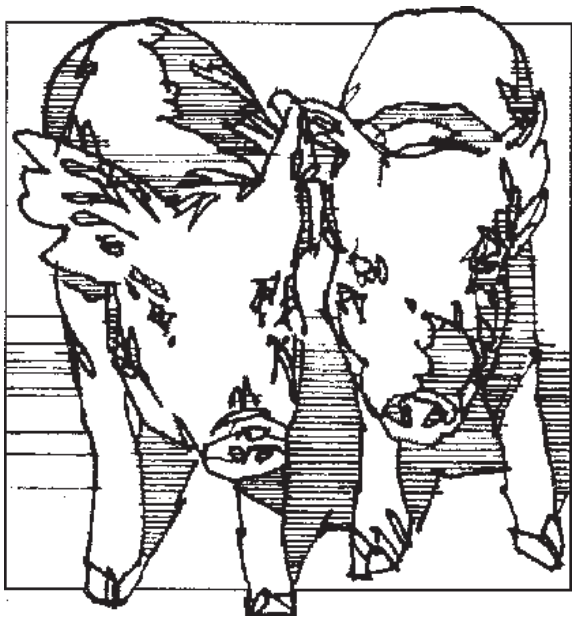

KANSAS
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SWINE DAY 1994

REPORT OF PROGRESS 717, AGRICULTURAL EXPERIMENT STATION, MARC A. JOHNSON, DIRECTOR

FOREWORD

It is with great pleasure that we present to you the 1994 Swine Day Report. This report represents the 25th Anniversary of our KSU Swine Industry Day Proceedings, and contains summaries of applied and basic swine research conducted at Kansas State University during the past year. Topics range from economics to physiology and nutrition. We hope that the information will be of benefit, as we attempt to meet the needs of the Kansas swine industry.

Editors, 1994 Swine Day Report,

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

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

ESTRUS AND EARLY PREGNANCY IN SOWS WEANED AT LESS THAN 11 OR MORE THAN 23 DAYS: EFFECTS OF VITAMIN A AND GONADOTROPIN TREATMENTS[1]

S. Tonn, P. Groothius, B. Boese, R. Blair, and D. L. Davis

Summary

The problem of reduced reproductive performance in sows weaned at 5 to 11 days (early weaned) after farrowing was assessed by comparing estrous and embryonic traits in these sows and others weaned at 23 to 31 days postpartum. The effects of treatment of both groups of sows with PG600® and vitamin A also were studied. PG600® increased the number of sows in estrus regardless of weaning age and reduced the interval from weaning to estrus for early-weaned sows. Both vitamin A and PG600® tended to increase the number of embryos recovered at 11.5 days after the onset of estrus.

(Key Words: Estrus, Embryo Survival, PG600®, Gonadotropins, Vitamin A.)

Introduction

New production protocols in the swine industry (referred to as "multiple-site production", "segregated early weaning", etc.) require weaning pigs at younger ages than previously. The reproductive performance of sows may be a problem when weaning occurs earlier than 3 weeks and they are scheduled for immediate rebreeding. Although the problems of a decreased estrous response and lower embryo survival are well known, the physiological causes have received limited attention. Further, current understanding of the successful reproductive function of the postpartum sow suggests that two treatments may be useful for minimizing reproductive problems.

These two treatments are vitamin A and PG600®. Injection of vitamin A at weaning can increase the number of pigs in the subsequent litter, suggesting effects on either the ovary or the uterus. Further, other data indicate that PG600®, a product that includes two gonadotropic hormones, hastens estrus in sows. These considerations led us to conduct the experiment reported here.

Procedures

After nursing their first litters for either 5 to 11 days (early weaned) or 23 to 31 days (conventionally weaned), 53 sows were assigned to either receive PG600® or saline at weaning (hormone treatment). One half of the sows receiving each hormone treatment received vitamin A (1,000,000 IU) at weaning and the other half received a placebo injection (the vehicle used for the vitamin A but not containing the vitamin). This provided a two × two factorial design for testing the effects of treatments singly or in combination. The injection treatments were applied to the two weaning ages in a 2×2×2 factorial arrangement.

Beginning 3 days after weaning, sows were checked for estrus three times per day by exposing them to a boar and testing for a standing reaction. Ovulation rate and early embryonic survival and development were

[1]The authors appreciate the donation of injectable vitamin A and placebo by Phoenix Scientific, St. Joseph, MO.

evaluated at 11.5 days after the onset of estrus. At that time, sows were subjected to surgery, and the number of corpora lutea counted as a measure of the number of eggs ovulated. The uterus was flushed and embryos counted and measured.

Results and Discussion

No interactions among the treatments were detected. The estrous response is presented in Table 1. Vitamin A did not affect the occurrence of estrus or the interval from weaning to estrus. However, effects of both the postpartum interval and PG600® treatment were apparent. Early-weaned sows were less (P<.05) likely to return to estrus during the 10-day detection period and took longer (P<.05) to return to estrus. Injection of PG600® increased (P<.025) the number of both early- and conventionally-weaned sows in estrus. Injection of PG600® also shortened (P<.05) the interval to estrus for early-weaned but not conventionally weaned sows.

Embryo development and survival are presented in Table 2. Sows weaned early had lower (P<.05) ovulation rates, and fewer (P<.05) embryos were recovered from their uterine. However, the percent of ovulations represented by embryos was similar for early- and conventionally-weaned sows. Both vitamin A and PG600® increased (P<.05) the number of embryos recovered. The two treatments appear to increase the number of embryos by different mechanisms. Although not statistically significant, PG600®-treated sows ovulated numerically more eggs. This effect seemed more pronounced for conventionally-weaned sows. In contrast, vitamin A-treated sows tended (P=.10) to have higher embryo survival. None of the treatments affected diversity in embryo development.

Responses of the sows in this experiment indicated that PG600® is an effective treatment for hastening return to heat by primiparous sows after either early or conventional weaning. The data also suggest that vitamin A treatment may increase early embryonic survival. Samples collected from these sows will be evaluated to assess effects of the treatments on uterine function. It is somewhat surprising that weaning at 5 to 11 days did not decrease early embryonic survival. Perhaps the effects of a shortened postpartum period on embryo survival become apparent after day 11.5.

Table 1. Estrous Traits of Early-Weaned and Conventionally Weaned Sows

Treatment	No. assigned	No. in estrus	(%)	Days from weaning to estrus
Early weaned	26	11	(42)	5.0
Control	14	3	(21)	5.9
PG600®	12	8	(75)[a]	4.1[b]
Placebo	13	6	(46)	5.0
Vitamin A	13	5	(39)	5.4
Conventionally weaned	27	23	(85)[c]	3.9
Control	13	9	(69)	4.1
PG600®	14	14	(100)[a]	3.7
Placebo	13	12	(92)	3.8
Vitamin A	14	11	(79)	3.9

[a]More (P<.025) than for control early-weaned sows.
[b]Less (P<.05) than for control early-weaned sows.
[c]More (P<.005) than for early-weaned sows.

Table 2. Ovulation Rate and Embryonic Survival of Early-Weaned and Conventionally Weaned Sows

Treatment	No.	Ovulation rate	Embryos recovered	Embryo survival, %
Control	12	17.7	10.9	69
PG600®	22	22.2	16.4[a]	75
Placebo	18	20.4	10.8	66
Vitamin A	17	20.9	16.5[b]	78[d]
Early weaned	11	15.9	9.9	73
Conventionally weaned	23	24.0[e]	17.4[c]	71

[a]More (P=.05) than control.
[b]More (P<.05) than placebo.
[c]More (P<.05) than early-weaned.
[d]Tends (P=.10) to be more than placebo.

Swine Day 1994

INJECTION OF VITAMIN A AT INSEMINATION AND REPRODUCTIVE PERFORMANCE IN GILTS[1]

D. L. Davis, D. Schoneweis[2], and M. Nelson

Summary

This experiment tested the hypothesis that an injection of vitamin A on the day of first detected estrus would improve reproductive performance of gilts. Gilts (432) were assigned to either receive vitamin A (1,000,000 IU) or placebo injected intramuscularly on the first day of estrus. No differences in farrowing rate, number of pigs farrowed per litter, or birth weight of pigs were detected. Possibly, gilts do not respond to vitamin A with improved fecundity. Other workers have reported an improvement in litter size for sows. Alternatively, treatment with vitamin A may need to precede estrus to improve litter size or multiple injections may be required. Experiments showing benefits for sows have treated them at weaning and, therefore, a few days before estrus.

(Key Words: Gilts, Vitamin A, Litter Size.)

Introduction

Several recent reports indicate that vitamin A, injected when the litter is weaned, increases the number of pigs farrowed in the next litter. The mechanism for this effect is not known but appears to be achieved by increasing embryo survival. Because the treatment is given at weaning, it precedes estrus by 3 or more days, and the importance of that interval is not known.

Gilts make up a significant proportion of swine breeding herds, and the number of pigs in the first litter may limit reproductive performance. The expected date of the next estrus usually is not known for gilts, making the administration of vitamin A before estrus difficult. Therefore, in the present experiment, vitamin A was administered on the day of first detected estrus.

Procedures

Gilts were moved to outside pens 22 days before the start of breeding and exposed to a mature boar (fenceline) to stimulate puberty. The boar was removed after 5 days and reintroduced 2 days before the start of breeding. Gilts were flushed by feeding a milo-soybean meal diet free choice beginning approximately 10 days before the start of breeding.

The experiment included 10 groups of gilts that were artificially inseminated from May, 1993 to March, 1994. Each breeding period was for 10 to 12 days, during which gilts were checked daily for estrus. When the standing reflex was detected, gilts were moved to a breeding-gestation building where they were placed in individual gestation stalls and injected with 2 ml of either vitamin A or placebo (the vehicle minus vitamin A).

Gilts were artificially inseminated (AI) on the first and second days of estrus. Pooled

[1]The authors appreciate the donation of injectable vitamin A and placebo by Phoenix Scientific, St. Joseph, MO.

[2]Department of Clinical Sciences.

semen (at least 3 billion motile sperm) from two or more boars was used for each AI. Gilts were checked for return to estrus from 18 to 23 days after AI, and pregnancy was checked (ultrasound) from 28 to 30 days after AI. Pregnant gilts were moved to outside pens for the remainder of gestation and fed individually 4 lb/day of a complete milo-soybean meal diet until approximately day 90 of gestation, when the daily feed was increased to 5 lb/day. Within a few days of expected farrowing, gilts were moved to the farrowing-nursery complex. At farrowing, the total number of pigs farrowed, the number born alive, and the birth weight of each pig were determined.

Results and Discussion

No effects of vitamin A treatment on farrowing rate or litter size were detected (table 1). Further, litter weight at farrowing was not affected by treatment (27.1 vs 27.3 lb for control and vitamin A-treated gilts, respectively). Breeding group differences ($P<.05$) were detected for farrowing rate and litter traits (Table 1). Farrowing rates ranged from 67 to 100%, and the number of pigs born alive from 7.6 to 11.2. Some of this variation appears to be related to season, but genotype also changed, with pigs before November 1993 sired by Yorkshire boars and those farrowed later sired by Duroc × Hampshire boars. The breed makeup of the gilts changed also in the rotational cross-breeding system used.

There are three possible explanations for the failure of vitamin A to improve litter traits. First, most of the research reporting positive effects has been conducted with sows. A second possibility is that the injection of vitamin A was administered too late. A third possibility is that multiple injections of vitamin A are required to elicit the effect. As described in the introduction, other experiments have studied the injection of vitamin A to sows at weaning, and, therefore, treatment preceded estrus by a few days. To apply a similar regimen to gilts in practical situations may require use of estrous synchronization, but no estrous synchronization products currently are labelled for use in gilts in the U.S.

Table 1. Fertility of Gilts Injected with Placebo or Vitamin A at Insemination

	Placebo				Vitamin A[a]			
Month inseminated	n	Farrowed (%)	Total born	Born alive	n	Farrowed (%)	Total born	Born alive
All months	216	181 (84)	10.6[b]	9.6[b]	216	191 (88)	10.1	9.3
May	22	21 (95)	10.0	8.8	21	20 (95)	11.3	10.2
June	23	22 (96)	10.1	9.7	23	23 (100)	10.4	9.3
July	24	16 (67)	10.4	9.3	23	19 (83)	10.7	10.1
August[c,d,e]	24	19 (79)	9.6	9.2	24	19 (79)	7.9	7.6
September[d]	20	16 (80)	10.5	7.9	21	21 (100)	11.1	8.7
November	22	17 (77)	11.6	11.2	21	17 (81)	9.9	9.4
December	20	19 (95)	11.7	10.8	21	19 (90)	10.6	10.4
January	20	17 (85)	11.8	11.2	22	21 (95)	10.4	9.7
February[d]	20	16 (80)	9.9	8.7	20	16 (80)	10.1	9.1
March[d,f]	21	18 (86)	10.4	9.2	20	16 (80)	9.0	8.5

[a]Vitamin A (1,000,000 IU) was injected on the first day of estrus.
[b]Pooled standard errors are .23 for total born and pigs born alive/litter.
[c]Fewer ($P<.05$) total pigs farrowed than for inseminations in all other months except March.
[d]Fewer ($P<.05$) live pigs farrowed than for inseminations in January, May, June, July, November, and December.
[e]Fewer live pigs farrowed than for inseminations in all other months except September.
[f]Fewer total pigs farrowed than for January and December inseminations.

INFLUENCE OF A SINGLE INJECTION OF BETA CAROTENE AND/OR VITAMIN A AT WEANING ON SUBSEQUENT REPRODUCTIVE PERFORMANCE OF SOWS[1]

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

Summary

A total of 956 sows was used to determine the influence of a single injection of beta carotene, vitamin A, or the combination of beta carotene and vitamin A at weaning on subsequent reproductive performance. At weaning, sows were allotted randomly to one of the following four treatments: 1) 5 ml of saline (control); 2) 5 ml of beta carotene (200 mg); 3) 2 ml of vitamin A (1,000,000 IU); or 4) 5 ml of beta-carotene and 2 ml of vitamin A. A total of 718 sows farrowed following a normal return to estrus (< 30 days) and normal gestation length. The other 238 sows that received the injections were removed from the study for failing to return to estrus within 30 days postweaning, failing to conceive, failing to farrow, and lameness. Farrowing rate ranged from 73.2 to 78.4% (average of 75.1%), but was not influenced significantly by treatment. Total pigs born, pigs born alive, or pigs born dead were not influenced by the injections. These results are different from previous research, which indicated that an injection of beta carotene or vitamin A increased number of pigs born alive. Number of pigs born alive (10.4) may have been too high on the farms used in this study to detect a significant improvement. Another possibility is that a second injection of beta carotene or vitamin A at breeding may be needed to elicit the increase in litter size.

(Key Words: Sows, Litter Size, Vitamin A, Beta Carotene.)

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. Relatively little information is available from commercial production units concerning the influence of a single injection of vitamin A or beta carotene at weaning on subsequent litter size. Additionally, the influence of injections of both beta carotene and vitamin A at weaning on subsequent litter size has not been determined. Therefore, the objective of this trial was to determine if a single injection of beta carotene and/or vitamin A at weaning would increase subsequent litter size in multiple parity sows.

Procedures

A total of 956 sows on three farms were used in this study. Before leaving the farrowing crate at weaning, sows were assigned randomly to one of the injection treatments. Sows were injected with either 5 ml of sterile saline (control); 5 ml of beta carotene (200

[1]Appreciation is expressed to BASF Corporation, Parsippany, NJ for financial support and providing the products for this study. The authors also wish to thank Haverkamp Bros. Inc., Bern, KS; Premium Pork Incorporated, Kensington, KS; and Phillips Farm, Drexel, MO, for data collection and use of facilities and animals.

mg); 2 ml of vitamin A propionate (1,000,000 IU); or 2 ml of vitamin A propionate and 5 ml of beta carotene. Injections were given with a 1.5 in, 18 gauge needle deep in the neck muscle to avoid injecting directly into fat tissue.

Previous sow performance, including number of previous litters, prior lactation length, number of pigs born alive and dead, and number of mummies, was recorded at weaning. Following weaning, sows were moved to an environmentally controlled breeding facility. Sows were checked with a boar twice daily for estrus. Once estrus was detected, sows were inseminated once every 24 hours until sows were not in standing estrus. Sows were mated naturally on two farms and with artificial insemination on the third farm. Interval from weaning to estrus was recorded.

Sows were fed 4 to 5.5 lb of feed per day throughout gestation. Gestation diets were 14% crude protein, corn- or milo-soybean meal based diets. Gestation diets on all three farms contained approximately 10,000,000 IU of added vitamin A per ton.

At farrowing, number of pigs born alive and dead and number of mummies were recorded. Litter birth weight was measured on two of the farms. Number of pigs fostered on and off of each sow were recorded. At weaning, litter weaning weight, average pig weight, and number of pigs weaned were recorded. However, because cross-fostering was done among treatments, weaning information cannot be attributed entirely to treatment.

Data were analyzed to determine if any farm by treatment interactions occurred. Because no interactions were present, data were pooled for analysis. Further analysis revealed that number of prior litters, prior lactation length, and prior number of pigs born alive were not significant covariates. Therefore, no covariates were used in the final analyses. The statistical model included farm and treatment as the only independent variables.

Results and Discussion

A total of 718 of the 956 sows returned to estrus within 30 days postweaning and farrowed after a normal gestation period. Thus, farrowing rate was 75.1%. Farrowing rate and interval from weaning to estrus were was not influenced significantly by treatment (Table 1).

Numbers of total pigs born, born alive, born dead, and mummies were not significantly influenced ($P > .30$) by injection treatment. Number of pigs born alive following injection with vitamin A or beta carotene showed a numeric advantage; however, the magnitude of the response was very small. Litter weaning weight and number of pigs weaned also were not influenced by treatment.

The results of this study indicate that a single injection of beta carotene and/or vitamin A at weaning did not improve subsequent reproductive performance. These results are different than the earlier trials at North Carolina State University. One reason for the difference in response may be the large number of pigs born alive to the control sows in this study (10.4 pigs). Additionally, the timing of the injection may have been wrong. Most of the initial work from North Carolina was conducted using two or more injections. If sows in this experiment had received another injection at breeding, the magnitude of the response might have been greater.

