between the ages of 26 and 55, and over 50% had at least some college experience. These consumer panelists found irradiated pork chops to be equal to non-irradiated controls for overall acceptance, meatiness, freshness, tenderness, or juiciness (Table 1). Especially impressive were the high scores for meatiness and freshness. These results were very encouraging, considering that threshold levels of 1.75 kGy for flavor changes in pork have been reported previously. With improving consumer attitudes toward irradiated, vacuum-packaged, boneless, pork chops, the potential for market acceptance is very promising.

Table 1. Mean Scores[a] and Standard Errors (SE) for Attributes of Irradiated, Boneless, Pork Chops Evaluated by Consumers[b]

	Dose, kGy		
Attribute[c]	0	2.5	SE
Overall acceptance	6.2	6.3	.2
Meatiness	7.3	7.4	.1
Freshness	6.7	6.8	.2
Tenderness	5.8	5.9	.2
Juiciness	5.5	5.7	.2

[a]9-point scale (1=dislike to 9=like extremely).
[b]n=108; 28 chops per treatment with 4 consumers per chop.
[c]No difference between nonirradiated and irradiated samples (P>0.05).

Swine Day 1995

FLAVOR AND AROMA OF LOW-DOSE IRRADIATED, BONELESS, PORK CHOPS

S. E. Luchsinger, D. H. Kropf, C. M. García Zepeda, E. Chambers IV, M. E. Hollingsworth, M. C. Hunt, J. L. Marsden, S. L. Stroda, E. J. Rubio Cañas, C. L. Kastner, W. G. Kuecker[1], and T. Mata[2]

Summary

Irradiation and irradiation source had little to no effect on flavor and aroma of boneless pork chops, either frozen or chilled. Coupled with consumer concerns about food safety and well-documented improvement in consumer attitudes about irradiated foods, irradiation of boneless pork chops has promising potential for market acceptance.

(Key Words: Irradiation, Flavor, Aroma.)

Introduction

Recent events involving food-borne infections in meat products have increased consumer awareness of possible food contamination with pathogens, especially *Escherichia coli* O157:H7. Of surveyed consumers, 43% were very concerned with food safety. Irradiation is one possible method to increase meat safety, especially when combined with good manufacturing practices. The World Health Organization stated that no toxicological hazard resulted from consuming food irradiated with up to 10 kilograys (kGy). Historically, consumers have rejected irradiation, but several studies indicate that consumer attitudes toward irradiation are changing. Even though the effects of irradiation on the survival of microorganisms in food have been well studied, little is known about the effects of low-dose irradiation on meat quality. Meat quality ultimately will determine consumer acceptance. The objective of this study was to determine the effects of irradiation on flavor and aroma of chilled and frozen boneless pork chops in two packaging systems.

Procedures

Nine center-cut boneless chops from each of 42 loins (NAMP #412B) per replication were cut 1.25 in thick. Loins were randomly assigned to temperature treatment and package type before cutting. Six chops per loin were assigned randomly to each of the six remaining treatments (irradiation). The remaining three chops per loin were assigned randomly to treatments to fulfill chop requirements. Individual loins and chops were tracked throughout the study. Only chops with NPPC color, firmness/wetness, and marbling scores of 2, 3, or 4; loin eyes of 4.5 to 6.5 in^2; and Minolta L* (lightness) values of 40 to 58 were used. Chops were either vacuum-packaged (VP) or packaged aerobically (AP). After packaging, chops were boxed and stored either frozen at 0 ± 3°F or chilled at 37 ± 3°F. Boxed products were stored for about 60 h and shipped with arrival within 24 h at either Iowa State University's Linear Accelerator Facility (electron beam, ISU, Ames, IA) or FOOD TECHnology Service, Inc. (Co^{60}, Mulberry, FL). After product temperature was stabilized overnight to either 0 or 37°F, chops were treated with either 0, 1.5, or 2.5 kGy (chilled) or 0, 2.5, or 3.85 kGy (frozen) of either nonradioactive electron beam (EB) or radioactive Co^{60}. After irradiation, products were stored overnight, returned to Kansas State University, and stored at either 0 ± 3 or 37 ± 3°F for

[1]Cryovac North America, Mount Prospect, IL.
[2]National Live Stock and Meat Board, Chicago, IL.

about 60 h. Prior to broiling, frozen chops were thawed at 34 ± 2°F overnight.

Five chops for each treatment for each replicate were broiled to 165°F internally, as measured by thermocouples attached to a temperature recorder. Eighteen texture/flavor attributes: animal hair-fat, animal hair-lean, bitter, bloody, browned/roasted, burnt, chemical-fat, chemical-lean, fat-like, juiciness, liver-like, pork identity, metallic, rancid-fat, rancid-lean, sour, sweet, and toughness were assessed by five professional flavor profile panelists using a structured 15-point scale (0 = none to 15 = very intense; 0.5 intervals). To avoid animal differences, each panelist evaluated treatment samples from the same loin. Each panelist received one chop per treatment. Pork identity aromas and off-odors were evaluated on raw and cooked chops by two professional aroma profile panelists using the 15-point scale. Off-odors also were evaluated during broiling.

Results and Discussion

Chilled Boneless Pork Chops. Dose level, irradiation source, and package type did not affect fat-like, juiciness, liver-like, metallic, and toughness flavor/textural attributes (Table 1). Animal hair-fat, animal hair-lean, burnt, chemical-fat, chemical-lean, liver-like, rancid-fat, and rancid-lean flavor intensities were inconsistent, but all treatment intensity levels were <1.6 on the sensory scale. Intensity levels of <1.6 would not be detected by most consumers of boneless pork chops.

Raw and cooked pork-aroma attributes were not influenced by dose level, package type, or irradiation source (Table 1). No off-odors were detected in the raw or cooked state or during broiling.

Bloody flavor increased as irradiation dose increased from 1.5 to 2.5 kGy. Electron beam (EB) VP chops had stronger sour notes than Co^{60} VP samples. Bitterness notes increased in AP samples as irradiation dose increased from 1.5 to 2.5 kGy and was greater in 2.5 kGy AP than in 2.5 kGy VP chops. Pork identity was less for EB VP 2.5 kGy than EB VP 1.5 kGy, EB AP 2.5 kGy and Co^{60} VP 2.5 kGy samples. Browned/roasted notes decreased in EB AP from control to 2.5 kGy samples, but Co^{60} AP and VP samples were not affected by dose. Co^{60} VP and EB AP controls had more browned/roasted notes than EB VP controls. Sweet notes were lower in Co^{60} AP 2.5 kGy than EB AP 2.5 kGy samples.

Frozen Boneless Pork Chops. Dose level, irradiation source, and package type did not affect bitterness, fat-like, pork identity, sour, and sweet flavor attributes (Table 2). Animal hair-fat, animal hair-lean, burnt, chemical-fat, chemical-lean, liver-like, and rancid-fat flavor intensities were inconsistent, but all treatment intensity levels were <1 on the sensory scale. Intensity levels of <1 would not be detected by most consumers of boneless pork chops. No rancid-lean flavor was detected.