In a recent trial at the University of Minnesota, a single injection of beta carotene improved farrowing rate by approximately 5%. The numerical response was similar in our trial; however, the Minnesota study was able to detect the improvement in farrowing rate because they used a greater number of animals. This economically important response must be further tested and verified.

In conclusion, these results indicate that further research must be conducted with beta carotene and/or vitamin A before their use will be adopted widely in herds with large litter sizes.

Table 1. Influence of Beta Carotene and/or Vitamin A on Sow Productivity[a]

Item[b]	Control	Beta carotene	Vitamin A	Vitamin A & beta carotene	CV
Total sows	250	241	236	229	- - -
Sows farrowed	183	189	174	172	- - -
Farrowing rate, %	73.2	78.4	73.7	75.1	- - -
Weaning to estrus, d	7.4	7.5	7.7	7.7	104.8
Total pigs born	11.13	11.29	11.21	11.43	27.3
Pigs born alive	10.36	10.48	10.51	10.57	27.1
Pigs born dead	.55	.61	.49	.67	169.2
Mummies	.20	.18	.20	.19	269.2

[a]Sows were injected with 200 mg beta carotene and/or 1,000,000 IU vitamin A at weaning.
[b]No significant treatment differences (P>.10).

DETERMINING THE VALINE REQUIREMENT OF THE HIGH-PRODUCING LACTATING SOW[1]

B. T. Richert, M. D. Tokach, R. D. Goodband, J. L. Nelssen, J. E. Pettigrew[2], R. D. Walker[2], L. J. Johnston[2], and S. A. Blum[3]

Summary

Two hundred-three large white × Landrace or large white × Chester White × Landrace sows (40 or 41/treatment, avg parity 3.7) were used in a 26 d lactation experiment to determine the valine requirement of high-producing sows. All diets were formulated to .9% lysine with all amino acids other than valine formulated to be at least 110% of their respective ratios relative to lysine. Synthetic valine replaced cornstarch to provide .75, .85, .95, 1.05, and 1.15% dietary valine. Corresponding valine:lysine ratios were 83, 94, 106, 117, and 128% of lysine. The experiment was conducted at two experiment stations from July, 1993 through January, 1994. Mean litter size of all treatments after adjustment was 10.33 pigs. Sow feed intake and grams of lysine intake were not different among treatments. Grams of valine intake increased linearly as dietary valine increased. Litter weight at d 21 and weaning increased linearly with increasing dietary valine. Litter weight gain from d 0 to 7 increased linearly as dietary valine increased to 1.15%. Litter weight gain from d 0 to 21 and d 0 to weaning increased linearly as dietary valine increased, with the greatest portion of the response observed as valine increased to 1.05% of the diet. Dietary valine had no effect on sow weight change, 10th rib backfat (BF) change, or last lumbar BF change from d 0 to 21 or d 0 to weaning. Days to estrus postweaning were not affected by dietary valine. These results demonstrate that high-producing sows have a dietary valine requirement of at least 117% of lysine during lactation (66.4 g/d valine), much greater than is currently recommended by NRC (1988; 100% of lysine) or ARC (1981; 70% of lysine) to maximize litter weaning weight and litter weight gain.

(Key Words: Valine, Lactation, Sows.)

Introduction

As genetic improvements continue to improve sow milk production, nutritional requirements also will continue to change. A previous study demonstrated that lysine requirement is highly correlated to the milk production of the sow. Research on other amino acids is scarce. Only one experiment has determined the valine requirement of the lactating sow. Piglets in that experiment gained only 3.62 lb from d 7 to 21 of lactation, approximately one-half of current piglet growth rates during lactation. Additionally, recent research in the lactating goat has demonstrated that valine has the highest oxidation rate of any amino acid in the goat mammary gland. As milk synthesis rates

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[1]Appreciation is expressed to Lonza, Inc. for financial assistance for this research project. We would like to acknowledge Nutri-Quest Inc. and BioKyowa Inc., St. Louis, MO, for partial donation of amino acids for this project. Appreciation also is expressed to the farm crews at the Waseca Southern Experiment Station and Morris West Central Experiment Station, University of Minnesota, for all their help in data collection.

[2]University of Minnesota.

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

increase with increased milk production, the valine requirement also would increase. Therefore, the objective of this experiment was to determine the valine requirement of the high-producing sow.

Procedures

Two hundred three primiparous and multiparous sows from the South Central (n=101) and West Central Experiment Stations (n=102) at the University of Minnesota were used in this experiment. Sows farrowed from July, 1993 through January, 1994. All sows originated from maternal line breeds (Yorkshire × Landrace or Yorkshire × Landrace × Chester White). Sows were moved into farrowing crates on approximately d 110 of gestation. Four farrowing groups of sows were used at both experiment stations, with sows allotted to one of five dietary treatments based on parity group. The three parity groups used were 1 and 2, 3 to 5, and 6 to 11.

The basal lactation diet is shown in Table 1. All diets were formulated to be in excess (at least 110%) of all nutrient estimates based on the NRC (1988) and ARC (1981) suggested ratios, except for valine. Diets were formulated to 14.3% CP, .9% lysine, .9% Ca, and .8% P. Synthetic L-valine replaced cornstarch in the basal diet in .1% increments to achieve the five dietary treatments, with valine concentrations of .75, .85, .95, 1.05, and 1.15%. The calculated valine to lysine ratios were 83.3, 94.4, 105.6, 116.7, 127.8% of lysine, respectively.

Table 1. Diet Composition[a]

Ingredient, %	Basal diet
Corn	72.803
SBM, 47%	16.731
Soybean oil	5.000
Dicalcium phosphate	2.708
Limestone	.594
Salt	.500
Cornstarch[b]	.400
Sow add pack[c]	.250
Vitamin premix[d]	.250
Trace mineral premix[e]	.150
Lysine-HCl	.268
L-threonine	.140
L-isoleucine	.090
DL-methionine	.072
L-tryptophan	.044
Total	100.0

[a]Basal diet was formulated to 14.3% CP, .9% lysine, .75% valine, .9% Ca and .8% P. Calculated levels of other amino acid in diets; .71% threonine, .20% tryptophan, .31% methionine, .59% methionine + cysteine, .69% isoleucine, 1.45% leucine, .39% histidine, .91% arginine.

[b]Cornstarch was replaced in .10% increments with L-valine to create the remaining four experimental diets with calculated dietary valine levels of .85, .95, 1.05, 1.15%.

Sows were allowed ad libitum access to feed and water from parturition until weaning. Feed intake was determined weekly, with orts collected and weighed once each week. Sows were weighed and scanned ultrasonically (Preg-Alert 2B; Renco, Minneapolis, MN) 2.4 inches off the midline on both sides of the body at the tenth rib and last lumbar to determine backfat thickness within 24 h postpartum, on d 21 of lactation, and at weaning. Sows were bled via vena puncture at d 21 of lactation to determine serum urea N, creatinine, and plasma amino acid concentrations. Piglets were cross-fostered between sows irrespective of dietary treatment until d 3 of lactation to improve uniformity of suckling intensity and to increase the number of pigs per sow to at least 10. Piglets were weighed at d 0, 7, 21, and weaning. Creep feed was not offered to the litters. On the day of weaning, sows were moved to a confinement breeding facility for observation of estrus. Sows were checked for signs of estrus daily for 15 days postweaning and were determined to be in estrus when the sow would stand to be mounted by a boar.

The GLM procedure of SAS was used to determine treatment effects. Litter size after cross-fostering was used as a covariate for all response criteria. Days of lactation were used as covariates for weaning litter weights, weaning litter weight gain, weaning sow backfat changes, and days to estrus. No treatment by parity group or treatment by station interactions (P>.10) occurred. All means reported are least squares means.

Results

Litter weight at d 7 increased at a linear (P<.09) rate as dietary valine increased (Table 2). Litter weight continued to improve linearly (P<.02) at d 21 and weaning (26 days) as dietary valine increased from .75 to 1.15%. Litter weights increased by 6.9 and 8.2 lb for d 21 and weaning, respectively, as valine increased from .75 to 1.15% in the diet .

Sow weight change at d 21 and weaning (Table 2) was not affected (P>.21) by dietary valine. Sow backfat (BF) loss at the tenth rib and last lumbar was not affected (P<.28) by increasing dietary valine.

Sow feed intake and, therefore, grams of lysine intake, (Table 2) tended to decrease and then increase (quadratic, P=.13). Sow feed intake was highest at .75% valine and lowest at .85% dietary valine. All lysine intakes were at or above the previously determined lysine requirement (54 g/day) for sows from these herds. Valine intake increased linearly (P<.001) as valine concentration increased in the diet, giving a range of 48.3 to 72.1 g/d.

Serum urea nitrogen (Table 2) on d 21 increased linearly (P<.001) as dietary valine increased from .75 to 1.15% in the diet. Additionally, serum creatinine concentrations tended to increase (P<.12) with increasing dietary valine.

Days to estrus postweaning (Table 2) were not affected by dietary valine levels, with values ranging from 4.87 to 5.19 days. Dietary treatment had no effect (P>.06) on the distribution of the days to return to estrus as measured by Chi-Square analysis. The percentage of sows in estrus by d 7 post-weaning ranged from 82.5 to 97.5 and from 89.7 to 97.5 by d 14 postweaning.

Discussion

The linear increase in litter weight by d 7 of lactation was only a trend, but represents an 8% gain. This result demonstrates that even early in lactation, when milk production is still increasing, litter growth rate can be affected by dietary amino acid balance. This is important, as we continue to make the weaning age younger and younger for increased throughput in the farrowing house or for use in a segregated early-weaning program. The greater the piglets' weight at weaning, the easier it is to start them on feed.

Litter weight increased by 5% at d 21 and weaning with increasing dietary valine. Litter weight increased by 6% at d 21 and weaning with increasing valine in the diet. Litter weight gain tends to plateau at 1.05% dietary valine; a valine:lysine ratio of 117%. This is the same ratio that maximized litter growth rate in the only other sow lactation valine trial conducted. However, great differences occur in milk production and litter growth rate between this experiment and the previous research. The previous research had only a 3.62 lb increase in piglet weight from d 7 to 21 of lactation at a dietary valine to lysine ratio of 117%, whereas we achieved a 7.97 lb piglet weight gain for the same time frame and valine to lysine ratio. This indicates that an optimal ratio of amino acids may be needed by the mammary gland for milk synthesis.

Sow weight change was not affected by dietary treatment and was close to zero. This was primarily due to the high feed intake of the sows in this experiment. Sow BF losses were minimal. Backfat change was not affected at the tenth rib and last lumbar by dietary valine. Dietary valine had no effect on days to estrus postweaning. This is likely due to minimal or no sow weight loss and high feed intake of the sows. Therefore, the sows were in excellent condition at the end of

the lactation period, resulting in no dietary effects on their reproductive function.

Serum urea nitrogen concentrations increased linearly with increasing dietary valine. We anticipated that the levels would have decreased as dietary valine approached the sow's requirement. However, in the only previous sow valine requirement trial, no change occurred in blood urea nitrogen. Serum creatinine concentrations also tended to increase, matching those of serum urea nitrogen. This may indicate an increased muscle catabolism to meet the increased milk production of the sows fed increased valine levels, therefore, leading to an increase in both BUN and creatinine.

This research demonstrates the need for a higher dietary valine concentration than is currently recommended by the NRC (1988) and the ARC (1981) for the high-producing lactating sow. The valine requirement for the lactating sow is at least 117% of lysine, and valine may be the first limiting amino acid in lactation diets formulated above .8% lysine.

Table 2. Effects of Dietary Valine on Sow and Litter Performance

	Valine, % (Valine:Lysine) ratio							
	.75	.85	.95	1.05	1.15		P value	
Item,	(83.3%)	(94.4%)	(105.6%)	(116.7%)	(127.8%)	CV	Linear	Quadratic
Lactation length, d	26.3	25.9	26.1	26.0	26.1	—	—	—
Pigs weaned[a]	10.16	10.18	10.13	10.17	10.25	3.7	.31	.38
Mean parity	4.35	4.30	4.29	4.27	4.16	—	—	—
Litter wt., lb								
d 0	34.3	34.1	34.5	34.1	35.1	13.9	.52	.57
d 7[a]	61.3	62.1	62.5	62.5	64.3	12.5	.09	.74
d 21[a]	137.6	137.9	141.1	143.3	144.5	11.9	.02	.92
Weaning[ab]	168.0	167.9	171.5	173.8	176.2	11.0	.02	.73
Initial backfat, in.								
Tenth rib	.85	.89	.89	.88	.89	—	—	—
Last lumbar	.98	1.01	1.00	1.00	.98	—	—	—
Backfat change, in.								
d 21 tenth rib[ac]	-0.04	-0.05	-0.06	-0.05	-0.07	147	.28	.91
d 21 last lumbar[ac]	-0.03	-0.04	-0.06	-0.02	-0.06	202	.38	.97
Weaning tenth rib[abc]	-0.08	-0.09	-0.10	-0.08	-0.09	86	.91	.75
Weaning last lumbar[abc]	-0.07	-0.06	-0.07	-0.05	-0.07	146	.75	.76
Initial sow wt. and change, lb								
Sow wt. d 0	468.2	481.5	474.8	483.6	483.8	10.8	.18	.72
d 0 to 21[ad]	2.59	-2.51	-4.58	2.22	-1.28	597	.78	.35
d 0 to weaning[abd]	2.22	-5.85	-5.76	-0.84	-2.60	407	.69	.21
Feed intake								
ADFI, lb[ab]	14.17	13.18	13.55	13.97	13.83	14.3	.90	.13
Lysine intake, g[ab]	57.8	53.8	55.3	57.0	56.5	14.3	.90	.13
Valine intake, g[ab]	48.3	50.9	58.4	66.4	72.1	14.7	.001	.20
Blood criteria, mg/dL								
Blood urea nitrogen[a]	16.4	17.6	17.8	19.2	19.5	19.9	.001	.76
Creatinine[a]	1.67	1.77	1.66	1.73	1.79	15.9	.12	.58
Return to estrus								
Days to estrus[ab]	4.95	5.19	5.07	4.87	5.19	22.1	.79	.92
Percent in estrus by d 7	97.5	82.5	89.7	90.2	93.0	—	—	—
Percent in estrus by d 14	97.5	90.0	89.7	90.2	95.3	—	—	—

[a]Number of pigs postfostering used as a covariate.
[b]Days of lactation used as a covariate.
[c]Initial sow backfat used as a covariate.
[d]Initial sow backfat used as a covariate.

THE EFFECT OF LYSINE AND VALINE FED DURING LACTATION ON SOW AND LITTER LACTATION PERFORMANCE[1]

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Summary

Two hundred two sows (98 parity 1 and 104 parity 2 sows) were used in a 2 × 3 factorial arrangement of treatments to determine the effect of dietary valine and lysine on sow lactation performance. Treatments included two levels of lysine (.8 or 1.2%) and three valine to lysine ratios (80, 100, 120% of lysine). This experiment was conducted at a research farm of a production facility in New South Wales, Australia from January to March, 1994. For all sows, increasing dietary lysine increased litter weaning weight and litter weight gain and reduced sow weight loss. Increasing dietary valine tended to increase litter weight gain. Parity 1 sows had a greater response in litter weight gain to dietary lysine than parity 2 sows. Parity 1 sows also exhibited a linear increase in litter weight gain as dietary valine increased. Parity 2 sows had an increase in litter weight gain at the low lysine level but a decrease in litter weight gain at the high lysine level with increasing valine in the diet. Both parities had a similar reduction in sow weight loss with increasing dietary lysine. The data also were separated into sows that weaned 10 or more pigs and sows that weaned fewer than 10 pigs. Sows that weaned 10+ pigs had a greater increase in litter weaning weight and litter weight gain when dietary lysine was increased from .8 to 1.2%. These sows also had a linear increase in litter weaning weights and litter weight gain as valine increased. Sows that weaned fewer than 10 pigs had no response to increasing lysine or valine. Serum urea nitrogen was increased by increased dietary lysine but was not affected by valine. The results demonstrates the need to increase dietary lysine and valine as milk production increases. The high-producing sow (10+ pigs weaned) requires increased lysine and valine to maximize litter growth rate and minimize sow weight loss. The independent increases in litter weaning weights from adding lysine and valine suggests separate modes of action in the high-producing sow for these amino acids in milk synthesis.

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

Introduction

Based on recent research conducted by Kansas State University and the University of Minnesota, the valine requirement for lactating sows appears to be higher than the ARC (1981) and NRC (1988) recommendations. Several research trials have demonstrated the benefit of increased protein and lysine in lactating diets for high-producing sows. However, no research has been conducted to evaluate whether the valine requirement is different at higher levels of milk production. Therefore, our objectives were to evaluate effects of increasing lysine and valine on sow and litter performance during lactation and to

[1]Appreciation is expressed to Lonza, Inc. for financial assistance of this trial and to Bunge Meats, Ltd. for their hospitality and assistance in conducting this research trial.

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determine if the response to valine changes as lysine increases in the diet, indicating a similar or additive response between these two amino acids on milk production.

Procedures

Two hundred two sows (98 parity 1 and 104 parity 2 sows) were used in a 2 × 3 factorial arrangement of treatments. Treatments included two levels of lysine (.8 or 1.2%) and three valine to lysine ratios (80, 100, 120% of lysine). The experiment was conducted at a research farm in a production facility in New South Wales, Australia from January to March, 1994. Sow and litter weights were recorded on day 2 postfarrowing after cross-fostering was completed and at weaning. Feed intake was recorded for the entire lactation period. The average lactation length was 23.7 days. Sows were scanned ultrasonically for backfat (BF) thickness at approximately 2.4 inches off the midline on both sides of the body at the 10th rib and last lumbar. There were eight groups of sows with five observations per treatment in each group. The first four groups of sows were bled via vena puncture on day 21 of lactation at 3 hours postconsumption of the initial morning feeding for determination of plasma urea nitrogen (PUN) and plasma creatinine concentrations.

Two basal diets were fed during lactation, one for each lysine level (Table 1). The .8% lysine diet contained .65% valine (80% valine:lysine). The 100% and 120% valine:lysine diets were created by replacing wheat starch in the basal diet with .15 and .30% L-valine, respectively. The 1.2% lysine diet contained .96% valine (80% valine:lysine). The 100 and 120% valine:lysine diets were created by replacing wheat starch with .24 and .48% L-valine, respectively. All .8% lysine diets were formulated to 14.4% CP, 1.0% Ca, and .8% P. All the 1.2% lysine diets were formulated to 20.6% CP, 1.05% Ca, and .8% P. A common gestation diet was fed to all sows following weaning to determine return-to-estrus interval and subsequent litter size (data not reported).

The GLM procedure of SAS was used to determine treatment effects. Days of lactation and litter size after cross-fostering were used as covariates for all data. Initial sow weight and initial sow backfat thickness were used as covariates for sow weight change and backfat change. Because of the increased response observed with the preliminary valine field trial conducted by KSU, the data set was split into two sow groups: sows that weaned 10 or more pigs, and sows that weaned fewer than 10 pigs. It demonstrated a greater response to dietary valine in sows weaning 10 pigs or more. The data also were divided into parity 1 and 2 sows to evaluate any effect of lysine and valine on litter growth rate and sow performance between parities.

Results

All Sows (Table 2). Increasing dietary lysine from .8% to 1.2% increased lysine intake from 35.7 to 55.7 g/day (P<.001). The increase in lysine intake increased litter weaning weights (P<.001), litter weight gain (P<.002), and average weanling pig weight (P<.006) and reduced sow weight loss (P<.001). Valine intakes ranged from 28.9 g/day on the .8% lysine basal diet to 67.3 g/day on the 1.2% lysine-120% valine diet (linear, P<.001). Increasing valine numerically increased litter weaning weight (P<.27), litter weight gain (P<.22), and average weaned pig weight (P<.18) within both lysine levels. Lysine or valine had no effect of sow BF loss.

Sows Weaning ≥ 10 Pigs vs Sows Weaning < 10 pigs (Tables 3 and 4). Two thirds of the sows weaned 10 or more pigs. In this group of sows, litter weaning weight, litter weight gain, and piglet weaning weights increased as lysine increased (P<.001) and valine increased (linear P<.04, quadratic P<.08). Average daily feed intake (ADFI) increased (P<.02) by .8 lb for sows fed the high lysine diet. Sow weight loss was reduced (P<.001) in sows fed the high lysine diet. Dietary valine had no effect (P>.17) on sow ADFI or weight loss. Neither lysine nor valine had an effect on sow BF loss. However, sows that weaned fewer than 10 pigs had no improvement in litter growth rate

(P>.72) and only a tendency for reduced sow weight loss (P<.13) as dietary lysine increased. Sows that weaned fewer than 10 pigs tended to have a quadratic (P<.13) response in litter weight gain with increasing dietary valine, with maximum litter weight gain observed at a 1:1 lysine to valine ratio.

All Sows, Parity 1 vs Parity 2 (Data Not Shown). Parity 1 sows had increased litter weaning weight (P<.005), litter weight gain (P<.002), and average piglet weaning weight (P<.005) as dietary lysine increased. Parity 1 sows also had a linear increase in litter weaning weight (P<.09) and litter weight gain (P<.08) as dietary valine increased. Parity 2 sows had a lysine by valine interaction for litter weaning weight (P<.08) and average weanling pig weight (P<.05). Parity 2 sows had a linear increase in litter and piglet weaning weights with increasing valine when fed the .8% lysine treatment, but had linearly decreasing litter and piglet weaning weights with increasing valine levels when fed 1.2% lysine. Both parity 1 and 2 sows had reduced sow weight loss (P<.006) with increased dietary lysine. Backfat loss was not affected (P>.40) by dietary treatment for parity 1 or 2 sows.

Blood Response Criteria (Data Not Shown). Plasma urea nitrogen (PUN) increased (P<.001) with increasing dietary lysine. As dietary valine increased, there was a numerical trend (P<.25) for reduced PUN. Plasma creatinine concentrations were not affected (P>.32) by dietary lysine or valine.

Discussion

The paper reported on page 10 demonstrated the need for increased dietary valine for the high-producing, lactating sow. The present experiment evaluates the valine response at two different lysine levels. Considering the whole data set (Table 2), increased lysine increased litter weaning weight by 9.3 lb, litter weight gain by 8.3 lb, and average weaned piglet weight by .7 lb. The increased dietary lysine also decreased sow weight loss by approximately 20 lb. Similar responses to increased dietary lysine from 35.7 to 55.7 grams/day have been documented in several studies, especially with parity 1 sows. Increasing dietary valine from 80% of lysine to 120% of lysine resulted in one-half of the response to lysine, with litter weaning weights and litter weight gains increasing by 4 lb. The valine response was not as great as that in previous research; however, the valine and lysine requirements appear to be dependent on the milk production of the sow.

Sows that have a greater milk production demand (lactating 10 or more pigs) were responsible for most of the lysine and valine response in this experiment. Sows that weaned 10 or more pigs had a 10 lb increase in litter weight gain with increased lysine and a 7.2 lb increase with increased valine to 120% of lysine. The valine response in sows nursing 10 or more pigs became greater as milk production (as measured by litter weaning weights) increases. For sows fed .8% lysine, valine increased litter weight gain by 4.8 lb at 120% of lysine compared with sows fed the 80% valine. The 1.2% lysine diet had increased litter weight gain of 9.6 lb at the 120% valine level compared with the 80% valine in the high lysine diets. The valine response in the high lysine diet matches the increase in litter weight gain from increased lysine and is additive to the lysine response. Thus, a 20 lb increase (10 lb from lysine and 10 lb from valine) in litter weight gain resulted from feeding the high-producing sow a diet containing high levels of lysine (1.2%) and valine (120% of lysine) compared to sows fed low levels of lysine (.8%) and valine (80 or 100% of lysine). However, sows that weaned fewer than 10 pigs had only a 1.7 lb increase in litter weight gain with increased lysine. The response to valine in sows weaning fewer than 10 pigs tend to be quadratic, with maximal litter weight gain (4.5 lb greater) at a valine level of 100% of lysine. Having the correct valine to lysine ratio in the diet gave a greater response in litter weaning weights than simply increasing lysine in the diet for the sows weaning fewer than 10 pigs. These results indicate that both valine and lysine are required for maximum litter weight gain. Weight loss was 10 (1.2% lysine) or 20 lb (.8% lysine) greater for sows nursing 10+ pigs than for sows nursing fewer than 10 pigs. Sow weight loss serves as an

additional indicator of the difference in the demand for milk production between these two groups of sows. Valine had no effect on sow weight loss. This suggests that the muscle catabolism associated with sow weight loss is to meet the lysine and(or) other amino acid needs of the lactating sow.

Parity 1 sows had significant increases in litter weight gain with increased dietary lysine (11.5 lb) and valine (7.4 lb). However, parity 2 sows had no response in litter growth rate with increasing lysine or valine concentrations. The difference may have been due to parity 2 sows being 90 lb heavier than parity 1 sows, providing more muscle mass from which to draw amino acids for milk production. An additional factor leading to the different responses to lysine and valine may be that the parity 1 sows had a 6.7 lb greater litter weight gain on the high lysine diet and 9 lb greater litter weight gains on the 120% valine:lysine diet than the parity 2 sows. Both parity 1 and 2 sows responded similarly to increased lysine with reduced sow weight loss. Valine had no effect on sow weight loss of parity 1 or 2 sows.

Plasma urea nitrogen increased with increased dietary lysine. Theoretically, PUN should decrease as the sow's amino acid requirements are met. This was the response to increasing valine in this trial; however, it was only a numerical trend. Sows with this level of milk production may not require 56 g/day of lysine, indicating that we may have exceeded the lysine requirement for these sows by feeding a 1.2% lysine diet. This would explain the increased PUN levels with increased lysine. Plasma creatinine levels were numerically lower for both increased lysine and valine; however, these were not significant and may have been due to the high coefficient of variation and difficulty in analyzing several of the samples.

In conclusion, the results of the present trial indicate the need to change dietary lysine and valine levels based on the milk production of the herd. The high-producing sow (and parity 1 sows) weaning 10 or more pigs requires increased lysine intakes (56 vs 36 grams/day) and increased dietary valine concentrations to maximize litter growth rate and milk production. A lower producing sow, however, requires less lysine (.8%) with valine at 100% of lysine to maximize litter growth rate. This trial also indicates that valine and lysine may be acting through different mechanisms in the mammary gland to increase litter weaning weights.

Table 1. Composition of Basal Diets[a]

	Lysine, %	
Item,	.80%[b]	1.2%[c]
Wheat	50.0	39.3
Barley	20.1	19.0
Millmix[d]	10.0	3.5
Wheat starch	1.0	1.88
Expeller soybean meal (44% CP)	11.8	30.8
Tallow	2.7	1.0
Salt	0.5	.5
Limestone	1.0	1.2
Dicalcium phosphate (18% P)	2.2	2.0
Lysine-HCl	.24	.19
D,L-methionine	.07	.17
L-threonine	.15	.21
L-isoleucine	.08	.06
L-tryptophan	.003	.003
L-histidine	.043	.06
Vit. and trace mineral premix[e]	.15	.15
Total	100.0	100.0

[a]Diets were fed for a 23.7 day lactation period.
[b]Valine levels of 80, 100, and 120% of lysine corresponding to .65, .80, and .95% dietary valine were created by replacing wheat starch in the basal diet in .15% increments with L-valine. All three diets were formulated to 14.4% CP, 1.0% Ca, .8% P.
[c]Valine levels of 80, 100, and 120% of lysine corresponding to .96, 1.20, and 1.44% dietary valine were created by replacing wheat starch in the basal diet in .24% increments with L-valine. All three diets were formulated to 20.6% CP, 1.05% Ca, .8% P.
[d]Consisted of mostly wheat midds.
[e]Activity level in grams per ton of feed: 15.0 vitamin A, 3.0 vitamin D3, 80.0 vitamin E, 3.5 vitamin B2, 2.0 vitamin B6, 0.02 vitamin B12, 0.2 biotin, 10.0 pantothenic acid, 0.5 folic acid, 15.0 niacin, 200.0 choline, 86.6 betaine, 1.0 iodine, 0.2 selenium, 20.0 copper, 80.0 iron, 55.0 manganese, 75.0 zinc, 100.0 endox (antioxidant).

Table 2. Effects of Dietary Lysine and Valine on Sow and Litter Lactation Performance: All Sows[a]

	Main effects of treatments					Individual dietary treatments							Probability values			
	Lysine, %		Valine, % of Lysine			.80% Lysine			1.2% Lysine					Valine		
Item,	.80	1.20	80	100	120	80	100	120	80	100	120	CV	Lys	Lin.	Quad.	Lys x Val
Sows per trt	104	98	70	66	66	36	31	37	34	35	29					
Litter WN wt., lb	140.7	150.0	143.8	144.6	147.6	138.6	138.9	144.5	148.9	150.3	150.7	13.8	.001	.27	.73	.74
Litter wt. gain, lb	100.0	108.3	102.8	102.9	106.7	98.7	98.6	102.8	107.0	107.3	110.5	17.3	.002	.22	.50	.99
Litter wt. gain/d, lb	4.61	4.97	4.73	4.75	4.90	4.53	4.55	4.74	4.93	4.94	5.06	17.4	.002	.24	.59	.96
Avg. piglet WN wt., lb	14.4	15.1	14.6	14.6	15.0	14.2	14.1	14.8	15.0	15.0	15.2	11.6	.006	.18	.33	.77
Sow wt. d 0, lb	420.6	419.0	420.1	416.6	422.7	424.3	419.7	417.9	415.9	413.5	427.5	12.8	..83	.78	.55	.58
Sow wt. loss, lb[b]	43.4	24.9	31.1	37.0	34.4	41.7	44.5	44.0	20.6	29.4	24.8	85.4	.001	.53	.35	.84
Initial tenth rib BF, in.	.79	.79	.74	.78	.84	.72	.81	.84	.76	.75	.85	24.2	.81	.01	.68	.34
Initial last lumbar BF, in.	.76	.77	.73	.75	.80	.72	.76	.79	.74	.74	.81	21.2	.74	.02	.58	.75
Tenth rib BF loss, in.[c]	.13	.14	.13	.14	.14	.13	.14	.11	.12	.13	.17	86.8	.40	.52	.88	.20
Last lumbar BF loss, in.[c]	.16	.16	.15	.16	.16	.15	.17	.16	.15	.16	.16	57.4	.96	.71	.46	.97
ADFI, lb	9.8	10.3	10.3	9.7	10.1	10.0	9.6	9.9	10.6	9.9	10.3	19.1	.11	.70	.12	.90
Lysine intake, g	35.7	55.9	46.9	44.3	46.1	36.1	34.8	36.0	57.6	53.8	56.1	18.9	.001	.60	.10	.71
Valine intake, g	35.7	55.7	37.5	44.3	55.3	28.9	34.8	43.3	46.1	53.8	67.3	19.4	.001	.001	.12	.07
No. of pigs WN	9.82	9.94	9.86	9.94	9.83	9.78	9.87	9.81	9.95	10.0	9.85	8.7	.34	.82	.48	.90

[a]Days of lactation used as a covariate. WN = weaning.

[b]Sow weight at d 0 used as a covariate.

[c]Sow initial backfat thickness used as a covariate.

Table 3. Effects of Dietary Lysine and Valine on Sow and Litter Lactation Performance: 10 or More Pigs Weaned/Litter[a]

	Main effects of treatments					Individual dietary treatments							Probability values			
	Lysine, %		Valine, % of Lysine			.80% Lysine			1.2% Lysine					Valine		
Item,	.80	1.20	80	100	120	80	100	120	80	100	120	CV	Lys	Lin.	Quad.	Lys x Val
Sows per trt	66	67	45	45	43	22	20	24	23	25	19					
Litter WN wt., lb	147.6	159.0	151.4	149.1	159.0	145.8	143.5	152.7	157.0	154.6	165.3	11.4	.001	.04	.06	.98
Litter wt. gain, lb	105.3	115.3	109.0	105.6	116.2	104.8	101.4	109.6	113.2	109.8	122.8	14.5	.001	.04	.02	.73
Litter wt. gain/d, lb	4.84	5.29	5.01	4.87	5.33	4.81	4.68	5.04	5.20	5.06	5.63	14.6	.001	.04	.03	.76
Avg. piglet WN wt., lb	14.1	15.1	14.3	14.3	15.2	13.8	13.8	14.7	14.9	14.8	15.8	10.9	.001	.01	.08	.98
Sow wt. d 0, lb	420.0	420.3	421.5	417.7	421.3	423.9	414.9	421.2	419.0	420.5	421.3	12.0	.97	.98	.70	.89
Sow wt. loss, lb[b]	51.0	28.5	36.8	40.4	42.0	47.2	51.8	54.0	26.5	29.0	30.0	70.5	.001	.39	.85	.96
Initial tenth rib BF, in.	.80	.81	.75	.82	.84	.73	.84	.82	.76	.80	.85	23.9	.80	.03	.43	.67
Initial last lumbar BF, in.	.76	.77	.72	.78	.80	.71	.78	.78	.73	.78	.82	21.3	.48	.03	.56	.90
Tenth rib BF loss, in.[c]	.16	.16	.16	.16	.15	.18	.17	.12	.15	.15	.18	73.3	.82	.60	.87	.11
Last lumbar BF loss, in.[c]	.17	.17	.17	.17	.17	.17	.17	.17	.16	.16	.18	53.4	.68	.77	.71	.84
ADFI, lb	9.7	10.5	10.1	9.8	10.4	9.7	9.3	10.1	10.5	10.3	10.7	18.2	.02	.38	.17	.90
Lysine intake, g	35.1	57.1	46.1	44.8	47.5	35.0	33.8	36.7	57.2	55.8	58.2	18.3	.001	.46	.20	.99
Valine intake, g	35.3	57.1	36.8	44.8	56.9	28.0	33.8	44.1	45.7	55.8	69.8	18.6	.001	.001	.19	.11
No. of pigs WN	10.49	10.50	10.57	10.46	10.46	10.60	10.44	10.43	10.54	10.48	10.49	4.7	.84	.29	.57	.85

[a]Days of lactation used as a covariate. WN = weaning.

[b]Sow weight at d 0 used as a covariate.

[c]Sow initial backfat thickness as a covariate.

Table 4. Effects of Dietary Lysine and Valine on Sow and Litter Lactation Performance: Less than 10 Pigs Weaned/Litter[a]

	Main effects of treatments					Individual dietary treatments							Probability values			
	Lysine, %		Valine, % of Lysine			.80% Lysine			1.2% Lysine					Valine		
Item,	.80	1.20	80	100	120	80	100	120	80	100	120	CV	Lys	Lin.	Quad.	Lys x Val
Sows per trt	38	33	26	21	24	14	11	13	12	10	11					
Litter WN wt., lb	129.1	130.9	130.0	134.1	125.9	128.9	129.5	129.0	131.1	138.7	122.8	14.0	.87	.72	.18	.40
Litter wt. gain, lb	91.5	93.2	91.9	96.4	88.8	90.8	93.0	90.6	92.9	99.7	87.0	17.5	.92	.87	.13	.56
Litter wt. gain/d, lb	4.21	4.30	4.24	4.45	4.07	4.18	4.28	4.16	4.30	4.62	3.97	17.4	.83	.72	.11	.51
Avg. piglet WN wt., lb	14.9	15.0	15.0	15.2	14.6	14.9	14.9	15.0	15.1	15.5	14.2	12.8	.77	.76	.39	.45
Sow wt. d 0, lb	420.6	416.4	417.0	413.5	424.9	424.1	429.0	408.8	410.0	398.0	441.0	14.4	.78	.66	.64	.21
Sow wt. loss, lb[b]	29.7	18.0	21.8	30.4	19.2	33.8	28.8	26.4	9.8	32.1	12.1	125.9	.13	.78	.22	.34
Initial tenth rib BF, in.	.78	.73	.74	.68	.85	.72	.76	.87	.75	.61	.84	24.8	.29	.04	.03	.26
Initial last lumbar BF, in.	.76	.74	.75	.69	.80	.74	.74	.79	.77	.65	.80	21.0	.65	.38	.06	.46
Tenth rib BF loss, in.[c]	.08	.10	.08	.08	.12	.06	.08	.10	.09	.08	.14	123.7	.47	.24	.54	.79
Last lumbar BF loss, in.[c]	.13	.14	.13	.16	.12	.12	.15	.12	.14	.17	.12	64.1	.59	.67	.21	.79
ADFI, lb	10.1	9.7	10.5	9.6	9.6	10.5	10.2	9.6	10.6	9.0	9.6	22.5	.26	.42	.56	.67
Lysine intake, g	36.6	51.7	46.0	42.8	43.7	38.1	36.8	35.0	53.9	48.9	52.5	23.0	.001	.45	.45	.66
Valine intake, g	36.4	51.6	36.8	42.9	52.3	30.6	36.9	41.6	43.1	48.9	62.9	22.2	.001	.001	.51	.19
No. of pigs WN	8.65	8.75	8.65	8.82	8.62	8.61	8.74	8.60	8.70	8.91	8.64	5.3	.37	.81	.13	.90

[a]Days of lactation used as a covariate. WN = weaning.