Raw and cooked pork-aroma attributes were not influenced by dose level, package type, or irradiation source (Table 2). No off-odors were detected during broiling or in cooked chops, and raw off-odor was inconsistent.

Bloody flavor was greater in VP chops then in AP. Metallic notes were lower in controls than irradiated samples. Toughness increased from AP control to 3.85 kGy AP samples, but VP samples were not influenced by dose. Browned/roasted notes were lower in EB 3.85 kGy than either EB 2.5 kGy or Co^{60} 3.85 kGy samples, and EB VP was lower for browned/roasted than EB AP chops. Juiciness was lower for Co^{60} VP 2.5 kGy samples than for Co^{60} AP 2.5 kGy.

Although a number of flavor/texture notes were affected by low-dose irradiation, no undesirable flavor scores exceeded 1.9 on a 15-point scale as scored by the professional panelists. This level of response should not result in consumer detection or rejection.

Table 1. Flavor/Textural and Aroma* Attributes for Irradiated Chilled Boneless Pork Chops as Affected by Dose Level, Irradiation Source, and Package Type

	Dose, kGy				Irradiation source[c]			Package type[d]		
Attribute	0	1.5	2.5	SE	EB	Co^{60}	SE	AP	VP	SE
Flavor/Textural										
Bloody	1.6[b]	1.4[b]	1.9[a]	.3	1.7	1.5	.3	1.5	1.7	.3
Burnt**	.2	.1	.1	.1	.1	.1	.1	.1	.1	.1
Chemical-fat**	.5	.9	1.0	.2	.8	.8	.2	1.1	.5	.2
Fat-like	1.3	1.5	1.3	.3	1.3	1.4	.3	1.3	1.3	.3
Juiciness	7.3	6.9	7.1	.4	7.1	7.1	.4	7.0	7.2	.4
Liver-like**	.1	.2	.3	.1	.2	.2	.1	.2	.2	.1
Metallic	1.7	1.6	1.9	.4	1.7	1.8	.4	1.7	1.8	.4
Rancid-fat**	.2	.5	.5	.1	.4	.4	.1	.6	.2	.1
Rancid-lean**	.0	.1	.2	.1	.1	.1	.1	.2	.0	.1
Toughness	6.6	6.8	6.8	.4	6.7	6.8	.4	6.9	6.7	.4
Aroma										
Raw pork identity	1.4	2.2	2.0	.3	1.7	2.0	.3	1.6	2.1	.3
Cooked pork identity	12.2	11.8	11.5	.2	12.0	11.6	.1	11.8	11.9	.1
Raw off-odor	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Cooking off-odor	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Cooked off-odor	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

[ab]Mean values within the same row within a variable with different superscripts are different ($P<0.05$).
[c]EB = electron beam; Co^{60} = Cobalt[60].
[d]AP = aerobic packaged; VP = vacuum packaged.
*15 point scale: 0 = none to 15 = very intense.
**No superscripts for statistical differences are shown, because these attributes did not satisfy the assumption of continuous response, i.e., they were affected inconsistently.

Table 2. Flavor/Aroma* Attributes for Irradiated Frozen Boneless Pork Chops as Affected by Dose Level, Irradiation Source, and Package Type

	Dose, kGy				Irradiation source[c]			Package type[d]		
Attribute	0	2.5	3.85	SE	EB	Co^{60}	SE	AP	VP	SE
Flavor										
Animal hair-fat**	.2	.4	.4	.2	.3	.3	.1	.3	.3	.1
Animal hair-lean**	.1	.4	.5	.2	.5	.3	.2	.4	.3	.2
Bitterness	1.0	1.0	1.0	.2	1.0	1.0	.2	1.0	1.0	.2
Bloody	1.6	1.8	1.7	.3	1.7	1.7	.3	1.6[b]	1.8[a]	.3
Burnt**	.1	.0	.0	.03	.0	.1	.03	.1	.0	.03
Fat-like	1.2	1.2	1.1	.3	1.2	1.1	.3	1.2	1.2	.3
Metallic	1.6[b]	1.9[a]	1.9[a]	.4	1.8	1.8	.4	1.7	1.8	.4
Pork identity	11.9	11.7	11.8	.2	11.8	11.9	.2	11.8	11.8	.2
Rancid-lean	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Sour	1.7	1.8	1.8	.3	1.7	1.8	.3	1.8	1.8	.3
Sweet	1.2	1.2	1.2	.1	1.2	1.2	.1	1.2	1.2	.1
Aroma										
Raw pork identity	1.2	1.8	1.1	.3	1.6	1.1	.2	1.3	1.4	.2
Cooked pork identity	12.0	11.9	11.5	.1	11.9	11.7	.1	11.7	11.9	.1
Raw off-odor	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Cooking off-odor	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Cooked off-odor	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

[ab]Mean values within the same row within a variable with different superscripts are different ($P<0.05$).
[c]EB = electron beam; Co^{60} = Cobalt^{60}.
[d]AP = aerobic packaged; VP = vacuum packaged.
*15 point scale: 0 = none to 15 = very intense.
**No superscripts for statistical differences are shown, because these attributes did not satisfy the assumption of continuous response; i.e., they were affected inconsistently.

Swine Day 1995

DISPLAY LIFE AND RELATED TRAITS OF LOW-DOSE IRRADIATED, BONELESS, PORK CHOPS

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Summary

Irradiation and vacuum-packaging caused a more intense and stable red color in boneless pork chops. Irradiation up to 2.5 kGy increased cooked internal redness in chilled chops. Oxidative rancidity was greater in aerobic packaging than vacuum-packaging and in irradiated aerobic packaged chops than controls. Irradiation of vacuum-packaged boneless pork chops has promising potential for market acceptance.

(Key Words: Irradiation, Color, Oxidation.)

Introduction

Recent events involving food borne infections in meat products have increased consumer awareness of possible food contamination with pathogens, especially *Escherichia coli* O157:H7. Of surveyed consumers, 43% were very concerned with food safety. Irradiation is one possible method to increase meat safety, especially when combined with good manufacturing practices. The World Health Organization stated that no toxicological hazard resulted from consuming food irradiated with up to 10 kilograys (kGy). Historically, consumers have rejected irradiation, but several studies indicate that consumer attitudes toward irradiation are changing. Even though the effects of irradiation on the survival of microorganisms in food have been well studied, little is known about the effects of low-dose irradiation on meat quality. Meat quality ultimately will determine consumer acceptance. The objective of this study was to determine the effects of irradiation on color and display life of chilled and frozen boneless pork chops in two packaging systems.