[b]Sow weight at d 0 used as a covariate.

[c]Sow initial backfat thickness used as a covariate.

Swine Day 1994

COMPARISON OF LACTATION DIETS CONTAINING VARIOUS PROTEIN SOURCES ON SOW AND LITTER PERFORMANCE[1]

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

Summary

A total of 188 lactating sows was used in Exp. 1 to determine the influence of a complex lactation diet containing oats, linseed meal, and alfalfa meal compared with a corn-soybean meal diet on sow and litter performance. No differences in sow and litter performance were observed. Therefore, a simple corn-soybean meal diet was adequate to maximize sow productivity. Average daily feed intake (ADFI) of sows by parity was also examined in Exp. 1. The ADFI of parity 1 sows was considerably lower than that of parity 3 sows, but litter weaning weights were similar. Thus, lactation diet formulation should account for the differences in feed intake by parity and be formulated on ADFI (average daily feed intake) and level of production. A total of 198 lactating sows was used in Exp. 2 to determine the influence of substituting 3 lb/ton of L-lysine HCl and corn for soybean meal in the lactation diet. No differences in sow and litter performances were observed. However, ADFI was excellent for both treatments, resulting in average daily lysine intakes of 67.6 and 69.7 g per day. This is approximately 14 g in excess of the reported requirement for this level of production. Thus, further research is needed to assess the use of L-lysine HCl in lactation diets.

(Key Words: Sows, Protein, Lysine.)

Introduction

Previous research has indicated that the high producing sow has a lysine requirement greater than NRC estimates to maximize sow and litter performance. Research also has shown that sow and litter performance is improved with increased feed intake in sows with a high genetic potential for milk production. Therefore, some swine industry personnel feel that a complex lactation diet with alternative protein sources will stimulate lactation feed intake, resulting in increased performance. Accordingly, the first experiment compared the influence on sow and litter performance of a complex lactation diet containing the alternative protein sources linseed meal, alfalfa meal, and oats versus a simple corn-soybean meal-based diet. The objective of the second experiment was to examine the influence of a corn-soybean meal diet with or without 3 lb/ton of lysine-HCl on sow and litter performance. This was based on the hypothesis that inclusion of 3 lb/ton of synthetic lysine in lactation diets would result in deficiencies of threonine and valine, which would limit sow performance.

Procedures

Experiment 1. On a commercial swine operation, 188 lactating sows were allocated randomly at farrowing to one of two diets. The diets were formulated to contain .98%

[1]The authors would like to thank Randy Spronk, Gene Jasper, and Sharon Jacobson, Pipestone, MN, for use of animals, facilities, and data collection.

lysine (Table 1). The simple diet was corn-soybean meal-based, and the complex diet contained 2.5% oats, 1.25% linseed meal, and 1.25% alfalfa meal. The diets were both supplemented with 2 lb L-lysine HCl per ton. The experiment was conducted from August to December, 1993.

Experiment 2. On the same commercial swine operation as Exp. 1, 198 lactating sows were allocated randomly at farrowing to one of two corn-soybean meal-based diets (Table 1). The two diets were formulated to contain .98% lysine. However, one diet had 3 lb/ton L-lysine HCl per ton and corn substituted for soybean meal on an equal lysine basis. The experiment was conducted from February to June, 1994.

During both experiments, litters were equalized within treatment by 48 h post-farrowing. Litters were weighed at birth and weaning (15.8 d, Exp. 1 and 15.6 d, Exp 2). Sows were provided ad libitum access to feed and water, and feed intake was recorded daily. Sows were housed in individual farrowing crates in environmentally controlled farrowing rooms. The minimum air temperature in the farrowing room was 68°F. Supplemental heat was provided in the piglet creep area. Piglets had no access to creep feed.

Results and Discussion

Experiment 1. Sow and litter performance was excellent for both treatments. No differences were observed in sow and litter performance between treatments, including ADFI and litter weaning weight. Results of this experiment indicate that oats, linseed, or alfalfa meal did not improve sow or litter performance. A simple corn-soybean meal diet would necessitate the procurement of fewer ingredients and simplify manufacture of the lactation diet.

Listed in Table 3 are ADFI and litter performance by parity. The results indicate a significant affect of parity on ADFI ($P<.01$). Parity 1 and 2 sows had lower ADFI than parity 3 to 6 sows. However, litter weaning weights were similar, which indicate that milk production was similar across parities. Thus, if one diet was fed in lactation, amino acid intake would be 30% lower in parity 1 and 2 sows, and the resulting deficit for milk production would have to be mobilized from body stores and could compromise subsequent reproductive performance. Therefore, lactation diets customized to herd ADFI and production levels may cause some parities to be underfed. Level of production and ADFI by parity should be considered when formulating lactation diets.

Experiment 2. Sow and litter performance was again excellent for both groups. Litter weaning weights averaged 101.7 and 101.2 lb for control and lysine treatments, respectively, with an average lactation length of 15.6 days. The excellent litter performance is a reflection of the high ADFI of the sows. Lysine intake averaged nearly 70 g/day or approximately 14 g per day greater than recommended for this level of production. Valine intake averaged 59 g/d and 66 g/d for the 3 lb/ton lysine-HCl and control sows, respectively. Threonine intake averaged 46 g/d and 52 g/d for the 3 lb/ton lysine-HCl and control sows, respectively. Subsequently, with lysine in excess of the requirement, threonine and valine, the most limiting amino acids, also may have been above the requirement, explaining why no differences were observed in sow and litter performance. Thus, further research is needed to assess the use of L-lysine HCl in lactation diets.

Table 1. Diet Composition

	Exp. 1		Exp. 2	
Item, %	Simple	Complex	Control	Lysine
Corn	71.50	67.40	67.32	71.33
Soybean meal (46.5% CP)	22.47	21.63	26.89	22.63
Monocalcium phosphate (21% P)	2.64	2.61	2.56	2.63
Oats	--	2.50	--	--
Alfalfa meal	--	1.25	--	--
Linseed meal	--	1.25	--	--
Soy oil	1.00	1.00	1.00	1.00
Salt	.50	.50	.50	.50
Trace mineral and vitamin premix[a]	.75	.75	.75	.75
Lysine-HCl	.1	.1	--	.15
Total	100.00	100.00	100.00	100.00

[a]To provide a minimum of per ton: 150 g Zn, 150 g Fe, 36 g Mn, 15 g Cu, 270 mg I, 270 mg Se, 10 million IU vitamin A, 1.5 million IU vitamin D, 40 thousand IU vitamin E, 30 mg B_{12}, 7.5 g riboflavin, 11 g pantothenic acid, 45 g niacin, 500 g choline, 200 mg biotin, 1500 mg folic acid.

Table 2. Sow and Litter Performance (Exp. 1)[a]

Item	Simple	Complex	P-Value	CV
Number of sows	98	90	--	--
ADFI, lb	14.4	14.9	.17	17.0
Pigs weaned	9.0	9.2	.21	12.7
Litter weaning weight, lb	96.1	97.8	.47	15.8
Average weaned pig weight, lb	10.7	10.7	.83	12.0
Wean to 1st service, d	5.9	7.1	.21	85.9

[a]Sows were blocked on parity. Lactation length and litter birth weight were used as covariates. No treatment by covariate interactions were noted. Average lactation length was 15.8 days, and average litter birth weight was 35.3 lb.

Table 3. Effect of Parity on Sow and Litter Performance (Exp. 1)[a]

	Parity						
Item	1	2	3	4	5	6	CV
Number of sows	43	30	21	27	20	38	--
ADFI, lb	11.3	13.5	15.1	14.6	16.1	15.3	17.0
Lysine, g/d	50.2	60.0	67.1	64.8	71.5	67.9	--
Litter weaning wt, lb	100.5	98.2	104.2	96.9	98.6	103.5	15.8
Wean to 1st service, d	11.8	8.2	7.6	4.9	5.1	5.7	85.9

[a]Lactation length and litter birth weight were used as covariates. No treatment by covariate interactions were noted. Average lactation length was 15.8 days.

Table 4. Sow and Litter Performance (Exp. 2)[a]

Item	3 lb Lysine	Control	P-Value	CV
Number of sows	99	99	--	--
ADFI, lb	15.3	15.8	.37	24.4
Lysine intake, g/d	67.6	69.9	.37	24.4
Pigs weaned	9.3	9.3	.99	16.7
Litter weaning weight, lb	101.2	101.7	.86	18.0
Average weaned pig weight, lb	11.0	11.0	.94	12.3
Wean to 1st service, d	6.1	7.1	.41	96.0

[a]Lactation length was used as a covariate. No treatment by covariate interactions were noted. Average lactation length was 15.6 days.

Swine Day 1994

PROCESSING PROCEDURES AND FEEDING SYSTEMS FOR SORGHUM-BASED DIETS GIVEN TO LACTATING SOWS

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

Summary

One-hundred twenty nine primiparous sows were used to determine the effects of alternative processing procedures and feeding systems on the nutritional value of sorghum grain-based diets for lactating sows. Treatments were a ground sorghum control, steam-flaked sorghum and extruded sorghum fed in meal form, or the ground sorghum control given as pellets or gruel (1:1 ratio of water and feed on a volume:volume basis). Average daily feed intake was greater for sows fed pelleted and gruel forms compared to sow fed the diets with steam-flaked and extruded sorghum. However, no differences occurred in sow weight or backfat losses among the treatments. Number of pigs weaned and percentage survivability were similar among treatments, except that steam-flaked sorghum supported greater litter weight gains than extruded sorghum. Apparent digestibilities of DM, N, and GE in sows fed steam-flaked and extruded sorghum were greater than in sows fed pelleted or gruel diets. Sows fed extruded sorghum tended to have the greatest digestibilities of DM, N, and GE and lowest excretions of DM and N in the feces. Severity of ulceration was not affected significantly by treatments, but keratinization was greatest for sows fed extruded sorghum. In conclusion, the alternative processing methods (steam-flaking and extrusion) and feeding systems (pellets and gruel) had little effect on sow and litter performance. However, nutrient digestibilities were improved for all treatments that involved heating (steam flaking, extrusion, and pelleting), and, thus, these treatments resulted in less fecal excretion of DM and N.

(Key Words: Sow, Sorghum, Steam-Flake, Extrusion, Pellet, Gruel, Digestibility.)

Introduction

Mash diets with ground cereal grains are the most prevalent feeding system for swine. In ruminants, however, alternative methods of processing sorghum grain consistently give improved energy utilization compared to grinding. Limited information is available concerning the effects of alternative methods of processing and the resulting feeding value of sorghum in swine diets. Therefore, an experiment was designed to determine the effects of alternative processing procedures of sorghum grain on sow and litter performance, nutrient digestibility, nutrient intake and excretion, and changes in stomach morphology of primiparous sows.

Procedures

Mill-run sorghum was ground through a 3/16" hammermill screen for the control diet. For steam flaking, the sorghum grain was steamed at atmospheric pressure (steam chest set at 221°F) for approximately 30 min. The flaked sorghum (19% moisture) was allowed to air-dry at 140°F prior to mixing into the diet (final moisture concentration of 10%). To prepare the extruded sorghum, an Insta-Pro® (Model 2000R) dry extruder was used. The sorghum was ground in a hammermill, and water was added to bring the sorghum to

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18% moisture before extrusion. The extrusion conditions were those deemed usual for sorghum processing (i.e., a throughput of approximately 1,240 lb/h and an average barrel temperature of 256°F). Pelleting was done in a Master Model California Pellet Mill®. The diet was preconditioned to 131°F and pelleted through a 1.5" thick die with 3/16" diameter holes. Average production rate was 3,550 lb/h with an average exit temperature of 144°F.

A total of 129 primiparous sows was used in the 21-d lactation experiment. On d 110 of gestation, the sows were allotted randomly to treatments and given 5 lb/d of the experimental diets to allow for adjustment to the diets before parturition. Treatments were a ground sorghum control, steam-flaked and extruded sorghum fed in meal form, and the ground sorghum control given as pellets or gruel (1:1 ratio of water and feed on a volume:volume basis). The lactation diets were formulated to .85% lysine, .9% Ca, .8% P, and 1.46 Mcal ME/lb (Table 1).

Table 1. Diet Composition[a]

Ingredient	%
Sorghum	66.70
Extruded soybeans	28.70
Monocalcium phosphate	2.08
Limestone	1.11
Salt	.50
KSU vitamin premix	.25
KSU mineral premix	.15
KSU sow add pack	.25
Lysine-HCl	.06
Antibiotic[b]	.10
Chromic oxide[c]	.10
Total	100.00

[a]The lactation diet was formulated to .85% lysine, .9% Ca, .8% P, and 1.46 Mcal ME/lb of diet.
[b]Provided 100 g/ton of chlortetracycline.
[c]Used as an indigestible marker.

The sows were penned individually in 2 ft × 7 ft farrowing crates. All litters were standardized at nine or more piglets within 24 h of parturition. Sow and litter weight and sow backfat measurements were taken at farrowing and on d 21 of lactation. Backfat thickness was measured at the first rib, last rib, and last lumbar vertebra. Final weight and backfat thickness of sows weaned prior to d 21 were adjusted by multiplying their daily weight and backfat losses by 21. The sows were allowed ad libitum access to feed and water. On d 18, grab samples of feces were collected from each sow, dried, and ground. Concentrations of Cr, DM, N, and GE in the feces and diets were determined to allow calculation of apparent digestibilities of DM, N, and GE using the indirect ratio method. Intake of digestible DM, N, and GE were calculated by multiplying nutrient intake by their respective apparent digestibilities. The portion of nutrient intake not digested was reported as fecal excretion. After weaning, the sows were fed 4 lb/d of the lactation diet for 10 d and slaughtered. Stomachs were collected and scored for severity of esophagogastric ulcers and keratinization. The scoring system used for ulcers was 0 = normal, 1 = erosions, 2 = esophagogastric ulcers, and 3 = severe esophagogastric ulcers. The scoring system used for keratinization was 0 = normal, 1 = mild parakeratosis, 2 = moderate parakeratosis, and 3 = severe parakeratosis. Because the stomach scores were categorical data, they were analyzed using the Cochran-Mantel-Haenszel procedure of SAS (an analysis of variance procedure designed for categorical data). Contrasts used to separate treatment means were: 1) ground sorghum vs other treatments; 2) mash treatments (steam-flaked and extruded sorghum) vs pelleted and gruel diet forms; 3) steam-flaked vs extruded; and 4) pelleted vs gruel.

Results and Discussion

Average daily feed intake was greater for sows fed the pelleted and gruel diets than for sows fed the mash diets with steam-flaked and extruded sorghum ($P<.05$). This re-

sponse was primarily because of the relatively low ADFI for sows fed extruded sorghum. However, no differences occurred in weight or backfat loss for sows fed the various treatments (P>.15).

Equalizing litters ensured no differences in number of pigs at initiation of the experiment (with an average of 10.1 live pigs/sow). Also, survivability and number of pigs weaned were similar (P>.20) among treatments. However, steam-flaked sorghum supported the greatest litter wt gains (P<.05).

Apparent digestibilities of DM, N, and GE were greater for sows fed steam-flaked sorghum and extruded sorghum than for sows fed the pelleted and gruel diets (P<.001). Sows fed the extruded sorghum tended to have the highest digestibilities of nutrients, with 13% greater intake of digestible N than sows fed the ground sorghum control. With increased digestibility of nutrients comes decreased excretion of nutrients. Excretion of DM was 22% less for sows fed the alternatively processed sorghums compared to the ground sorghum control (P<.001). However, this improvement in digestibility never translated into an improvement in litter weaning weight.

The number of stomachs given each score for ulceration and keratinization and a mean score for each treatment are provided in Table 4. Treatment had no effect on severity of ulceration (row mean scores differ test, P>.74). However, sows fed extruded sorghum had the greatest stomach keratinization scores (P<.001).

In conclusion, the alternative processing methods (steam-flaking and extrusion) and feeding systems (pellets and gruel) had little effect on sow and litter performance. However, nutrient digestibilities were improved for all treatments that involved heating (steam flaking, extrusion, and pelleting), and, thus, these treatments resulted in less fecal excretion of DM and N.

Table 2. Effects of Alternative Processing Procedures and Feeding Systems for Sorghum on Performance of Sows[a]

Item	Ground	Steam-flaked	Extruded	Pelleted	Gruel	CV
No. of sows	30	22	26	26	25	--
Sow wt, lb						
Postfarrowing	376.5	372.4	382.1	378.9	386.8	7.3
d 21 of lactation[b]	361.0	357.7	373.8	371.7	373.8	8.2
Change	-15.4	-14.7	-8.3	-7.3	-9.3	162.1
Sow backfat thickness, in						
Farrowing	.97	.91	.96	.99	.96	18.3
d 21 of lactation[d]	.93	.87	.93	.97	.97	20.0
Change	-.04	-.04	-.03	-.01	.01	513.9
ADFI, lb[be]	9.88	9.54	8.95	9.53	9.99	12.4
No. of pigs/litter						
Initial	10.3	10.0	9.9	10.1	10.3	15.1
Weaned	9.5	9.4	9.3	9.2	9.5	13.9
Survivability, %	93.1	94.8	94.0	91.4	93.0	9.0
Litter wt, lb						
Initial	28.5	28.6	28.5	28.5	28.5	15.1
d 21[c]	106.5	110.3	101.5	102.6	100.9	12.3
Gain[c]	78.0	81.7	73.0	74.1	72.4	17.0

[a]A total of 129 primiparous sows (22 to 30 sows/treatment).
[bc]Steam-flaked vs extruded (P<.10 and .05, respectively).
[de]Steam-flaked and extruded vs pelleted and gruel (P<.10 and .05, respectively).