Procedures

Nine center-cut boneless chops from each of 42 loins (NAMP #412B) per replication were cut 1.25 in thick. Loins were assigned randomly to temperature treatment and package type before cutting. Six chops per loin were randomly assigned to each of the six remaining treatments (irradiation). The remaining three chops per loin were assigned randomly to treatments to fulfill chop requirements. Individual loins and chops were tracked throughout the study. Only chops with NPPC color, firmness/wetness, and marbling scores of 2, 3, or 4; loin eyes of 4.5 to 6.5 in^2; and Minolta L* (lightness) values of 40 to 58 were used. Chops were either vacuum-packaged (VP) or packaged aerobically (AP). After packaging, chops were boxed and stored either frozen at 0 ± 3°F or chilled at 37 ± 3°F. Boxed products were stored for about 60 h and shipped with arrival within 24 h at either Iowa State University's Linear Accelerator Facility (electron beam, ISU, Ames, IA) or FOOD TECHnology Service, Inc. (Co^{60}, Mulberry, FL). After product temperature was stabilized overnight to either 0 or 37°F, chops were treated with either 0, 1.5, or 2.5 kGy (chilled) or 0, 2.5, or 3.85 kGy (frozen) of either nonradioactive electron beam (EB) or radioactive Co^{60}. After irradiation, products were stored overnight, returned to Kansas State University,

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and stored at either 0 ± 3 or 37 ± 3°F for about 60 h. Prior to broiling, frozen chops were thawed at 34 ± 2°F overnight.

Two chops for each treatment for each replicate were broiled to 165°C internally, as measured by thermocouples attached to a temperature recorder. Cooking loss percentage and cooked internal color traits were evaluated.

Remaining raw chops were displayed at either 0 ± 3 or 37 ± 3°F under 150 foot candles light intensity. After 0, 3, 7, 14, and 21 d display, duplicate chops were evaluated for total plate count (TPC) using standard procedures, a modified 2-thiobarbituric acid analysis (TBA) to assess oxidative rancidity, and instrumentally for color. Purge percentage was determined at day 0 only.

Results and Discussion

Chilled Boneless Pork Chops. Vacuum-packaged irradiated chops were redder (greater a*) than AP counterparts at 0, 3, 7, and 14 d (Figure 1). No redness difference was observed between packs for controls, except day 3 VP was higher than day 3 AP. Redness increased with greater irradiation dose at 3, 7, and 14 d for VP chops, but decreased from 0 to 1.5 kGy at 7 d and across all doses at 14 d for AP chops. No redness difference was observed across display days for all doses for VP chops. Yellowness (b*) increased with longer display for both package types. VP chops had more stable a*/b* (red/yellow) ratios across doses for all display days. By day 21, 2.5 kGy chops were becoming lighter and less red than on previous display days.

Cooking loss was not affected by dose, irradiation source, or package type. Purge was greater in VP than AP chops. Irradiation up to 2.5 kGy increased cooked internal redness (a*). Total plate counts (TPC) decreased from 0 to 2.5 kGy in both package types, but AP was greater than VP at all doses. Oxidative rancidity levels (TBA) did not differ between doses for VP for either irradiation source (Figure 2). However, TBA values increased from 0 to 1.5 kGy for electron beam (EB) AP and from 0 to 2.5 kGy for Co^{60} AP. TBA values for VP chops were stable across display days for both sources and all dose levels. AP chops had greater TBA values than VP at all display days for 1.5 and 2.5 kGy doses.

Frozen Boneless Pork Chops. No difference for redness (a* values) was observed between irradiation sources at all doses and display days for VP. VP chops were redder than AP for all doses and display days and both sources. By 21 d, irradiated chops were indicating a trend toward yellowness.

Purge was greater in VP chops than AP regardless of irradiation source. Irradiation did not affect cooked internal redness (a*). However, EB AP chops had greater internal redness (a* values) than EB VP and Co^{60} AP samples. Control samples had greater TPC than irradiated at 0, 7, and 14 d. TPC decreased from 0 to 7 d for 2.5 and 3.85 kGy chops. TBA values did not differ between doses for VP chops, but AP samples increased from 0 to 2.5 kGy (Figure 3). AP chops had greater TBA values than VP at 2.5 and 3.85 kGy. In addition, TBA increased from 0 to 14 d in AP, with no difference observed across display days for VP chops.

Figure 1. Comparison of Mean Values for Raw Redness (a* Values) across Days 0, 3, 7, and 14 for Package Type by Dose Level (SE = 0.6) in Chilled Boneless Pork Chops.

Figure 2. Comparison of Mean Values for Oxidative Rancidity Levels (TBA Values) across Dose Level for Irradiation Source by Package Type (SE = 0.1) in Chilled Boneless Pork Chops.

Figure 3. Comparison of Mean Values for Oxidative Rancidity Levels (TBA Values) across Dose Levels for Package Type (SE = 0.02) in Frozen Boneless Pork Chops.

Swine Day 1995

A COMPARISON OF RISK AND RETURN FOR CONTRACT AND INDEPENDENT HOG FINISHING

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Summary

Risks associated with independent hog finishing have prompted producers to seek alternative production and marketing methods. A means of reducing risk has developed through contract hog finishing. Research results indicate that risk-neutral producers require contract base payments ranging from $11.25 to $14.00 per head. Strongly risk-averse producers require contract base payments ranging from $4.75 to $7.75 per head. The lower ends of the ranges are for a contract with performance incentives. The upper ends of the ranges are for a flat contract without performance incentives. Calculated required base payments are similar to those payments currently received by contract hog finishers.

(Key Words: Risk Management, Contract Hog Production.)

Introduction

Growth in contract hog production has been documented through surveys initiated by James Rhodes and Glen Grimes at the University of Missouri. Survey results for 1992 indicated that contract hog producers marketed 14 to 16 million head of hogs. This number is an increase from a 1986 survey estimating contract marketings at 9.5 million head of hogs. The 1992 survey indicated that 79% of all contract hog operations existed in the North Central region of the U.S. A 1993 survey indicated an increase in contract hog producers of 27.8% over 1992 survey findings. Of the 10,995 producers entering contract hog production for 1993, 7,337 of these producers were finishing contractors. Producers responding to the 1993 survey marketed over 50,000 head of hogs annually and anticipated a growth rate of 30% between 1993 and 1994. Furthermore, large producers anticipated doubling 1993 marketings by 1996.

Farms marketing less than 1,000 hogs annually have dropped from an estimated 670,000 in 1970 to the most recent estimate of 213,000 farms in 1993, whereas the amount of pork produced has actually increased in recent years. This trend is due to economies of size for larger herds. USDA estimates show that average hog production costs decline from $60/cwt for inventories of 140 head to $43/cwt for inventories of 10,000 head. Increasing herd size to capture economies of size requires a large capital outlay. As herd size increases, management needs also increase. Hog production contracts are potential means of alleviating management constraints and capital constraints.

Several advantages and disadvantages exist for contract hog production. Publications by James Rhodes indicate advantages, including access to new technology, access to market information, increased specialization, equal or superior access to all inputs including capital, and the production of volume and quality of hogs that attract packer premiums rather than discounts. Disadvantages to producers from contract finishing include reduction in management flexibility, contract risk, limited returns, and commingling of pigs. Contract risk involves costs associated

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with the contract not being renewed by the contractee and litigation costs from a failed contract.

Realization of low hog prices in 1994 may have temporarily slowed contract hog expansion. However, hog prices during 1995 have again offered profits for producers. Scheduled openings of packing plants by IBP in Indiana and Seaboard in Oklahoma will create an additional 15,000 head/daily of killing capacity and potentially push hog prices higher. Increased expansion in contract hog production will soon follow as investors recognize the potential for high returns on investment historically realized for hog production. With the increasing supply of contracts available, hog finishers need be aware of the relationship between independent and contract costs and profits. The objective of this study was to determine the level of contract payments for which producers would switch from independent to contract hog finishing.

Procedures

Three individual hog-finishing contracts and independent hog production were evaluated to determine the level of contract payments for which producers would switch from independent to contract hog finishing. Contract **A** offers finishers a relatively low base payment and high performance premiums (Table 1). Contract **B** offers finishers a relatively high base payment and low performance premiums (Table 2). Contract **C** offers finishers a flat per/pig rate with no performance premiums. Performance payment schedules were determined using F/G and death loss values from Iowa State Swine Enterprise Reports. Average performance payments for contract **A** were $2.80/pig for F/G and ($0.10)/pig for death loss efficiency, and average performance payments for contract **B** were $0.33/pig for F/G and $0.05/pig for death loss.

Using data obtained through the Kansas State University Farm Management Data Base, yearly returns over variable costs to independent hog finishing were computed for the period 1986 to 1994. Data were used to estimate costs for independent and contract production. Variable costs ($5.98/pig) incurred by contract producers included: labor, repairs-tools-supplies, gas-fuel-oil, personal property tax, general farm insurance, utilities, and interest paid. Independent producers incurred variable costs ($59.72/pig) of: labor, repairs-tools-supplies, feed purchased, farm organization fees, veterinary-medicine, livestock marketing and breeding fees, gas-fuel-oil, personal property tax, general farm insurance, utilities, auto expense, and interest paid.

This study used calculated returns over variable costs to hog finishing and stochastic dominance to compare contract and independent hog finishing for risk-neutral (profit maximizer), slightly risk-averse, and strongly risk-averse producers. Stochastic dominance is a technical procedure used to evaluate potential alternative production strategies.

Although the risk level (i.e., risk neutral, slightly risk averse, and strongly risk averse) of the producer may be ambiguous, most producers would be risk neutral to slightly risk averse. A risk-averse producer would prefer a low level of variability in annual returns or a low probability of negative returns. Average returns for independent hog finishing are substantially higher than those for contract finishing. However, independent hog returns are considerably more variable, and negative returns occur periodically. Thus, risk-averse producers or those wanting to better manage cash flows may prefer contract production.

Results and Discussion

Table 3 provides a summary of base payments for which hog finishers would switch from independent to contract finishing for alternative risk levels. Note, for contract **A** and contract **B**, performance premiums were not included in base payments. A producer who is not particularly concerned about risk would require a base payment of $11.25/pig for contract **A** and $14.00/pig for contract **C**. A producer who is extremely concerned about the variability of returns (i.e., a risk-averse producer) would require a

base payment of $4.75/pig for contract **A** and $7.75/pig for contract **C**.

Adding average premium payments to base payments for contracts **A** and **B** in Table 3 yields a relative means of comparing all contracts. Upon making these calculations, payment levels for each alternative contract were approximately equal for the risk-neutral and slightly risk-averse producer. This indicates that the contracts chosen for this study have been derived by the contractee to mirror each other based on historical performance of finishers. Payment levels for contract **C**, per pig payment, are representative of the levels currently received by finishers.

Performance- and cost-adjusted required payment levels for contracts **A** and **B** begin to noticeably differ from those of contract **C** for the strongly risk-averse producer. This is indicative of the variability observed for contracts offering performance payments relative to a flat per pig payment.

Summary statistics of returns over variable costs for a risk-averse finisher evaluating contract and independent hog finishing are listed in Table 4. Independent hog finishing realized considerably higher returns over variable costs ($11.27/pig) than did contract hog finishing ($5.49/pig for **A**, $5.08/pig for **B,** and $5.44/pig for **C**). A measure of variability between returns over variable costs for alternative finishing methods is the coefficient of variation. The coefficient of variation for contract finishing ranged from 0.079 to 0.107, whereas that for independent finishing was 1.178. That is, independent-finishing returns over variable costs yielded 11 times more variability in returns/pig than did contract-finishing returns over variable costs.

Producers seeking to continue hog finishing need to realize the risks associated with independent and contract finishing. Although contract finishing offers less variability in returns, a particular contract must be chosen to fit an individual finisher's management skills.

Table 1. Bonus Payment Schedule for Contract A

F/G (lbs feed/lbs gain)	Dollars per head sold	Death loss (percent)	Dollars per head sold
2.80-2.89	5.10	0.00-0.00	2.10
2.90-2.99	4.80	0.01-0.50	1.80
3.00-3.09	4.50	0.51-0.99	1.50
3.10-3.19	4.20	1.00-1.50	1.20
3.20-3.29	3.90	1.51-1.99	0.90
3.30-3.39	3.60	2.00-2.50	0.60
3.40-3.49	3.30	2.51-3.00	0.30
3.50-3.59	3.00	3.01-3.99	0.00
3.60-3.69	2.70	4.00 or above	split death loss
3.70-3.79	2.40		
3.80-3.89	2.10		
3.90-3.99	1.80		
4.00-4.09	1.50		
4.10-4.19	1.20		
4.20-4.29	0.90		
4.30-4.39	0.60		
4.40-4.49	0.30		
4.50 or above	0.00		

Table 2. Bonus Payment Schedule for Contract B

F/G (lbs feed/lbs gain)	Dollars per head sold	Death loss (percent)	Dollars per head sold
0.00-2.29	7.00	0.00-0.99	1.50
2.30-2.39	6.50	1.00-1.99	1.00
2.40-2.49	6.00	2.00-2.99	0.50
2.50-2.59	5.50	3.00 or above	0.00
2.60-2.69	5.00		
2.70-2.79	4.50		
2.80-2.89	4.00		
2.90-2.99	3.50		
3.00-3.09	3.00		
3.10-3.19	2.50		
3.20-3.29	2.00		
3.30-3.39	1.50		
3.40-3.49	1.00		
3.50-3.59	0.50		
3.60 or above	0.00		

Table 3. Contract Base Payments ($/Pig/Year) Levels for Which Hog Finishers Will Switch from Independent to Contract Finishing

	Risk level		
Contract	Risk neutral[a]	Slightly risk averse[a]	Strongly risk averse[a]
Contract **A**	$11.25	$8.00	$4.75
Contract **B**	$13.50	$10.50	$7.25
Contract **C**	$14.00	$10.75	$7.75

[a]If the base payment is higher than the level indicated, a producer would prefer contract production over independent production. If the base payment is lower than the level indicated, a producer would prefer independent production over contract production.

Table 4. Summary Statistics of Returns over Variable Costs for a Slightly Risk-Averse Hog Finisher, $/Pig/Year

Contract	Average	Minimum	Maximum	CV[a]
Contract **A**	$5.49	$4.51	$6.69	0.107
Contract **B**	$5.68	$5.05	$6.89	0.093
Contract **C**	$5.54	$4.56	$6.14	0.079
Independent	$11.27	($13.62)	$28.27	1.178

[a]CV represents the coefficient of variation, which is defined to be standard deviation divided by the mean.