Table 3. Effects of Alternative Processing Procedures and Feeding Systems for Sorghum on Apparent Digestibility, Intake, and Excretion of Nutrients[a]

Item	Ground	Steam-flaked	Extruded	Pelleted	Gruel	CV
Apparent digestibilities, %						
DM[bcdg]	77.2	81.8	84.3	81.2	79.1	4.2
N[bceg]	70.9	77.7	83.8	76.1	73.3	5.9
GE[bceh]	75.6	80.9	87.1	81.8	77.7	4.3
Digestible DM intake, g/d	3,073	3,205	3,132	3,112	3,213	10.5
Digestible N intake, g/d	80	83	90	83	83	12.6
DE intake, Mcal/d	12.9	13.5	13.9	13.5	13.5	11.2
DM excretion, g/d[bcg]	935	688	602	728	897	14.2
N excretion, g/d[bcf]	33	20	17	27	32	17.1

[a]A total of 129 primiparous sows (22 to 30 sows/treatment).
[b]Ground vs other treatments (P<.001).
[c]Steam-flaked and extruded vs pelleted and gruel (P<.001).
[de]Steam-flaked vs extruded (P<.10 and .001, respectively).
[fgh]Pelleted vs gruel (P<.10, .05, and .001, respectively).

Table 4. Effects of Alternative Processing Procedures and Feeding Systems on Stomach Morphology of Sows[a]

Item	Ground	Steam-flaked	Extruded	Pelleted	Gruel	CV
Stomach ulceration						
Total observations	30	22	25	26	25	--
Normal	15	13	15	10	12	--
Erosions	8	2	3	3	2	--
Ulcers	6	6	5	11	9	--
Severe ulcers	1	1	2	2	2	--
Mean score[bc]	.85	.84	.82	1.33	1.10	108.0
Stomach keratinization						
Total observations	30	22	25	26	25	--
Normal	5	6	0	1	3	--
Mild	8	8	6	10	3	--
Moderate	14	4	10	12	13	--
Severe	3	4	9	3	6	--
Mean score[de]	1.57	1.46	2.24	1.83	1.98	46.0

[a]A total of 128 primiparous sows (22 to 30 sows/treatment).
[b]Scoring system: 0 = normal; 1 = erosion; 2 = ulcer; and 3 = severe ulcer.
[c]Cochran-Mantel-Haenszel statistic, row mean scores differ test (P>.74).
[d]Scoring system: 0 = normal; 1 = mild; 2 = moderate; and 3 = severe.
[e]Cochran-Mantel-Haenszel statistic, row mean scores differ test (P<.001).

INFLUENCE OF DIET COMPLEXITY AND WEANING AGE ON CARCASS CHARACTERISTICS AND GROWTH PERFORMANCE FROM WEANING TO MARKET[1]

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Summary

A total of 180 barrows (initially 7.4 or 11.9 lb and 9 or 19 d of age) was used in a growth assay to determine the influence of two weaning ages and three diet complexity sequences on growth performance and carcass characteristics. The growth performance of pigs used in this trial was excellent, as shown by the range of average age at 240 lb from 144 to 149.7 d. Growth performance was similar regardless of weaning age. Thus, when health status and environment are similar, pigs weaned at 19 d of age can attain a weight of 240 lb at the same age as pigs weaned at 9 d of age. The three complexity sequences varied widely in diet composition and the length of time the complex diets were fed. The high complexity sequence was formulated to achieve maximal gain regardless of cost, the medium complexity sequence was formulated to closely match current Kansas State University recommendations, and the low complexity diets were very simple diets with minimal amounts of alternative ingredients fed for short periods of time. Pigs performed the best on the high or medium sequence in Phase I postweaning. However, growth performance of pigs fed the simple sequence was similar to that of pigs in the medium or high sequences for the 15 to 40 lb phase. Thus, the data tend to indicate that diet complexity is critical in the first week postweaning, but the complexity can be decreased rapidly for feeding high health-status pigs without reducing performance. This experiment illustrates the tremendous growth potential of the high health-status pigs and that similar growth and performance can be achieved from pigs weaned at 9 and 19 d of age.

(Key Words: Starter Pig, Diet Complexity, Growth.)

Introduction

Segregated early weaning has become a standard management practice on many farms as a means of disease control. Several experiments have demonstrated the benefits of early weaning for disease elimination. The benefits of increasing the health status have included much higher growth rates and improved expression of the pigs potential to produce lean meat. Therefore, our objective was to compare the growth of 9- and 19-d-old weaned pigs raised in the same environment under the same management when obtained from a herd with a high health status. It is also known that immune stimulation elicits compounds that have a negative effect on pigs' feed intake. One of the primary objectives when formulating nursery diets is selecting ingredients that will stimulate feed intake to maximize performance. The selected ingredients thus make the diet more complex. Therefore, when the negative effects of infectious disease have been eliminated, complex diets may not be needed to stimulate feed intake and maximize nursery growth performance. Therefore, our two objectives were 1) to compare the growth performances of pigs weaned at 9 d and at 19

[1]Appreciation is expressed to Newsham Hybrids, Colorado Springs, CO, for partial support in kind.

d of age and 2) to examine the influence of diet complexity on the growth performance of high health-status pigs.

Procedures

A total of 180 barrows (initially 7.4 lb or 11.9 lb and 9 or 19 d of age) were used. Pigs were fed three different diet complexities for each of the two weaning ages. Thus, the six treatments were a high, medium, or low complexity phase-feeding sequence for the 9-d-old weaned pigs and a high, medium, or low sequence fed to the 19-d weaned pigs. Diet composition and phase-feeding scheme are listed in Tables 1 and 2. Diet complexity was altered by varying the level of dried whey, lactose, soy products, spray-dried porcine plasma, spray-dried blood meal, and select menhaden fishmeal in the diets. Pigs were phase fed according to weight with complexity decreasing as weight increased for each phase-feeding sequence. The high complexity diet sequences were designed to maximize gain regardless of price. These diets consisted of high levels of high quality alternative protein sources and milk products. The complex diets also were fed to heavier weight pigs than normally recommend. Diets fed in the high complexity sequence were similar to many diets formulated in the commercial feed industry. The medium complexity diet sequences also consisted of many of the same high quality alternative protein sources and milk products used in the high complexity diet sequences. However, they were not fed for such long periods or at such high levels. These diets were formulated to balance between maximal growth performance and optimal economics. The medium complexity sequences were formulated to closely match the current Kansas State University recommendations. The low complexity diet sequences were extremely simple diets that were composed of extremely low levels of spray-dried porcine plasma, select menhaden fish meal, and dried whey. These ingredients were also only included in the diets for short time periods. All diets within a weight range were formulated to the same dietary lysine level. Pigs were fed diets formulated to contain 1.7% lysine from weaning to 11 lb, 1.5% lysine from 11 to 15 lb, 1.4% lysine from 15 to 25 lb, 1.3% lysine from 25 to 40 lb, 1.2% lysine from 40 to 140 lb, and .9% lysine from 140 to 240 lb. All pigs were fed the same diets from 40 to 240 lb.

Pigs were housed in the same environmentally controlled nursery for the first 55 d postweaning. Pigs were allotted by weight and placed in pens containing five pigs per pen initially. Each pen was 4 ft × 4 ft with slotted metal flooring. A self-feeder and nipple waterer were located in each pen to allow ad libitum consumption of feed and water. A control group composed of only pigs weaned at 9 d of age was housed in an identical nursery. The purpose of the control group was to compare the growth performance of the 9-d-old groups between barns. The comparison was made to make sure that the 19-d-old pigs did not contaminate the 9-d-old pigs with infectious disease that might have hindered growth performance. At 55 d postweaning, pigs were moved to an open-fronted building (4 ft × 15 ft pens with solid flooring). Each pen contained a single-hole feeder and a nipple waterer to accommodate ad libitum access to feed and water. When the mean wt of pigs in a pen averaged 25, 40, and 240 lb, the pig weighing closest to the pen mean was slaughtered for carcass chemical composition. Carcass measurements were recorded 24 h postmortem for the 240-lb pigs.

Data were analyzed as a randomized complete block design. General linear model procedures were used with initial weight as a blocking factor. Main effect and interaction contrasts then were examined to determine effects of weaning age and diet complexity.

Results and Discussion

The growth performance of pigs used in this growth assay was excellent, as shown by the range of average ages at 240 lb (144 to 149.7 d; Table 3). Pigs fed the medium complexity diet were the youngest at 240 lb. Note that the pigs weaned at 9 d attained a weight of 15 lb at a younger age than the pigs weaned at 19 d of age, although the 9-d-old pigs had a lower ADG from weaning to

15 lb. The younger age can be explained by the fact that the pigs were younger at weaning and were in an accelerated phase of growth compared to the 19-d-old pigs. However, at 25 lb, no difference in age occurred between the two groups weaned at different ages, and the similar growth was maintained for the remainder of the experiment. This can be explained by the 19-d-old pigs having superior ADG and feed efficiency from 15 to 25 lb than the 9-d-old pigs. Thus, when health status and environment are similar, conventionally weaned pigs at 19 d of age can attain a weight of 240 lb at the same age as pigs weaned at 9 d of age.

The effect of diet complexity was most pronounced in the early postweaning period. The 9-d-old pigs fed the high diet complexity during the period from weaning to 11 lb had the best ADG, which was driven by increased ADFI from weaning to 11 lb. The ADG was then similar between diet complexities for the 9-d-old weaned pigs during the 11 to 15 lb period. A similar response was observed for the 19-d-old pigs from weaning to 15 lb, with the high and medium complexities giving better ADG than the low complexity treatment. The 19-d-old pigs then had similar ADG in the 15 to 25 lb period across diet complexities. Therefore, complexity did not affect ADG in the 15 to 40 lb period. However, complexity had a significant effect on ADG ($P<.01$) in the 40 to 240 lb period, with the medium complexity treatment giving the best ADG for both the 9-d and 19-d groups. The data tend to indicate that diet complexity is critical in the first week postweaning, but that in high health-status pigs, the complexity can be decreased rapidly without reducing performance. The data also indicate that a very complex diet sequence fed in the nursery phase does not maximize performance in the subsequent growing-finishing phase.

Carcass characteristics at 240 lb are listed in Table 4. The results indicate an interaction ($P<.02$) for amount of leaf fat. The interaction is the result of pigs weaned at 9 d of age and fed the low complexity diets having the most leaf fat (Table 4). Although no significant differences occurred for average backfat, tenth rib backfat, and loin eye area, the pigs weaned at 9 d of age and fed the low complexity diets had the greatest amount of backfat and the smallest longissimus muscle area.

The high complexity sequences resulted in a higher cost per lb of gain and poorer growth performance than the medium complexity sequences (Table 5). The feed cost per lb of gain was higher from weaning to 40 lb, lower from 40 to 240 lb, and slightly higher for the overall growth period when comparing the medium complexity sequence to the low complexity sequence. If the producer can take advantage of the increased throughput, the decreased days to market would result in lowering the fixed costs per pig, and, hence, pigs fed the medium complexity sequences would have lower or similar cost per lb of gain compared to pigs fed the low complexity sequences. Thus, the balance between growth performance and economics would indicate feeding a medium complexity diet in the immediate postweaning period and rapidly decreasing the complexity for the remainder of the finishing period.

In conclusion, this experiment illustrates the tremendous growth potential of the high health-status pig. This experiment also indicates that similar growth and performance can be achieved from pigs weaned at 9 and 19 d of age, even when fed diets with a wide range of complexities. More research is needed to further define the effects of nursery diet complexity on pigs with different health status.

Table 1. Diet Composition

	Weaning to 11 lb			11 to 15 lb				15 to 25 lb			25 to 40 lb		40 to 140 lb	140 to 240 lb
Item	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Corn	31.24	31.62	31.75	40.78	40.41	40.00	32.94	48.62	51.07	50.01	53.50	61.04	60.36	77.85
Dried whey	30.00	25.00	20.00	25.00	25.00	20.00	20.00	20.00	10.00	5.00	15.00	--	--	--
Lactose	5.00	5.00	--	5.00	--	--	--	--	--	--	--	--	--	--
Soybean meal (48.5% CP)	--	14.12	31.48	--	16.19	25.92	38.23	16.76	28.56	36.87	25.41	34.19	34.85	19.51
Moist extruded soy protein concentrate	8.73	--	--	8.19	--	--	--	--	--	--	--	--	--	--
Spray-dried porcine plasma	10.00	7.50	2.00	7.50	7.50	2.50	--	3.00	--	--	--	--	--	--
Select menhaden fishmeal	6.00	6.00	6.00	3.00	--	--	--	3.00	--	--	3.00	--	--	--
Spray-dried blood meal	--	1.75	--	1.75	1.75	2.50	--	2.00	2.50	--	--	--	--	--
Soybean oil	6.00	6.00	6.00	5.00	5.00	5.00	5.00	3.00	3.00	3.00	--	--	2.00	--
Monocalcium phosphate (21% P)	1.14	1.15	.85	1.62	1.79	1.70	1.46	1.46	1.85	1.82	.88	1.46	1.21	.98
Antibiotic[a]	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	.19	.165	.23	.47	.64	.68	.67	.50	.80	.84	.55	.90	.88	.92
Vitamin premix	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.20	.15
Trace mineral	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.10
DL-methionine	.119	.124	.113	.112	.142	.123	.116	.77	.102	.078	.033	.039	--	--
Copper sulfate	.075	.075	.075	.075	.075	.075	.075	.075	.075	.075	.075	.075	--	--
L-lysine HCl	.10	.10	.10	.10	.10	.10	.10	.15	.15	.15	.15	.15	--	--
Salt	--	--	--	--	--	--	--	--	.25	.75	--	.75	.35	.35
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100

[a]To provide 50 g/ton carbadox

Table 2. Diet Sequence Fed for Each Treatment[a]

	Diet sequence						
	9 d weaning			19 d weaning			
Item, lb	High	Med	Low	Hight	Med	Low	Lysine, %
Weaning to 11	A	B	C	na[b]	na	na	1.70
11 to 15	D	F	G	D	E	G	1.50
15 to 25	H	I	I	H	I	J	1.40
25 to 40	K	L	L	K	L	L	1.30
40 to 140	M	M	M	M	M	M	1.20
140 to 240	N	N	N	N	N	N	.90

[a]Pigs were fed within each treatment diet sequences varying in complexity and decreasing in complexity as pig weight increased. Each letter represents the diet listed in Table 1.
[b]Not applicable because 19 d pigs weighed more than 11 lb at the initiation of the experiment.

Table 3. Effect of Weaning Age and Diet Complexity on Growth Performance[a]

	9 d weaning			19 d weaning			P value			
Item	High	Med	Low	High	Med	Low	Age	Diet	A×D[b]	CV
Wean to 11 lb										
ADG, lb	.51	.44	.42	--	--	--	na[c]	.01	na	5.7
ADFI, lb	.48	.44	.43	--	--	--	na	.10	na	10.1
F/G	.95	.99	1.00	--	--	--	na	.18	na	5.1
11 to 15 lb										
ADG, lb	.80	.79	.75	--	--	--	na	.57	na	11.2
ADFI, lb	.95	.86	.85	--	--	--	na	.03	na	7.0
F/G	1.18	1.10	1.15	--	--	--	na	.06	na	5.1
Wean to 15 lb										
ADG, lb	.64	.59	.55	.79	.80	.68	.01	.01	.36	10.0
ADFI, lb	.70	.63	.60	.68	.70	.66	--	--	.03	6.5
F/G	1.09	1.06	1.08	.86	.87	.96	--	--	.01	3.1
15 to 25 lb										
ADG, lb	.97	.95	.96	1.01	1.05	1.03	.01	.95	.56	7.0
ADFI, lb	1.31	1.27	1.24	1.19	1.24	1.29	--	--	.04	6.2
F/G	1.35	1.34	1.30	1.17	1.18	1.26	--	--	.01	2.6
25 to 40 lb										
ADG, lb	1.34	1.29	1.22	1.33	1.28	1.33	.13	.07	.05	5.0
ADFI, lb	1.96	1.96	1.93	1.85	1.86	1.92	.01	.67	.09	3.2
F/G	1.46	1.53	1.59	1.39	1.46	1.45	.01	.01	.11	2.9
40 to 240 lb										
ADG, lb	1.93	2.01	1.95	1.96	2.03	1.92	.82	.01	.40	2.9
ADFI, lb	5.59	5.65	5.52	5.55	5.88	5.65	--	--	.01	1.5
F/G	2.90	2.81	2.83	2.83	2.90	2.94	--	--	.01	1.7
AGE, d										
11 lb	16.2	17.2	18	--	--	--	na	.01	na	3.7
15 lb	22	23.3	24.0	24.0	24.0	25.3	--	--	.03	2.4
25 lb	34.3	34.3	35.3	33.7	33.7	35.8	.50	.01	.42	3.6
40 lb	44.3	47.3	48.0	45.2	45.7	46.5	.11	.01	.07	3.1
140 lb	98.5	99.2	100.0	104.5	103.7	105.0	.01	.07	.33	1.2
240 lb	148.0	144.5	149.2	147.5	144.0	149.7	--	--	.03	0.3

[a]Pigs weaned at 9 d of age were initially 7.4 lb, and pigs weaned at 19 d of age were initially 11.9 lb. Each number is the mean of 6 pens (5 barrows per pen from weaning to 25 lb, 4 barrows per pen 25 to 40 lb, and 3 barrows per pen 40 to 240 lb).
[b]Age × Diet interaction.
[c]Not applicable because 19 d pigs weighed more than 11 lb at the initiation of the experiment.

Table 4. Effect of Weaning Age and Diet Complexity on Carcass Characteristics at 240 Lb[a]

	9 d weaning			19 d weaning			P Value			
Item	High	Med	Low	High	Med	Low	Age	Diet	AxD[b]	CV
Leaf fat, lb	3.0	2.7	4.3	2.7	3.0	2.2	--	--	.02	31.3
Backfat										
Average, in	.96	.96	1.08	.96	.99	.98	.45	.45	.45	13.8
Tenth rib, in	1.01	1.04	1.25	1.06	1.19	1.05	.95	.48	.17	20.9
Longissmus muscle area, in^2	6.04	6.19	5.41	5.97	6.12	6.09	.51	.46	.41	13.2

[a]Pigs weaned at 9 d of age were initially 7.4 lb, and pigs weaned at 19 d of age were initially 11.9 lb. Pigs were fed varying complexity dietary regimens in the nursery from weaning to 40 lb. Pigs were then fed common diets from weaning to market. Each number is the mean for 6 pigs.