Swine Day 1995

ESTIMATED BUDGETS FOR SEPARATE-SITE SWINE PRODUCTION

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Summary

Budgets were developed to help Kansas swine producers analyze the economics of separate-site production. Return on investment (ROI) was estimated at 9.5% in each of the three production phases. Returns over total costs were very sensitive to transfer price between phases (weaned pig and feeder pig price) as well as production efficiencies and input costs.

(Key Words: Economics, Budgets, Separate-Site Production.)

Introduction

The modern practice of dividing traditional farrow-to-finish hog production into three distinct phases is revolutionizing the swine industry. The age separation practice, known as segregated early weaning (SEW), produces healthier, more efficient pigs and helps to maximize the genetic potential of today's breeding stock. The most popular modern production system is a three-site, all-in, all-out system consisting of a breeding-gestation-farrowing site, a nursery site, and a growing-finishing site. The ability to take advantage of this technology may help Kansas hog producers remain competitive in the industry.

Because this technology is relatively new in Kansas, budgets reflecting this technology need to be estimated or projected so interested producers can make informed decisions concerning future production. Although it is important for producers to develop budgets based on their own production level and costs, relevant records often will not be available to adequately evaluate a new or different technology. The following three budgets were estimated to help producers evaluate the economic potential of separate site swine production utilizing new technology in Kansas. The following is a brief discussion of the budgets. For a more detailed listing of assumptions used in the budgets, a copy of the complete budget can be requested from your county Extension office.

Procedures

Economic Costs vs. Cash-Flow Costs. Cash-flow costs can, and often are, significantly different than economic costs. Cash-flow costs are those costs that require an out-of-pocket payment. Economic costs, as defined here, are all costs that need to be paid in the long run and include labor, depreciation, and interest on investment. The following budgets are based on economic costs so they should give an indication of long-run profit potential.

Price and Cost Assumptions. Relevant prices and costs should be used for developing budgets. Historical averages (5 year) are used here for finished pig price and feed costs. Other variable costs are based on historical records and projections made by the authors.

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Historically, if pigs were not finished, they were marketed as 40- to 50-lb feeder pigs and a market price on which to base projections was available. However, a reliable market for early-weaned (10 lb) pigs does not currently exist. Also, the value of a feeder pig coming out of the nursery from an SEW program may not be comparable to the value of a traditional feeder pig going through an auction because of better quality and health. Therefore, values for both the weaned pig and feeder pig need to be estimated. These values are estimated by allocating the income received from the finished pig back to the individual phases by percent of total costs occurring in each phase. Prices also are estimated by examining what prices would result in all three phases earning a comparable return on investment at average production with a given finished-pig price. It is important to note that production levels will change cost per pig significantly. Thus, the estimated values for weaned pigs and feeder pigs using this methodology are very dependent on production levels.

Production Level. Costs per unit and net returns in swine production are highly dependent on production levels. The following estimated budgets include three different production levels. Production levels vary for a number of reasons, such as livestock quality/genetics, weather, input levels, and management. Budgeting at multiple production levels can help producers examine the financial risk of a livestock enterprise that is related directly to production risk.

Production levels for farrowing operations are assumed to vary with differences in the number of pigs sold per litter and the number of litters per sow per year. Varying these two factors results in different numbers of pigs sold per sow per year. Thus, returns are very sensitive to number of weaned pigs marketed per sow per year. This is because many costs will decrease on a per-pig basis as production increases. Production levels for nursery and finishing operations are assumed to vary with differences in the feed efficiency. Varying this production factor, which has a major impact on profitability, allows an analysis of alternative projected economic results.

Capital Investment. The capital invested in farrowing, nursery, and finishing facilities varies greatly and is dependent upon the size and type of facilities constructed. The success of the SEW concept is dependent upon high quality facilities that require large capital investments. Investment costs here are based on current costs projections and depreciated over 10 years. Salvage values are estimated at 20% for buildings and 0% for equipment at the end of 10 years. A central farrowing house with liquid manure facilities and slotted floors is estimated at $1,980 per sow (66 sq. ft. per sow), with the equipment inside the building costing an additional $800 per sow. The gestation building is estimated to cost $360 per sow (20 sq. ft. per sow), and the equipment inside the building is estimated to cost an additional $150 per sow. A nursery building with liquid manure handling facilities and narrow slotted floors is estimated to cost $102 per pig (3.5 sq. ft. per pig), with the equipment inside the building costing an additional $8 per pig. A finishing building with liquid manure handling facilities and a totally slatted floor is estimated to cost $144 per pig (8 sq. ft. per pig), with the equipment inside the building costing an additional $20 per pig. Office facilities, site preparation, and miscellaneous items also are included in the capital requirements for all budgets. The capital requirements are assumed to be the same for all production levels. Thus, fixed costs per pig are functions of throughput, which varies in the farrow-to-wean budget, but is held constant in the nursery and finishing budgets.

Results and Discussion

Using the average production level, net return on investment (ROI) is approximately 9.5% for each of the three phases. Approximately 30% of the total cost of producing a finished pig occurs in the farrow-to-wean phase. Based on this and equating ROI between phases, a weaned pig price of $33.50 and feeder pig price of $51.75 are

incorporated into the budgets. The break-even price for weaned pigs is approximately $32 per head at average production. However, increasing pigs weaned per sow per year from 19 to 22 decreases the break-even price to less than $28 per head. In the farrow-to-wean budget, many costs are relatively fixed once production begins (do not vary as productivity per sow varies). Therefore, productivity level represents the biggest risk and has the biggest impact on weaned pig break-even price per head and profitability.

In many cases, the nursery and finishing phases are aggregated, because the same person is doing both. However, they are separated from a budgeting standpoint here, because they represent two separate production phases. The nursery phase has more input price risk than does the farrowing phase, but production efficiency and health are still major risk concerns. Using a purchase (transfer in) price of $33.50 for a 10-lb pig requires a selling (transfer out) price of $51.75 per head for the 60-lb feeder pig to achieve a similar ROI as the other phases.

The finishing phase has a larger percent of total costs that vary directly with the level of production. Therefore, the finishing phase has more input price risk than either the nursery or farrowing phases. Production efficiency and health are still major concerns, but managing input costs, specifically feed, in the finishing budget will have a big impact on profitability. Using a purchase (transfer in) price of $51.75 for a 60-lb feeder pig and the 5-year average of $45.75/cwt for the finished pig results in an ROI of 9.5%.