[b]Age × diet interaction.

Table 5. Effect of Weaning Age and Diet Complexity on Feed Cost[a]

	9 d weaning			19 d weaning		
Item	High	Med	Low	High	Med	Low
Weaning to 40 lb						
Total, $	8.13	5.30	4.47	5.54	3.82	3.32
$ / lb gain	.249	.162	.137	.197	.136	.118
40 to 240 lb						
Total, $	35.57	34.62	34.85	35.34	36.40	36.57
$ / lb gain	.178	.173	.174	.177	.182	.183
Weaning to 240 lb						
Total, $	43.69	39.92	39.32	40.89	40.22	39.89
$ / lb gain	.188	.172	.169	.179	.176	.175

[a]Ingredient prices used were corn; $2.20/bu, soybean meal; $200/ton, dried whey; $.262/lb, spray-dried porcine plasma $2.00/lb, spray-dried blood meal; $.45/lb, select menhaden fish meal; $.406/lb. No charge was included for feed processing or delivery.

DIETARY LYSINE REQUIREMENTS OF SEGREGATED EARLY-WEANED PIGS[1]

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Summary

A total of 320 (160 barrows and 160 gilts) 14- to 18-d-old pigs (initially 10.2 ± 2.2 lb) was used to determine the optimal level of dietary lysine needed for the segregated early-weaned pig. Two diet formulation methods were used with six dietary lysine levels within each formulation method, resulting in a 2 × 6 factorial arrangement of treatments. The first formulation method consisted of a basal diet that contained 1.95% lysine. Increasing levels of cornstarch replaced L-lysine to achieve the other five dietary treatments (1.2, 1.35, 1.50, 1.65, and 1.80% dietary lysine). All other amino acids in each diet were maintained at the same level as in the 1.95% lysine treatment. The second formulation method consisted of a basal diet (1.2% lysine) with the five additional treatments achieved by adding synthetic lysine and other essential amino acids to maintain an ideal amino acid ratio, relative to lysine. All diets contained 20% dried whey, 10% lactose, 7.5% spray-dried porcine plasma, 5.0% spray-dried wheat gluten, 5.0% select menhaden fish meal, 5.0% soybean oil, and 1.75% spray-dried blood meal. No lysine × formulation method interactions occurred for average daily gain (ADG) or average daily feed intake (ADFI) throughout the 28 d period. However, lysine × formulation method interactions were observed for feed efficiency (F/G) from d 0 to 7, d 0 to 14, and d 0 to 28. From d 0 to 7 postweaning, ADG was improved quadratically as dietary lysine increased and appeared to be maximized at 1.65% dietary lysine. Feed efficiency was lowest for pigs fed 1.80% lysine for the first diet formulation method and for pigs fed 1.95% lysine for the second diet formulation method. From d 0 to 14 postweaning, ADG and F/G were improved by increasing dietary lysine, with both response criteria maximized in pigs fed approximately 1.65% dietary lysine. However, ADFI was not affected during the 28-d experiment. These data suggest that segregated early-weaned pigs require approximately 5.2 and 6.2 g/d of lysine from d 0 to 7 and d 0 to 14 postweaning, respectively, to optimize growth performance. Based on these results, the diet for pigs < 11 lb needs to be formulated to contain at least 1.7% lysine. The transition diet (11 to 15 lb) should be formulated to contain approximately 1.5 to 1.6% lysine.

(Key Words: Pigs, Lysine, Requirements, Segregated Early Weaning.)

Introduction

Research from Iowa State University has demonstrated that segregated early-weaned pigs of high health status have higher lysine requirements than pigs with conventional health status. However, experimental lysine levels used ranged from .60% to 1.80% with increasing levels of .30%, and the level of soybean meal was altered within each diet. From this research, it is hard to determine the appropriate lysine requirement needed in a high nutrient dense diet.

[1]Appreciation is expressed to Global Ventures, Pipestone, MN, for providing the pigs used in this research.

As seen in that research, formulating experimental diets to evaluate the lysine requirement in this age of pig poses some unique problems. In older pigs, corn-soybean meal ratios generally are altered to increase the dietary lysine concentration, and other amino acids are set using an ideal amino acid ratio to assure that lysine is the first limiting amino acid. However, this method is not practical when dealing with early-weaned pigs because of the delayed-type hypersensitivity reaction seen with high levels of soybean meal. Therefore, to more appropriately define the lysine requirements of early-weaned pigs, two different formulation methods were used. The first formulation method was designed to evaluate different lysine levels with all other amino acids held constant. All other amino acids were set to be above their projected requirements based on the highest level of dietary lysine. The second formulation used a basal diet, to which lysine and other synthetic amino acids were added in a ratio relative to lysine to provide the additional treatments. This procedure was used to minimize excess amino acids and to prevent amino acid imbalances from occurring. In short, if the ratio of other amino acids relative to lysine is important for maximizing growth performance, the first method of formulation would tend to overestimate the lysine requirement. However, if utilization of high levels of synthetic amino acids limits pig performance, the second formulation method might underestimate lysine requirements.

Procedures

A total of 320 (160 barrows and 160 gilts) 14 to 18-d old pigs was blocked by weight and allotted to one of 12 dietary treatments. There were four pigs per pen, with a total of six pens per treatment. Two diet formulation methods were used for this experiment and six dietary lysine levels for each diet formulation method, resulting in a 2 × 6 factorial arrangement. The first method consisted of formulating a basal diet that contained 1.95% lysine. Increasing levels of cornstarch replaced L-lysine HCl to achieve the other five dietary treatments (1.2, 1.35, 1.50, 1.65, and 1.80% dietary lysine). All other amino acids in each diet were maintained at the same level as in the 1.95% lysine treatment. The second method consisted of formulating diets using the digestible ratios proposed to maintain ideal amino acid ratios in all diets. The appropriate ratios were met by increasing the levels of synthetic amino acids in each diet (Table 1). The first method of formulation might tend to overestimate the lysine requirement because the diets containing the higher level of lysine will be approaching the appropriate amino acid ratio. The second method of formulation might tend to underestimate the lysine requirement because of possible decreased utilization of high levels of synthetic amino acids used in the diets containing higher levels of lysine. All diets contained 20% dried whey, 10% lactose, 7.5% spray-dried porcine plasma, 5.0% spray-dried wheat gluten, 5.0% select menhaden fish meal, 5.0% soybean oil, and 1.75% spray-dried blood meal.

Pigs were housed in an environmentally controlled nursery in which the temperature was maintained at approximately 94°F for the first week of the trial and lowered approximately 3°F per week to maintain pig comfort. Pens were 4 ft × 4 ft, with slatted metal flooring and contained a four-hole self-feeder and one nipple waterer to allow ad libitum access to food and water. Pigs were weighed and feed disappearance was determined on d 7, 14, 21, and 28 to calculate ADG, ADFI, and F/G.

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

Results

No lysine × formulation method interactions were observed for ADG or ADFI throughout the 28 d period (Table 2). However, a lysine × formulation method interactions were observed for F/G during d 0 to 7, d 0 to 14, and d 0 to 28. Because of these interactions, data are presented for each diet

formulation separately. From d 0 to 7 postweaning, ADG was improved (quadratic, P<.01) as dietary lysine increased, with ADG appearing to be maximized between 1.65 and 1.80% dietary lysine. Feed efficiency, from d 0 to 7 postweaning, was improved quadratically (P<.01) and linearly (P<.01) for the first and second diet formulations, with feed efficiency lowest for pigs fed 1.80% lysine for the first diet formulation method and for pigs fed 1.95% lysine for the second diet formulation method. From d 0 to 14 postweaning, ADG was improved (quadratic, P<.01) by increasing dietary lysine and was maximized at approximately 1.65% dietary lysine. A lysine × formulation method interaction was observed for F/G from d 0 to 14 with F/G being improved quadratically (P<.01) and linearly (P<.01) for the first and second diet formulations. For the overall experiment (d 0 to 28 postweaning), ADG and F/G were both improved (quadratic, P<.01) with increasing dietary lysine. However, ADFI was not affected during the 28-d experiment.

Discussion

Results from this experiment suggest that the dietary lysine requirement for the segregated early-weaned pig is greater than current National Research Council estimations. The NRC (1988) estimate for the 11 to 22 lb pig is 1.15% lysine. Also, the NRC (1988) suggests that a pig of this weight requires 5.3 g/d of lysine to support expected ADG, ADFI, and F/G of .55 lb, 1.01 lb, and 1.84, respectively. From d 0 to 14 postweaning (where pigs covered the weight range of 10.2 to 22.2 lb), approximately 6.2 g/d of lysine was required to support ADG, ADFI, and F/G of .88 lb, .84 lb, and .96, respectively. The performance of pigs in this research clearly shows the benefits of a segregated early-weaning program.

Average daily feed intake was not influenced by dietary lysine for the 28-d experiment. However, pigs in this research consumed 17% less feed than NRC estimates. Therefore, the increase in dietary lysine over NRC estimates may have been a function of lower feed intake and also a greater lysine need for protein deposition because pigs of high health status generally have lower protein catabolism. Also, pigs used in this research were considerably younger at 10 lb when compared to pigs used to set the current NRC requirements. Thus, health and genetic potential will dictate the lysine requirement to optimize growth performance of segregated early weaned pigs.

A lysine × formulation method interaction was observed for F/G for the 28-d experiment. This may have been the result of different utilization of the synthetic amino acids used in the two different diet formulation methods. In the first formulation method, amino acid imbalances may have occurred in pigs fed the lower lysine levels. As dietary lysine increased, the amino acid imbalances perhaps were minimized, resulting in improved efficiency with the second formulation method, each diet had the same ratio of other amino acids relative to lysine. Use of this formulation method should have avoided amino acid imbalances. However, data suggest that a higher lysine content was needed to reach maximum feed efficiency with this formulation procedure. This response is depicted in the following graph.

These data suggest that segregated early-weaned pigs require approximately 5.2 to 6.2 g/d of lysine from d 0 to 7 and d 0 to 14 postweaning to optimize growth performance. Formulation method had little influence on the response to dietary lysine. However, changes in feed efficiency suggest changes in nitrogen utilization with high levels of excess amino acids (formulation method #1) or high levels of synthetic amino acids (formulation method #2). Based on these results, the diet for pigs < 11 lb needs to be formulated to contain at least 1.7% lysine. The transition diet (11 to 15 lb) should be formulated to contain approximately 1.5 to 1.6% lysine.

Table 1. Composition of Experimental Diets

	Formulation 1[a]	Formulation 2[b], Lysine, %					
Item,	1.20 Lysine, %	1.20	1.35	1.50	1.65	1.80	1.95
Corn	38.93	39.23	39.23	39.23	39.23	39.23	39.23
Dried whey	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Lactose	10.00	10.00	10.00	10.00	10.00	10.00	10.00
SD porcine plasma	7.50	7.50	7.50	7.50	7.50	7.50	7.50
SD wheat gluten	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Fish meal	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Soybean oil	5.00	5.00	5.00	5.00	5.00	5.00	5.00
SD blood meal	1.75	1.75	1.75	1.75	1.75	1.75	1.75
Monocalcium P	1.73	1.73	1.73	1.73	1.73	1.73	1.73
Antibiotic[c]	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Cornstarch	.95	2.50	2.17	1.67	1.18	.59	.003
SBM, 46.5%	.52	.20	.20	.20	.20	.20	.20
L-isoleucine	.45		.09	.18	.270	.360	.454
L-threonine	.39		.001	.098	.196	.293	.391
Zinc oxide	.38	.38	.38	.38	.38	.38	.38
Limestone	.30	.30	.30	.30	.30	.30	.30
Vitamin premix	.25	.25	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15	.15	.15
DL-methionine	.21		.032	.078	.124	.17	.215
L-cystine	.20		.019	.064	.109	.154	.199
L-valine	.20					.096	.201
L-trypthophan	.10			.025	.052	.079	.106
L-lysine HCl	.002	.014	.204	.394	.585	.775	.965
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[a]Diet formulation #1 consisted of L-lysine replacing cornstarch to provide 1.35, 1.50, 1.65, 1.80, and 1.95% dietary lysine levels.
[b]Diet formulation #2 consisted of L-lysine, L-isoleucine, L-threonine, DL-methionine, L-cystine, L-valine, and L-trypthophan replacing cornstarch to maintain the same amino acid ratios relative to lysine within each dietary lysine level.
[c]Provided 50 g/ton carbodox.

Table 2. Performance of Pigs (16 ± 2 D) Fed Increasing Levels of Dietary Lysine with Two Diet Formulation Techniques[a]

	Formulation #1 Dietary Lysine, %						Formulation #2 Dietary Lysine, %						
Item	1.20	1.35	1.50	1.65	1.80	1.95	1.20	1.35	1.50	1.65	1.80	1.95	CV
d 0 to 7													
ADG, lb[bc]	.56	.67	.73	.75	.77	.71	.61	.70	.74	.77	.76	.83	12.2
ADFI, lb	.63	.64	.63	.62	.63	.63	.61	.69	.71	.69	.64	.68	11.0
F/G[def]	1.12	.96	.87	.84	.83	.89	1.00	.99	.96	.90	.85	.83	7.9
d 0 to 14													
ADG, lb[bc]	.63	.76	.82	.86	.86	.87	.73	.80	.84	.90	.87	.89	9.1
ADFI, lb	.81	.84	.82	.81	.82	.84	.84	.89	.91	.87	.84	.86	9.2
F/G[def]	1.29	1.10	.99	.95	.96	.97	1.15	1.11	1.08	.97	.98	.97	5.8
d 0 to 28													
ADG, lb[bc]	.88	1.03	1.08	1.09	1.08	1.09	.98	1.04	1.09	1.07	1.10	1.11	5.6
ADFI, lb	1.28	1.27	1.24	1.24	1.23	1.28	1.27	1.29	1.29	1.24	1.27	1.29	6.6
F/G[defg]	1.46	1.24	1.15	1.13	1.13	1.17	1.30	1.23	1.18	1.16	1.15	1.16	3.9

[a]Means represent a total of 320 pigs (average weight = 10.2 lb) with 4 pigs per pen and 6 replications per treatment. Pigs were 14 to 18 d of age and were PIC (L26 × C15).
[b]Quadratic effect of increasing dietary lysine (P<.01).
[c]Linear effect of increasing dietary lysine (P<.01).
[d]Lysine × formulation method interaction (P<.01)
[e]Linear effect of increasing dietary lysine for formulations 1 and 2 (P<.01).
[f]Quadratic effect on increasing dietary lysine for formulation 1 (P<.01).
[g]Quadratic effect on increasing dietary lysine for formulation 2 (P<.01).

Swine Day 1994

THE INFLUENCE OF INCREASING DIETARY METHIONINE ON THE PERFORMANCE OF THE EARLY-WEANED PIG (10 ± 4 D OF AGE)[1]

K. Q. Owen, J. L. Nelssen, R. D. Goodband, M. D. Tokach, S. S. Dritz, L. J. Kats, and B. T. Richert

Summary

Four hundred thirty-five pigs (initially 7.7 lb and 10.1 ± 4 d of age) were used to determine the influence of increasing dietary methionine on growth performance of the early-weaned pig (10 d of age). Pigs were blocked by weight in a randomized complete block design, resulting in six to 13 pigs per pen and a total of eight pens per treatment. Experimental diets were fed from d 0 to 21 postweaning. Dietary methionine levels were achieved by adding increasing liquid methionine (Alimet) to a common basal diet. The control diet was corn-based and contained 8.7% moist extruded soy protein concentrate, 10% spray-dried porcine plasma, 25% dried whey, 5% dried skim milk, 3% fish meal, and 1.75% spray-dried blood meal. All diets were formulated to contain 1.8% lysine. Liquid methionine replaced sucrose in the control diet to provide dietary methionine levels of .36, .40, .44, .48, .52, and .56%. Each diet contained .62% cystine and 704 g of added choline chloride (60%). During d 0 to 7 postweaning, average daily gain (ADG) and feed efficiency (F/G) were improved by increasing dietary methionine, with optimal performance observed between .48 and .52% dietary methionine. However, average daily feed intake (ADFI) was not affected by dietary methionine. For the entire period (d 0 to 21 postweaning), ADG and F/G were improved with increasing dietary methionine and optimized between .48 to .52% dietary methionine. On d 7 postweaning, plasma urea nitrogen was reduced as dietary methionine increased, with pigs fed the .52% methionine having the lowest plasma urea nitrogen concentrations. These data suggest that the early-weaned pig (10-d of age) needs approximately .48 to .52% dietary methionine when fed a diet containing 1.8% lysine to optimize growth performance.

(Key Words: Methionine, Starter Pigs, Growth.)

Introduction

Advances in high nutrient density diets has allowed the adoption of medicated and segregated early weaning as a common management technique. Segregated early weaning (SEW) involves weaning pigs at 5 to 10 days of age and moving the pigs to a site separate from the sow herd. This allows producers to break disease cycles from the sow to piglet, which substantially improves pig performance. Our limitation for the SEW diets is an understanding of the appropriate amino acid levels needed to optimize pig performance. Because high levels of spray-dried blood products (porcine plasma and blood meal) are utilized in this SEW diet, and blood products are deficient in methionine, this is often the first limiting amino acid. Previous research at Kansas State University has shown substantial improvements in performance of 21-d-old pigs when DL-

[1]The authors would like to thank Novus International, Inc., St. Louis, MO, for providing the liquid methionine and for partial funding of this research and to Feed Specialties Inc., Des Moines, IA, for donating the soy products. Appreciation also is expressed to Ellen Johncock and Eichman Brothers, St. George, KS, for use of pigs and facilities.

methionine was added to Phase I diets containing high levels of blood products. Therefore, the objective of this study was to determine the methionine requirement of the early-weaned pig (10-d of age).