Table 1. Farrow-to-Weaned Pig Cost-Return Projections

	Marketable pigs weaned/sow/year			Your farm
Item	16.0	19.0	22.0	
Variable Cost per Pig Sold:				
1. Grain	$4.13	$3.51	$3.07	
2. Protein	2.30	1.97	1.73	
3. Base mix: vitamins, minerals, etc.	1.14	0.97	0.85	
4. Pig starter	0.00	0.00	0.00	
5. Feed processing	0.57	0.49	0.43	
6. Labor	7.29	6.14	5.30	
7. Veterinary, drugs, and supplies	1.10	1.00	0.90	
8. Utilities, fuel, and oil	1.65	1.50	1.35	
9. Transportation and marketing costs	0.55	0.50	0.45	
10. Building and equipment repairs	1.29	1.09	0.94	
11. Breeding/genetic charge (sum of lines a to d)	6.15	5.29	4.66	
a. Depreciation	(2.90)	(2.44)	(2.11)	
b. Semen	(2.00)	(1.79)	(1.64)	
c. Interest	(1.14)	(0.96)	(0.83)	
d. Insurance	(0.11)	(0.10)	(0.08)	
12. Profession fees (legal, accounting, etc.)	0.55	0.50	0.45	
13. Interest on 1/2 variable costs	0.65	0.53	0.44	
A. Total Variable Costs	$27.38	$23.48	$20.56	
Fixed Costs per Pig Sold:				
14. Depreciation on buildings and equipment	5.54	4.66	4.03	
15. Interest on buildings and equipment	3.70	3.12	2.69	
16. Insurance and taxes on buildings and equipment	0.63	0.53	0.46	
B. Total Fixed Costs	$9.87	$8.31	$7.18	
C. Total Costs per Pigs Sold	$37.25	$31.80	$27.74	
Returns per Pig Sold				
17. Weaned pig	$33.50	$33.50	$33.50	
D. Gross Returns per Pig Sold	$33.50	$33.50	$33.50	
E. Returns over Variable Costs (D – A)	$6.12	$10.02	$12.94	
F. Returns over Total Costs (D – C)	($3.75)	$1.70	$5.76	
G. Weaned Pig Break-Even Price, $/head				
18. To cover variable costs	$27.38	$23.48	$20.56	
19. To cover total costs	$37.25	$31.80	$27.74	
H. Total Feed Costs (lines 1 to 5)	$8.14	$6.94	$6.07	
20. Cwt pork produced	0.10	0.10	0.10	
21. Feed cost/cwt	$81.41	$69.41	$60.70	
I. Asset Turnover (D/Investment) /1	42.41%	50.36%	58.31%	
J. Net Return on Investment [(F + 11c +13 + 15)/Investment] /1	2.20%	9.48%	16.92%	

/1 Investment equals total value of breeding herd and buildings and equipment.

Table 2. Feeder Pig Nursery Cost-Return Projections

	Feed efficiency (feed/gain, lb)			Your farm
Item	2.00	1.80	1.60	_____
Variable Cost per Pig Sold:				
1. Grain	$2.29	$2.06	$1.83	_____
2. Protein	2.88	2.59	2.30	_____
3. Base mix: vitamins, minerals, etc.	1.84	1.66	1.47	_____
4. Pig starter	2.12	1.91	1.70	_____
5. Feed processing	0.45	0.41	0.36	_____
6. Labor	0.92	9.92	9.92	_____
7. Veterinary, drugs, and supplies	0.50	0.50	0.50	_____
8. Utilities, fuel, and oil	0.25	0.25	0.25	_____
9. Transportation and marketing costs	0.50	0.50	0.50	_____
10. Building and equipment repairs	0.39	0.39	0.39	_____
11. Profession fees (legal, accounting, etc.)	0.25	0.25	0.25	_____
12. Interest on 1/2 variable costs and weaned pig	0.61	0.60	0.59	_____
A. Total Variable Costs	$12.99	$12.03	$11.06	_____
Fixed Costs per Pig Sold:				
13. Depreciation on buildings and equipment	1.57	1.57	1.57	_____
14. Interest on buildings and equipment	1.15	1.15	1.15	_____
15. Insurance and taxes on buildings and equipment	0.23	0.23	0.23	_____
B. Total Fixed Costs	$2.94	$2.94	$2.94	_____
C. Total Costs per Pigs Sold	$15.94	$14.97	$14.01	_____
Returns per Pig Sold				
16. Feeder pig	$51.75	$51.75	$51.75	_____
17. Less cost of weaned pig	33.50	33.50	33.50	_____
18. Less death loss	1.55	1.55	1.55	_____
D. Gross Returns per Pig Sold	$16.70	$16.70	$16.70	_____
E. Returns over Variable Costs (D – A)	$3.70	$4.67	$5.63	_____
F. Returns over Total Costs (D – C)	$0.76	$1.73	$2.69	_____
G. Feeder Pig Break-Even Price, $/head				
19. To cover variable costs	$48.05	$47.08	$46.12	_____
20. To cover total costs	$50.99	$50.02	$49.06	_____
H. Total Feed Costs (lines 1 to 5)	$9.58	$8.62	$7.66	_____
21. Cwt pork produced	0.48	0.48	0.48	_____
22. Feed cost/cwt pork	$19.88	$17.89	$15.90	_____
I. Asset Turnover (D/Investment) /1	45.00%	45.00%	45.00%	_____
J. Net Return on Investment [(F + 12 +14)/Investment] /1	6.77%	9.35%	11.93%	_____

/1 Investment equals total value of breeding herd and buildings and equipment.

Table 3. Finishing Barn Cost-Return Projections

	Feed efficiency (feed/gain, lb)			Your farm
Item	3.30	3.10	2.90	_____
Variable Cost per Pig Sold:				
1. Grain	$20.19	$18.96	$17.74	_____
2. Protein	10.98	10.31	9.65	_____
3. Base mix: vitamins, minerals, etc.	4.10	3.85	3.60	_____
4. Pig starter	0.00	0.00	0.00	_____
5. Feed processing	2.75	2.58	2.41	_____
6. Labor	1.96	1.96	1.96	_____
7. Veterinary, drugs, and supplies	0.80	0.80	0.80	_____
8. Utilities, fuel, and oil	0.25	0.25	0.25	_____
9. Transportation and marketing costs	2.00	2.00	2.00	_____
10. Building and equipment repairs	0.82	0.82	0.82	_____
11. Profession fees (legal, accounting, etc.)	0.50	0.50	0.50	_____
12. Interest on 1/2 variable costs and feeder pig	2.40	2.36	2.32	_____
A. Total Variable Costs	$46.74	$44.40	$42.05	_____
Fixed Costs per Pig Sold:				
13. Depreciation on buildings and equipment	4.87	4.87	4.87	_____
14. Interest on buildings and equipment	3.49	3.49	3.49	_____
15. Insurance and taxes on buildings and equipment	0.67	0.67	0.67	_____
B. Total Fixed Costs	$9.03	$9.03	$9.03	_____
C. Total Costs per Pigs Sold	$55.77	$53.42	$51.08	_____
Returns per Pig Sold				
16. Finished pig	$112.09	$112.09	$112.09	_____
17. Less cost of feeder pig	51.75	51.75	51.75	_____
18. Less death loss	2.24	2.24	2.24	_____
D. Gross Returns per Pig Sold	$58.10	$58.10	$58.10	_____
E. Returns over Variable Costs (D – A)	$11.36	$13.70	$16.04	_____
F. Returns over Total Costs (D – C)	$2.33	$4.67	$7.01	_____
G. Feeder Pig Break-Even Price, $/head				
19. To cover variable costs	$41.11	$40.16	$39.20	_____
20. To cover total costs	$44.80	$43.84	$42.89	_____
H. Total Feed Costs (lines 1 to 5)	$38.01	$35.71	$33.41	_____
21. Cwt pork produced	1.80	1.80	1.80	_____
22. Feed cost/cwt pork	$21.11	$19.83	$18.55	_____
I. Asset Turnover (D/Investment) /1	52.36%	52.36%	52.36%	_____
J. Net Return on Investment [(F + 12 +14)/Investment] /1	7.40%	9.48%	11.55%	_____

/1 Investment equals total value of breeding herd and buildings and equipment.