Procedures

Four hundred thirty-five pigs (initially 7.7 ± 2.1 lb and 10.1 ± 4 d of age) were allotted randomly by weight to one of six dietary methionine treatments. For the first 21 d postweaning, pigs were fed diets containing either .36, .40, .44, .48, .52, or .56% dietary methionine (Table 1). The control diet was formulated to contain 1.8% lysine, .36% methionine, 1.0% Ca, and .90% P. Cornstarch was replaced by liquid methionine (Alimet, an 88% aqueous solution of DL-2-hydroxy-4-(methylthio) butanoic acid, DL-HMB) to achieve the experimental methionine levels. Because cystine can meet half the total sulphur amino acid requirement, cystine content of all diets was .67%. This exceeds the amount needed to meet the highest level of methionine (based on a 50:50 mixture of methionine and cystine). To ensure that methionine was the first limiting amino acid, dietary isoleucine, threonine, and tryptophan were maintained relative to lysine according to the ratio proposed by researchers at the University of Illinois. The levels of corn, moist extruded soy protein concentrate (8.7%), dried whey (25%), spray-dried porcine plasma (10%), dried skim milk (3%), and spray-dried blood meal (1.75%) were identical in all experimental diets.

Six to 13 pigs per pen were used in each block with six pens per treatment. Pigs were housed in an environmentally controlled nursery in 5 × 7 ft pens. Pens contained a four-hole self-feeder and one nipple waterer to allow ad libitum consumption of feed and water. Pigs were weighed and feed disappearance was measured on d 7, 14, and 21 after weaning to determine ADG, ADFI, and F/G. Blood samples were taken on d 7 and 14 postweaning to determine blood urea N.

Data were analyzed as a randomized complete block design. General linear model procedures were used with initial weight serving as the blocking factor. Orthogonal polynomial contrasts were used to determine linear and quadratic effects.

Table 1. Control Diet Composition, %[a]

Ingredient	Control
Corn	37.32
Soy protein concentrate	8.65
Dried whey	25.00
Spray-dried porcine plasma	10.00
Dried skim milk	5.00
Select menhaden fish meal	3.00
Soy oil	5.00
Monocalcium phosphate	1.87
Spray-dried blood meal	1.75
Antibiotic[b]	1.00
Limestone	.42
Vitamin premix	.25
Mineral premix	.15
Lysine, 98%	.10
Copper sulfate	.08
Cystine	.11
Choline chloride	.10
Cornstarch[c]	.20
Total	100.00

[a]Control diet (SEW) was formulated to contain 1.8% lysine, .36% methionine, 1.0% Ca and .90% P.
[b]Provided 50 g/ton apramycin.
[c]Liquid methionine (Alimet) replaced corn starch on a lb/lb basis to achieve the .40,.44, .48, .52, .56% dietary methionine experimental diets.

Results and Discussion

During d 0 to 7 postweaning, ADG and F/G were improved (linear, P<.01) by increasing dietary methionine, with optimal performance observed between .48 and .52% dietary methionine. However, ADFI was not

affected by dietary methionine. For the entire period (d 0 to 21 postweaning), ADG and F/G were improved (linear, P<.05) with increasing dietary methionine and optimized between .48 to .52% dietary methionine.

On d 7 postweaning, plasma urea nitrogen was reduced (quadratic, P<.10) as dietary methionine increased, with pigs fed the diet containing .52% methionine having the lowest plasma urea nitrogen concentrations. However, pigs fed .44% dietary methionine had the lowest blood urea nitrogen concentration on d 14 postweaning.

These data suggest that the early-weaned pig (d 10) needs approximately .48 to .52% dietary methionine when fed a diet containing 1.8% lysine to optimize growth performance. This implies that a methionine to lysine ratio of approximately 28% exists for the 10-d-old pig. This research adds to earlier results from our laboratory and the University of Illinois indicating that the optimal methionine to lysine ratio is approximately 28% for pigs from 7 to 40 lb. However, more work is needed to further address the requirements of other amino acids for the segregated early-weaned pig (d 10).

Table 2. Performance of Pigs Fed Increasing Levels of Dietary Methionine[a]

	Dietary methionine, %						
Item	.36	.40	.44	.48	.52	.56	CV
d 0 to 7							
ADG, lb[b]	.23	.26	.28	.30	.31	.31	22.6
ADFI, lb	.27	.27	.29	.28	.30	.30	13.8
F/G[b]	1.21	1.08	1.06	1.01	1.02	1.00	14.8
d 0 to 14							
ADG, lb[b]	.36	.40	.40	.44	.43	.43	14.1
ADFI, lb	.47	.48	.47	.49	.47	.48	9.2
F/G[b,d]	1.31	1.21	1.19	1.15	1.12	1.14	7.3
d 0 to 21							
ADG, lb[b]	.49	.53	.54	.55	.55	.57	7.6
ADFI, lb[c]	.62	.63	.65	.66	.64	.66	7.4
F/G[c]	1.29	1.20	1.22	1.23	1.20	1.18	7.2
Pig weight, lb							
d 0	7.78	7.80	7.75	7.83	7.77	7.75	1.1
d 7[b]	9.42	9.62	9.73	9.93	9.92	9.92	4.3
d 14[b]	12.83	13.42	13.32	13.95	13.81	13.81	5.8
d 21[b]	18.00	18.94	19.07	19.33	19.20	19.73	4.5

[a]Four hundred thirty-five weanling pigs (initially 7.6 lbs and 10.1 d of age) were used with 6 to 13 pigs/pen and 8 pens/treatment.
[b,c]Linear effect of dietary methionine (P<.01 and P<.10, respectively).
[d]Quadratic effect of dietary methionine (P<.10).

APPROPRIATE METHIONINE:LYSINE RATIO FOR THE SEGREGATED EARLY-WEANED PIG[1]

K. Q. Owen, R. D. Goodband, J. L. Nelssen, M. D. Tokach, S. S. Dritz, B. T. Richert, and K. G. Friesen

Summary

A total of 350 crossbred pigs (9.0 ± 2 d old and 8.4 lb +/- 2.5 BW) was used to determine the appropriate methionine:lysine ratio in diets for the segregated early-weaned pig. Two lysine levels (1.8 and 1.4%) and five methionine levels within each lysine level were used in a 2 × 5 factorial arrangement. Methionine:lysine ratios ranged from 21.5 to 33.5%. From d 0 to 21 postweaning, all diets contained 25% dried whey, 12% lactose, 7.5% spray dried porcine plasma, 6.0% select menhaden fish meal, and 1.75% spray-dried blood meal. The basal diets containing 1.4 and 1.8% lysine were formulated to contain .301 and .387% dietary methionine, respectively. Cornstarch was replaced by Alimet(equivalent to 88% methionine) to provide the four additional experimental methionine concentrations for each lysine level. Cystine contents of all diets within each lysine level were identical at .52 and .66% for the 1.4 and 1.8% lysine diets, respectively. All other amino acids were formulated on a digestible basis to ensure that methionine was first limiting. No methionine × lysine interactions were observed throughout the 21-day experiment. Increasing dietary methionine increased average daily gain (ADG) during each week of the trial, with the maximum observed at approximately .50 and .39% methionine in the diets containing 1.8 and 1.4% dietary lysine, respectively (27.5% of lysine). Dietary methionine level had no effect on feed efficiency (F/G). Increasing dietary lysine improved ADG and F/G. In conclusion, with either dietary lysine level used, maintaining methionine at 27.5% of lysine was required to maximize growth from d 0 to 21 postweaning.

(Key Words: Pigs, Growth, Methionine, Sulfur Amino Acids, Lysine.)

Introduction

Segregated early weaning involves weaning pigs at 5 to 10 d of age and moving the pigs to a site separate from the sow herd. This breaks the vertical transmission of disease from the sow to piglets, which substantially improves pig growth performance. Advances in nutrition, environmental regulation, and management techniques have allowed the adoption of segregated early weaning as a common management technique. The major limitation in diets for this age of pig is an understanding of the appropriate amino acid levels needed to optimize pig performance. Lysine is generally thought of as the first limiting amino acid in swine diets. However, previous research at Kansas State University reports that methionine becomes the first limiting amino acid in high nutrient dense diets containing spray-dried blood coproducts (porcine plasma and blood meal) because of their low methionine concentrations.

Therefore, the objective of this experiment was to determine the appropriate methi-

[1]Appreciation is expressed to Novus International, Inc., St. Louis, MO, for financial support and for the Alimet used in this experiment. Appreciation is also expressed to Newsham Hybrids, Colorado Springs, CO, for providing partial support and the pigs used in this research.

onine:lysine ratio needed to obtain optimal growth performance in the segregated early-weaned pig.

Procedures

Three hundred-fifty crossbred pigs (9.0 ± 2 d old and 8.4 lb) were allotted by weight, in a 2 × 5 factorial arrangement, to pens (4 ft × 4 ft) with tri-bar flooring. Blocks were based on initial weight, with five pigs per pen and seven replications (pens) per treatment. Pigs were housed in an environmentally regulated nursery in which the initial temperature (94°F) was reduced by 5°F each week. Pens contained a four-hole self-feeder and one nipple waterer to allow ad libitum consumption of feed and water.

Treatments were arranged in a 2 × 5 factorial arrangement with two lysine levels (1.4 and 1.8%) and five methionine:lysine ratios (21.5, 24.5, 27.5, 30.5, and 33.5%). A control diet was formulated for each lysine level (1.4 and 1.8%). Soybean meal content was increased to formulate the 1.8% lysine diet. The control diet with 1.4% lysine was formulated to contain .301% methionine (.25% digestible), .52% cystine, .90% Ca, and .80% P. The diet with 1.8% lysine contained .387% methionine (.33% digestible), .66% cystine, .90% Ca, and .80% P. Cornstarch was replaced by Alimet (an 88% aqueous solution of DL-2-hydroxy-4- (methylthio) butanoic acid, DL-HMB) to provide the four additional experimental methionine concentrations for each lysine level (.301, .343, .385, .427, and .469% at 1.4% lysine and .387, .441, .495, .549, and .603% at 1.8% lysine). Cystine contents of all diets within each lysine level were identical. Dietary isoleucine, threonine, and tryptophan were maintained relative to lysine according to a ratio proposed for the 20- to 40-lb pig. Additionally, choline chloride was supplemented to all diets at .10%. All diets contained 25% dried whey, 12% lactose, 7.5% spray dried porcine plasma, 6.0% select menhaden fish meal, and 1.75% spray-dried blood meal. Pigs and feeders were weighed on d 7, 14, and 21 to determine ADG, ADFI, and F/G.

Data were analyzed as a randomized complete block design in a 2 × 5 factorial arrangement. Data were analyzed for methionine × lysine interactions. Analysis of variance was performed using the GLM procedure of SAS, and linear and quadratic polynomials were evaluated.

Results and Discussion

No methionine × lysine interactions were observed for any of the response criteria during the 21-day experiment (Table 2). From d 0 to 7 postweaning, increasing dietary methionine increased (quadratic, P<.01) ADG and ADFI regardless of dietary lysine. Inflection point analysis projected maximum ADG at a methionine:lysine ratio of 27%. Increasing dietary lysine improved (P<.01) ADG and F/G from d 0 to 7 postweaning, with pigs fed 1.8% lysine having 10 and 7% greater ADG and F/G, respectively, than those fed 1.4% lysine.

From d 0 to 14 postweaning, increasing dietary methionine improved ADG (quadratic, P<.01), ADFI (quadratic, P<.01), and F/G (linear, P = .11). Inflection point analysis projected maximum ADG at a methionine to lysine ratio of 27 and 27.5% for pigs fed the 1.4 and 1.8% lysine treatments, respectively. Cumulative (d 0 to 21 postweaning) ADG (quadratic, P<.01), ADFI (quadratic, P<.05), and F/G (quadratic, P<.05) were improved by increasing dietary methionine. Inflection point analysis projected maximum ADG at a methionine to lysine ratio of 28% for pigs fed either 1.4 or 1.8% lysine and maximum F/G at a ratio of 28.2% for pigs on the 1.8% lysine treatment. Increasing dietary lysine improved ADG (P<.01) and F/G (P<.01) from d 0 to 14 and for the overall experiment.

These data agree with earlier research conducted at Kansas State University on the appropriate methionine requirement for the Phase I and Phase II diets (Swine Day, 1993). Additionally, the methionine:lysine

ratio is similar to the ratio suggest by researchers at the University of Illinois. In conclusion, these data suggest that the early weaned pig requires a methionine:lysine ratio of approximately 27.5 to 28% to optimize growth performance.

Table 1. Composition of Basal Diets[a]

	Dietary lysine, %	
Item, %	1.4	1.8
Corn	25.22	35.20
Soybean meal (48% CP)	13.5	3.74
Dried whey	25.00	25.00
Spray-dried porcine plasma	7.50	7.50
Select Menhaden fish meal	6.00	6.00
Lactose	12.00	12.00
Soybean oil	5.00	5.00
Monocalcium phosphate	1.26	1.43
Spray-dried blood meal	1.75	1.75
Limestone	.13	.17
Mineral premix	.15	.15
Vitamin premix	.25	.25
L-lysine•HCl	.27	.10
Antibiotic[b]	1.00	1.00
Copper sulfate	.08	.08
Corn starch[c]	.22	.17
Alimet	.04	-
L-Isoleucine	.10	.05
L-cystine	.22	.25
L-threonine	.15	.02
Choline chloride (60%)	.10	.10
L-Tryptophan	.06	.04
Total	100.00	100.00

[a]Diets were formulated to contain either .387 or .301% dietary methionine (1.4 and 1.8% lysine, respectively) and .9 Ca, and .8% P from d 0 to 21 postweaning.
[b]Provided 50 g/ton carbadox.
[c]Alimet replaced cornstarch on a lb/lb basis to provide .343, .385, .427 and .469% dietary methionine in the 1.4% lysine diet and .441, .495, .549, and .603% dietary methionine in the 1.8% lysine diet.

Table 2. Performance of Pigs Fed Increasing Dietary Methionine at Two Lysine Levels[a]

		1.8% Lysine					1.4% Lysine					
	Met., %	.387	.441	.495	.549	.603	.301	.343	.385	.427	.469	
Item	Met:lys, %	21.5	24.5	27.5	30.5	33.5	21.5	24.5	27.5	30.5	33.5	CV
d 0 to 7												
ADG,lb[bf]		.45	.50	.54	.46	.45	.42	.44	.45	.47	.40	17.2
ADFI,lb[b]		.42	.45	.48	.43	.42	.41	.45	.43	.46	.39	14.5
F/G[f]		.94	.92	.89	.94	.94	.98	1.04	.99	.98	.99	9.5
d 0 to 14												
ADG,lb[bf]		.63	.68	.73	.68	.66	.56	.60	.64	.65	.60	10.4
ADFI, lb[b]		.66	.69	.72	.67	.68	.65	.70	.71	.73	.67	9.7
F/G[ef]		1.07	1.01	.99	.98	1.03	1.17	1.17	1.12	1.13	1.12	5.6
d 0 to 21												
ADG, lb[bdf]		.77	.84	.88	.83	.82	.71	.76	.82	.82	.77	6.8
ADFI, lb[c]		.89	.90	.91	.87	.87	.86	.91	.94	.96	.88	7.7
F/G[cdf]		1.15	1.07	1.04	1.05	1.07	1.21	1.19	1.15	1.16	1.15	4.5

[a]Three hundred fifty weanling pigs (initially 8.4 lb and 9.0 ± 2 d old) were used with 5 pigs per pen and 7 pens per treatment.
[bc]Quadratic effect of dietary methionine (P<.01 and .05, respectively).
[de]Linear effect of dietary methionine (P<.01 and = .10).
[f]Lysine effect (P<.01).

THE EFFECTS OF INCREASING DIETARY LYSINE IN THE PHASE III STARTER DIET ON GROWTH PERFORMANCE OF SEGREGATED EARLY-WEANED PIGS[1]

K. Q. Owen, R. D. Goodband, J. L. Nelssen, M. D. Tokach, J. R. Bergstrom, K. G. Friesen, J. W. Smith, II, and B. T. Richert

Summary

One hundred forty-four high-health, high-lean growth barrows were used to determine the dietary lysine requirement to maximize growth performance from 40 to 75 lb. The experiment was designed as a randomized complete block, with blocks established on initial weight. Prior to the start of the study, pigs were fed a common Phase II diet (1.4% lysine) for 14 d. After the 14 d acclimation period, pigs were allotted to each of six dietary treatments, ranging from .75 to 1.25% digestible lysine (.91 to 1.49% total dietary lysine). Pigs were housed in pens of four, with six replicate pens per treatment. Pig weights and feed disappearance were measured on d 7, 14, and 21 of the experiment to calculate average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G). Average daily gain increased with increasing dietary lysine from 40 to 75 lb, with a maximum observed at approximately 1.25 to 1.37% total lysine. Average daily feed intake from 40 to 75 lb was not influenced by dietary lysine. Increasing dietary lysine resulted in improved F/G, with pigs fed between 1.25 and 1.37% lysine having the best F/G. Based on the feed intake observed in this study, high-lean growth barrows that have been segregated early-weaned to improve health status require at least 16 to 17 g/d of lysine from 40 to 75 lb to maximize ADG and F/G. These requirements for the Phase III starter diet are substantially higher than previously recommended.

(Key Words: Pigs, Growth, Genotype, Lysine.)

Introduction

Previous research at Kansas State University has indicated that high-lean growth pigs have a greater dietary lysine requirement compared with medium-lean growth pigs. Furthermore, gilts of a high-lean growth potential require approximately 1.15% dietary lysine (approximately 18 g/d) from 80 to 120 lb. This requirement presents some unique diet formulation problems, because many current lysine recommendations are 1.10 to 1.15% for pigs from 25 to 50 lb. If requirements for 90 to 120 lb gilts are approximately 1.15%, perhaps the intense selection for lean tissue deposition also has increased the lysine requirement of the lighter pig. In addition, research from Iowa State University has demonstrated that the dietary lysine requirement is higher in pigs that have been segregated early-weaned to enhance health status. Therefore, the objective of this experiment was to determine the dietary lysine requirement of high-health, high-lean growth pigs from 40 to 75 lb.

[1]We would like to acknowledge Nutri-Quest Inc. and BioKyowa Inc., St. Louis, MO, for partial financial and amino acid support for this project. Appreciation also is expressed to Newsham Hybrids, Colorado Springs, CO, for partial financial support and for the pigs used in this project.