Swine Day 1995

SUMMARY OF KANSAS STATE UNIVERSITY SWINE ENTERPRISE RECORD [1]

R. D. Goodband, B. T. Richert, M. L. Langemeier [2], M. D. Tokach [3], and J. L. Nelssen

Summary

The Kansas Swine Enterprise Record Program evaluates biological and economic performance and is part of a cooperative record-keeping project with extension personnel and swine producers in Kansas, Nebraska, and South Dakota. From July 1, 1994 to June 31, 1995, profit per cwt of pork produced for these producers (37 semi-annual and 20 annual data) averaged $4.75 for the first 6 months of 1995, but a loss of $1.22 occurred for the past year. Producers in the top one-third in terms of profitability had average profits of $3.44 per cwt, whereas producers in the bottom one-third had average losses of $7.07 per cwt for the year. Critical factors separating low- and high-profit producers included feed costs, unpaid labor, fixed costs, and death loss.

(Key Words: Enterprise, Records, Analysis, Profitability.)

Introduction

Production and financial records have become essential management tools of many swine producers. Production records measure the productivity of an operation. Financial records measure economic performance. An accurate set of records allows producers to compare their efficiency levels with those of other producers and to track performance over time. Records are particularly useful when making capital purchases of buildings and equipment and in evaluating a change in an operation (e.g., will buying higher quality breeding stock pay for itself).

Kansas State University joined the University of Nebraska and South Dakota State University in a cooperative record-keeping program in January of 1991. This program compiles individual producer records on production and financial factors into state and regional summaries. Enterprise summaries are provided for farrow-to-finish, feeder pig producing, feeder pig finishing, combination (less than 70% of pigs sold as either market hogs or feeder pigs), and seedstock operations. Many of the items are recorded on the basis of per cwt of pork produced. Recording costs on a per cwt basis facilitates comparisons between producers of various sizes.

Regional Group Summary

Individual producers collect data on hog inventories, hog sales, hog purchases, feed inventories, feed purchases, operating expenses, labor, fixed expenses, and herd performance. These individual producer data were used by extension personnel to compile the 1994-95 regional (KS, NE, and SD) group summaries for farrow-to-finish operations reported in Table 1. Records of 37 producers are summarized for the first 6 months of 1995, and records of 20 producers are summarized for the 12-month period June 1994 to July 1995. Profit per cwt of pork

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produced on an economic life depreciation basis (Line 20) is used to separate producers into top and bottom one-third profit groups. Thus, all other items represent the means for that particular profit group. The information in Table 1 allows producers to compare the performance of their operation to that of other producers in the program.

Profit per cwt of pork produced averaged above breakeven ($4.75 per cwt) over the first 6 months of 1995. However, profits varied substantially between producers. For the first 6 months of 1995, producers in the top one-third in terms of profitability had average profits per cwt of $11.32. Producers in the bottom one-third had average losses of $2.07 per cwt. Profit differences remained similar between these two groups for the year (+$3.44 vs -$7.07), but the average profit margin was lower for the whole year because of low prices during late fall 1994.

Notice that returns over cash costs (Line 2) were positive for all three profit groups for the last 6 months and the whole year with the exception of the low 1/3 profit group. Typically, most producers can cover cash costs, even when prices are relatively low. However, producers in the bottom one-third profit group were not able to cover unpaid labor and fixed costs for the entire year; thus, their return to management was negative (line 3) for the year. Although market conditions have improved dramatically since the fall of 1994, these producers will need to cover unpaid labor and fixed costs to stay in business in the long-run. The need to develop some management options that will improve their profitability in the future is indicated.

Line 4 presents the annual rate of return on capital invested in the swine operation. This rate should be compared to the rates that can be earned on other investments (e.g., banks, stocks). The return on capital for producers in the high one-third profit group was substantially more than the average return on capital for all 20 producers for the entire year. Note that the return on capital for producers in the bottom one-third profitability group was negative (-12.42) for the entire year.

Variable costs per cwt (Line 10) can be broken down into four categories: feed costs (Line 5), other operating expenses (Line 6), interest costs on operating capital (Line 9), and unpaid labor and management (Line 38). Total costs per cwt include these variable costs, plus interest charges on investments in buildings and equipment (Line 12) and economic life depreciation, taxes, and insurance costs (Line 13). Producers in the top one-third profit group had lower costs for each of the variable (32.93) and total (36.37) cost categories compared to the average producers' variable (35.52) and total (39.69) costs per cwt of pork produced. A $8.13 per cwt difference in total costs existed between producers in the top and bottom one-third profit groups for the past year.

Feed costs per cwt accounted for $3.05 or 37.5% of the difference in total costs for the two profit groups. The top one-third producers were able to purchase their feed for $.49/cwt less (line 52) for the year. A 6.5% improvement in feed efficiency occurred between producers in the top vs bottom one-third profit groups for the whole year.

Other operating expenses include utilities, hired labor, supplies, repairs, veterinarian costs, and professional dues. Other operating expenses and interest costs on capital accounted for 24.6% and 10.48% of the difference in total costs between producers in the high- and low-profit groups, respectively.

More efficient use of available labor can be a key difference in producer profitability. Unpaid labor and management were $1.35 per cwt higher for producers in the low-profit group than for producers in the high-profit group for the past year. This difference in unpaid labor and management accounted for 16.6% of the difference in total costs per cwt between the two groups.

Differences in fixed costs per cwt accounted for the remaining 16.7% of the difference in total costs between producers in the high- and low-profit groups for the year.

Producers in the top one-third group had more litters per sow per year (line 25) com-

pared with those in the bottom one-third, 2.10 vs 1.80, respectively. Producers in the top one-third group weaned more pigs per litter (line 28), and, therefore, produced more pigs per crate (line 30). Producers in the top one third had lower preweaning, finishing, and sow death losses (lines 32, 33, and 34). Producers in the bottom one-third group had relatively more capital invested in facilities per cwt of pork produced (22.57 vs 14.10). This indicates that lower-profit producers may have newer facilities or may need to improve their throughput with the facilities to spread the fixed costs out over more pigs produced.

Finally, swine enterprise records serve as a useful management tool for individual producers to monitor their individual herd's production and economic performance over the previous 6 months and for the year. As swine production becomes more competitive, the identification of good or problem areas of an operation becomes increasingly essential for producers to maintain profitability. By comparing an individual's records to the group summary, key economic criteria can be identified and management strategies implemented to improve profitability. The KSU Swine Enterprise Record program is an integral part of the swine extension service offered by Kansas State University.

Table 1. Regional Group Summary Averages for Farrow-to-Finish Operations (KS, NE, and SD)

	Farrow-to-finish operations					
	Semi-annual data (38 farms)			Annual data (22 farms)		
Item	Average	High 1/3	Low 1/3	Average	High 1/3	Low 1/3
1. Net pork produced, lbs.	230,949	221,236	259,789	528,779	632,195	553,564
2. Income over feed, oper. exp., oper. int., & hired labor	29,003	37,550	19,694	28,974	57,879	(1,914)
3. Profit or return to management, ELD	11,476	24,474	(263)	(5,325)	24,961	(40,701)
4. Annual rate of return on capital, ELD	20.26	42.52	.51	3.49	17.33	-12.42
Variable expenses:						
5. Total feed expense/cwt pork produced	24.27	23.12	25.47	24.05	23.00	26.05
6. Other oper. expenses (total)/cwt pork produced	5.87	4.72	7.84	6.08	5.50	7.51
a. Utilities; fuel, electricity, phone/cwt pork produced	1.11	1.10	1.21	1.25	.90	1.76
b. Vet. expenses and medications/cwt pork produced	.98	.74	1.01	.86	.96	.85
c. Remainder of other oper. expenses/cwt pork produced	3.78	2.88	5.62	3.97	3.65	4.89
7. Total cost of labor/cwt of pork produce	4.59	4.36	4.56	4.80	4.04	5.67
8. Total oper. capital inv./cwt of pork produced	18.53	17.24	20.03	17.37	16.41	19.46
9. Int. cost on oper. invest./cwt of pork produced	2.22	2.07	2.40	2.08	1.97	2.34
10. Total variable cost/cwt of pork produced	35.76	33.24	38.46	35.52	32.93	39.70
Fixed and total costs:						
11. Total fixed cap. inv. (ELD)/cwt of pork produced	23.97	14.20	28.74	18.40	14.10	22.57
12. Int. chg. on fixed inv. (ELD)/cwt of pork produced	2.40	1.42	2.87	1.84	1.41	2.26
13. E.L. deprec., taxes and ins. cost/cwt of pork produced	2.84	1.97	2.87	2.33	2.03	2.55
14. Tax deprec., taxes and ins. cost/cwt of pork produced	2.49	1.40	2.92	1.71	1.57	1.63
15. Fixed cost (ELD)/female/period	93.16	66.41	102.59	168.69	153.37	173.95
16. Fixed cost (ELD)/crate/period	409.28	290.43	486.80	775.23	602.20	826.18
17. Total cost (ELD)/cwt of pork produced	40.99	36.63	44.20	39.69	36.37	44.50
18. Total cost (ELD)/female/period	771.84	686.28	777.01	1590.77	1607.22	1547.10
19. Total cost (ELD)/crate/period	3324.38	3047.17	3642.25	6919.59	6320.76	6991.13
Income and profit						
20. Profit based on econ. life deprec./cwt of pork produced	4.75	11.32	-2.07	-1.22	3.44	-7.07
21. Profit based on tax deprec./cwt of pork produced	5.92	12.49	-1.38	.08	4.42	-5.25
22. Profit based on econ. life deprec./female/period	97.23	213.44	-32.43	-30.87	147.84	-243.48
23. Profit based on econ. life deprec./crate/period	404.76	938.42	-126.63	-191.36	606.94	-1179.64

Semi-annual date January 1, 1995 - June 30, 1995 & annual date July 1, 1994 - June 30, 1995.
Profit and fixed and total costs are based on econ. life deprec. (ELD) unless stated otherwise.

Table 1. Regional Group Summary Averages for Farrow-to-Finish Operations (KS, NE, and SD) (cont'd)

Item	Semi-annual data (38 farms) Average	High 1/3	Low 1/3	Annual data (22 farms) Average	High 1/3	Low 1/3
Production summary:						
24. Average female inventory	124	114.50	144.79	134	151.14	157.46
25. Number of litters weaned/female/period	1.00	1.03	.94	1.98	2.10	1.84
26. Number of litters weaned/crate/period	4.41	4.66	4.55	8.69	8.78	8.24
27. Number of live pigs born/litter farrowed	10.52	10.47	10.22	10.50	10.42	10.44
28. Number of pigs weaned/litter farrowed	8.78	8.92	8.16	8.81	8.92	8.51
29. Number of pigs weaned/female/period	8.96	9.17	8.15	17.60	18.60	16.08
30. Number of pigs weaned/crate/period	39.22	40.67	39.60	76.61	75.84	71.13
31. Number of pigs sold/litter/period	7.63	6.85	7.19	7.83	7.51	7.46
Death loss:						
32. Birth to weaning (% of no. born)	13.58	13.99	13.36	14.72	12.36	16.75
33. Weaning to market (% of no. weaned)	5.89	4.99	7.88	5.16	4.50	6.78
34. Breeding stock (% of breeding herd maintained)	2.38	2.41	2.93	4.58	4.61	5.74
Labor:						
35. Labor hours/cwt of pork produced	.59	.56	.58	.62	.57	.69
36. Labor hours/female/period	11.27	10.13	10.02	25.13	25.95	24.02
37. Labor hours/litter weaned/period	11.21	9.83	10.89	12.55	11.98	13.01
38. Cost of unpaid labor & mgmt./cwt of pork produced	3.40	3.33	2.74	3.30	2.46	3.81
39. Total cost of labor (paid + unpaid)/cwt of pork produced	4.59	4.36	4.56	4.80	4.04	5.67
40. Total cost of labor (paid + unpaid)/female/period	87.48	79.08	80.16	193.27	183.47	195.38
41. Return/hour for all hours of labor and management	17.50	30.47	5.76	6.45	14.96	-3.61
Marketing and purchases:						
42. Number of market hogs sold	848	749.17	970.58	1934	2142.43	2124.57
43. Average weight/head for market hogs sold	238	246.67	241.80	248	253.59	245.17
44. Average price received for market hogs/cwt	38.56	39.59	39.60	38.26	38.92	37.57
45. Number of feeder pigs sold	65.27	33.83	67.33	40.75	36.86	55.29
46. Average weight/head of feeder pigs sold	53.50	46.81	59.35	48.89	69.39	46.45
47. Average price received/head for feeder pigs sold	39.16	33.00	39.18	41.27	50.44	30.07
48. Average price received/cwt for feeder pigs sold	70.75	81.75	57.19	96.41	78.63	63.60
Feed cost and consumption:						
49. Total lbs of feed fed/cwt of pork produced	368	361.58	376.93	373	359.53	384.78
50. Total lbs of grain fed/cwt of pork produced	289	282.51	299.19	293	283.67	301.03
51. Total lbs of supplement fed/cwt of pork produced	79	79.07	77.74	80	75.85	83.74
52. Average costs of diets/cwt	6.61	6.38	6.79	6.44	6.40	6.76

Semi-annual date January 1, - June 30, 1995 & annual date July 1, 1994 - June 30, 1995.

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