Procedures

A total of 144 (45 d old barrows) pigs was used to determine the appropriate dietary lysine requirement of pigs weighing from 40 to 75 lb. Pigs were early weaned at 7 days of age and fed high nutrient dense diets from weaning to 25 lb. After pigs reached 25 lb, they were fed a common diet (1.4% lysine, 2.5% spray-dried blood meal, and 10% dried whey) for 10 days. At this time, pigs were weighed and blocked by weight and allotted to each of six dietary treatments. Pigs were allowed another 4-day adjustment period (where they remained on the common diet) to permit social acclimation. Four pigs per pen and six pens per treatment were used.

Dietary treatments were fed for a 21-d period starting when the pigs were approximately 45 d of age and weighed 40 +/- .6 lb. Digestible lysine levels were .75, .85, .95, 1.05, 1.15, and 1.25%, with corresponding total lysine levels of .90, 1.02, 1.14, 1.25, 1.37, and 1.49% (Table 1). All diets were formulated on a digestible amino acid basis, with all amino acids other than lysine formulated to meet or exceed suggested requirements. L-lysine HCl was fixed at .15% of the diet and soybean meal was adjusted to increase dietary lysine concentrations.

Pigs were housed in an environmentally regulated nursery in which the initial temperature (80°F) was reduced by 3°F each week. Pens (4 ft × 4 ft) contained a four-hole self-feeder and one nipple waterer to allow ad libitum consumption of feed and water. Pigs and feeders were weighed on d 7, 14 and 21 of the experiment to calculated ADG, ADFI, and F/G.

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

Results

From d 0 to 7 of the experiment, ADG and F/G were improved (linear, $P<.01$) with increasing digestible lysine (Table 2). Pigs fed the highest level of digestible lysine had 20% higher ADG and 20% better F/G ratio than pigs fed the lowest level of digestible lysine (which is close to the current NRC, 1988 estimates). Increasing digestible lysine improved ADG and F/G (quadratic, $P<.01$) from d 0 to 14 and for the overall trial (d 0 to 21). However, ADFI was not influenced ($P>.10$) by dietary lysine at any point during the experiment.

Discussion

The results of this experiment indicate that the dietary lysine requirement to optimize growth performance for the high-health, high-lean growth barrow is greater than current National Research Council estimates for conventionally reared pigs. Although ADG and F/G improved linearly over the first 7 d of the experiment, overall (d 0 to 21) ADG and F/G appeared to plateau for barrows fed 1.05% digestible lysine (1.25% total lysine). Our original objective was to evaluate lysine requirements for 25- to 50-lb pigs. However, because initial starting weights were heavier than anticipated, data for the first 7 d of the experiment represent the weight period from 40 to 50 lb, which is closest to the weight period for the Phase III diet. Data for the first 7 d show that performance was maximized for pigs fed at least 1.25% digestible lysine (1.49% total lysine), suggesting that current lysine recommendations for the Phase III diet need to be increased to ensure that high-health, segregated early-weaned pigs get at least 16 g/d of lysine. These data represent a 2.75 g/d (11%) increase above NRC estimates. During the next 14 d of the experiment (pig weight period of 50 to 75 lb), performance was influenced quadratically as digestible lysine increased, with pigs fed 1.05% digestible lysine (1.25% total lysine) appearing to have the best ADG and F/G. Based on a

practical phase-feeding program, this lysine level corresponds with earlier research at Kansas State University using high-lean growth gilts from 80 to 120 lb. This research demonstrated that .94% digestible lysine (1.15% total lysine) is needed to optimize protein deposition. Also, as seen in earlier work with high-lean growth gilts, ADFI was not influenced by dietary lysine. However, barrows in this experiment consumed approximately 3.0 lb of feed/d from 40 to 75 lb. This ADFI is lower than current NRC estimates, indicating that much of the higher lysine requirement is a function of feed intake. The higher requirement also is needed for the greater demand for protein synthesis in high-health, high-lean pigs.

In summary, the lysine requirements for pigs of high-lean growth genetics that have been segregated early-weaned to improve health status exceed current recommendations. The results suggest that high-health, high-lean growth barrows require at least 16 to 17 g/d (1.25% to 1.35% total lysine) of lysine to optimize growth performance when fed from 40 to 75 lb.

Table 1. Diet Composition

	Digestible lysine, %					
Ingredient,%	.75	.85	.95	1.05	1.15	1.25
Corn	72.30	68.35	64.38	60.41	56.44	52.47
Soybean meal, (48.5% CP)	19.48	23.49	27.50	31.52	35.53	39.54
Soybean oil	3.00	3.00	3.00	3.00	3.00	3.00
Monocalcium phosphate (21% P)	2.24	2.17	2.10	2.03	1.96	1.89
Antibiotic[a]	1.00	1.00	1.00	1.00	1.00	1.00
Limestone	.96	.948	.93	.92	.90	.89
Salt	.35	.35	.35	.35	.35	.35
Vitamin premix	.25	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15	.15
L-Lysine HCl	.15	.15	.15	.15	.15	.15
Copper sulphate	.075	.075	.075	.08	.103	.12
L-threonine	.036	.048	.070	.075	.075	.075
L-tryptophan	.004	.014	.026	.038	.05	.061
DL-methionine	.003	.002	.017	.031	.045	.059
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated analysis, %						
Crude protein	15.74	17.35	18.97	20.58	22.19	23.80
Total lysine	.91	1.02	1.14	1.25	1.37	1.49
Ca	.90	.90	.90	.90	.90	.90
P	.80	.80	.80	.80	.80	.80

[a]Provided 50 g/ton carbodox.

Table 2. Performance of Pigs Fed Increasing Levels of Dietary Lysine from 40 to 75 lb[a]

	Digestible lysine, %[b]						
Item	.75	.85	.95	1.05	1.15	1.25	CV
d 0 to 7							
ADG, lb[c]	1.32	1.37	1.52	1.58	1.61	1.65	8.7
ADFI, lb	2.29	2.26	2.33	2.28	2.33	2.33	7.4
F/G[c]	1.76	1.66	1.54	1.45	1.47	1.41	8.8
d 0 to 14							
ADG, lb[cd]	1.48	1.53	1.62	1.73	1.76	1.71	4.6
ADFI, lb	2.67	2.71	2.66	2.71	2.71	2.73	4.7
F/G[cd]	1.81	1.77	1.64	1.57	1.54	1.59	3.7
d 0 to 21							
ADG, lb[cd]	1.52	1.61	1.64	1.71	1.73	1.69	4.4
ADFI, lb	2.87	3.02	2.91	2.96	2.95	3.04	5.3
F/G[cd]	1.89	1.88	1.77	1.73	1.70	1.79	3.7

[a]One hundred forty four pigs were used (initially 40.1 lb and 44 d of age), 4 pigs/pen and 6 replications/treatment.
[b]Corresponding total lysine levels are: .90, 1.02, 1.14, 1.25, 1.37, and 1.49%.
[c]Linear effect of dietary lysine (P<.01).
[d]Quadratic effect of dietary lysine (P<.01).

EFFECTS OF ALTERNATIVE SOY SOURCES ON GROWTH PERFORMANCE IN EARLY-WEANED PIGS

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Summary

A total of 144 pigs (initial body wt of 10.4 lb) was used in a 56-d growth assay to determine the effects of different soybean preparations on growth performance and cost of gain in nursery pigs. Experimental diets were fed in three phases from d 0 to 35 postweaning (i.e., d 0 to 7, 7 to 21, and 21 to 35). Treatments were a soybean meal-based regimen; a dry-extruded whole soybeans (mill-run) regimen; and a specially processed soy products regimen (i.e., soy isolate in Phase I, soy concentrate in Phase II, and extruded soy flour in Phase III). All diets were formulated to 1.55, 1.25, and 1.15% lysine for Phases I, II, and III, respectively. Fat additions to the soybean meal and specialty soy product treatments were 2, 2, and 3%, for Phases I, II, and III, respectively. The diets with extruded soybeans had more total fat (2.5, 3.8, and 4.8% greater percentage ether extract in Phases I, II, and III, respectively) than the soybean meal-based control. On d 35 postweaning, the pigs were switched to the same soybean meal-based grower diet (.9% lysine) for a period of 3 wk. During Phase I (d 0 to 7 postweaning), pigs fed soybean meal gained 25% less and were 22% less efficient than those fed extruded soybeans and the specially processed soy products. Average daily feed intake was not affected by dietary treatment; however, pigs fed the specially processed soy product had the greatest ADG of any treatment, and numerically, the best efficiencies of gain. No statistical differences were found for ADG, ADFI, or F/G among treatments from d 7 to 21, 21 to 35, or 35 to 56 of the experiment. Thus, overall (from d 0 to 56 postweaning), pigs fed the various soybean protein sources had similar growth performance. However, overall costs per pound of gain were $.33, $.34, and $.42 for pigs fed extruded soybeans, soybean meal, and the specialty soy products, respectively. In conclusion, although the specially processed soy products regimen (i.e., soy isolate) supported the greatest growth performance immediately after weaning (d 0 to 7), the best cost of gain was achieved by feeding extruded soybeans. However, the additional fat provided by extruded soybeans did not influence pig performance in this experiment.

(Key Words: Pigs, Soybeans, Extrusion, Growth, Cost of Gain.)

Introduction

To avoid the high costs of milk products and the antinutritional factors found in soybean meal, many nutritionists and livestock feeders have elected to use specially processed soybean products in diets for weanling pigs and calves. In the past few years at Kansas State University, several research projects have been conducted to identify the soybean source that gives the best performance in newly weaned pigs. Jones et al. (p 54, 1989 KSU Swine Day) reported that specially processed soy protein isolate was of similar nutritional value, with a much lower cost, compared to the proteins from dried skim milk and dried whey. More recently, Hancock et al. (p 40, 1991 KSU Swine Day) observed equal or greater growth performance (depending on soybean genotype) when soybean meal and soy oil in a nursery diet were replaced with dry-extruded whole soybeans. However, use of extruded whole soybeans to replace soybean meal adds con-

siderably more fat than we currently recommend (i.e., 2 to 3% added fat) for nursery diets, and previous research at KSU (p 77, 1989 KSU Swine Day) indicated no benefit from high-fat nursery diets fed immediately after weaning. Therefore, the objective of this experiment was to evaluate the nutritional value of highly refined soybean products, extruded whole soybeans, and soybean meal and to determine the consequences of these soybean products on cost of gain during the nursery phase.

Procedures

A total of 144 pigs (initial body wt of 10.4 lb) was used in a 56-d growth assay. The pigs were blocked by weight and assigned to three treatments based on sex and ancestry. There were six pigs per pen and eight pens per treatment. The experimental diets were fed in three phases (d 0 to 7, 7 to 21, and 21 to 35) from d 0 to 35 postweaning. Treatments were a soybean meal-based regimen; a dry-extruded whole soybeans regimen; and a specially processed soy products regimen (i.e., soy isolate in Phase I, soy concentrate in Phase II, and extruded soy flour in Phase III). The extruded soybeans were mill-run and prepared with dry extrusion using an Instra-Pro® extruder. Barrell temperature during extrusion was 297.7°F. Phase I diets (Table 1) were formulated to 1.55% lysine and .44% methionine with 20% dried whey, 10% lactose, 2% spray-dried blood meal, and 8% porcine plasma protein. Phase II diets (Table 2) were formulated to 1.25% lysine and .35% methionine with 20% dried whey and 2% spray-dried blood meal. Phase III diets (Table 3) were formulated to 1.15% lysine and .32% methionine. Fat additions to the soybean meal and specialty soy product treatments were 2, 2, and 3% for Phases I, II, and III. These are the fat additions we normally recommend. The diets with extruded soybeans had more total fat (2.5, 3.8, and 4.8% greater percentages ether extract in Phases I, II, and III, respectively) than the soybean meal-based control diet, but these had surprisingly small effects on calculated metabolizable energy (ME) concentrations of the diets (Tables 1, 2, and 3). Thus, one of our objectives was to determine if the extra fat from practical diets with extruded soybeans would affect growth performance. The diets for all three phases were fed in pelleted form. On d 35 postweaning, the pigs were switched to the same soybean meal-based grower diet (Table 3) for a period of 3 wk. The grower diet was formulated to .9% lysine, .7% Ca, and .6% P and was fed in meal form.

The pigs were housed in an environmentally controlled nursery room for the nursery experiment and transferred to a grower facility for the growing phase. The temperature was maintained at approximately 90°F for the first week of the experiment and reduced by 5°F per week thereafter. The pigs had ad libitum access to feed and water. Weight gain and feed disappearance were recorded on d 7, 21, 35, and 56 of the experiment to allow calculation of ADG, ADFI, and F/G.

Results and Discussion

During Phase I (d 0 to 7 postweaning), pigs fed soybean meal gained 25% less and were 22% less efficient than those fed extruded soybeans and the specially processed soy products ($P<.001$). Average daily feed intake was not affected by dietary treatment; however, pigs fed the specially processed soy product had the greatest ADG of any treatment ($P<.001$) and, numerically, the best efficiency of gain (improvements of 35 and 26% for ADG and F/G, respectively, compared to the soybean meal-based control).

No differences were found among treatments ($P>.2$) for ADG, ADFI, or F/G from d 7 to 21, 21 to 35, or 35 to 56 of the experiment. Thus, overall (from d 0 to 56 postweaning), pigs fed the various soybean protein sources had similar growth performance. However, cost of gain was different. The average cost of nursery diets with extruded soybeans was 2 and 26% less than that of diets with soybean meal and specially processed soy products (using ingredient costs of $235.20/ton for soybean meal, $213.67/ton for soybeans, $20/ton for extrusion cost, $770/ton for soy protein isolate, $580/ton for soy protein concentrate, $290/ton for soy

flour, and $35.60/cwt for soybean oil). For d 0 to 7, cost per pound of gain was lowest for pigs fed extruded soybeans, but for d 0 to 35, cost of gain was identical for pigs fed extruded soybeans and soybean meal. Pigs fed the specially processed soy products had relatively high cost of gain for d 7 to 21 and 21 to 35, resulting in the greatest cost of gain for the overall nursery phase (i.e., d 0 to 35). For d 0 to 56, cost of gain for pigs fed extruded whole soybeans was 3% less than that for pigs fed soybean meal and 27% less than that for pigs fed the specially processed soy products. We should note, however, that the overall advantage in cost of gain for pigs fed extruded soybeans compared to soybean meal resulted from differences for d 35 to 56 while the animals were fed the same diet. Whether this was a carryover effect from d 0 to 35 or simply a chance effect will require further investigation.

In conclusion, the best cost of gain was achieved by feeding extruded soybeans, although the greater fat concentration in these diets did not greatly increase calculated ME or improve efficiency of gain as one might expect. Feeding the specially processed soy products (i.e., soy isolate) during Phase I did improve growth performance of weanling pigs, but for the overall nursery period, the specially processed soy products had the greatest cost of gain. Thus, decisions on which soy product(s) to include in nursery diets should be made by considering the value of differences in early growth performance and the cost of the various soy products at any particular time.

Table 1. Diets for Phase I, %[a]

Item	Soybean meal	Extruded soybeans	Specialty products[b]
Corn	35.08	27.78	43.32
Dried whey	20.00	20.00	20.00
Soybean meal	18.56	--	--
Extruded soybeans	--	27.86	--
Soy isolate	--	--	10.10
Lactose	10.00	10.00	10.00
Porcine plasma protein	8.00	8.00	8.00
Soybean oil	2.00	--	2.00
Blood meal	2.00	2.00	2.00
Monocalcium phosphate	1.97	1.83	2.05
Limestone	.65	.78	.82
Vitamins and minerals premix[c]	.40	.40	.40
L-lysine HCl	.10	.10	.10
DL-methionine	.16	.17	.13
Copper sulfate	.08	.08	.08
Antibiotic[d]	1.00	1.00	1.00
Calculated analysis			
CP, %	21.5	21.7	22.1
Ether extract, %	3.9	6.4	4.1
ME, kcal/lb	1,463	1,479	1,480

[a]Phase I diets were formulated to 1.55% lysine, .44% methionine, .9% Ca, and .8% P.
[b]Specialty products were soy isolate for Phase I, soy concentrate for Phase II, and soy flour for Phase III.
[c]KSU vitamin and mineral premixes.
[d]Provided 150 g/ton of apramycin.

Table 2. Diets for Phase II, %[a]

Item	Soybean meal	Extruded soybeans	Specialty products
Corn	48.12	38.84	54.63
Dried whey	20.00	20.00	20.00
Soybean meal	23.72	--	--
Extruded soybeans	--	35.00	--
Soy concentrate	--	--	16.58
Soybean oil	2.00	--	2.00
Blood meal	2.00	2.00	2.00
Monocalcium phosphate	1.68	1.52	2.32
Limestone	.74	.89	.74
Vitamin and mineral premix	.40	.40	.40
L-lysine HCl	.10	.10	.10
DL-methionine	.06	.07	.05
Copper sulfate	.08	.08	.08
Salt	.10	.10	.10
Antibiotic[b]	1.00	1.00	1.00
Calculated analysis			
CP, %	19.3	19.5	19.7
Ether extract, %	4.3	8.1	4.4
ME, kcal/lb	1,478	1,509	1,503

[a]Phase II diets were formulated to 1.25% lysine, .35% methionine, .9% Ca, and .8% P.
[b]Provided 50g/ton of carbadox.

Table 3. Diets for Phase III and the Common Grower Diet, %[a]

Item	Soybean meal	Extruded soybeans	Specialty products	Grower
Corn	64.49	54.52	66.11	67.91
Soybean meal	28.62	--	--	24.26
Extruded soybeans	--	41.56	--	--
Extruded soy flour	--	--	26.80	--
Soybean oil	3.00	--	3.00	5.00
Monocalcium phosphate	1.59	1.43	1.69	1.20
Limestone	.90	1.08	1.02	.88
Vitamin and mineral premix	.40	.40	.40	.40
L-lysine HCl	.10	.10	.10	--
DL-methionine	.02	.03	--	--
Copper sulfate	.08	.08	.08	--
Salt	.30	.30	.30	.30
Antibiotic	.50[b]	.50[b]	.50[b]	.05[c]
Calculated analysis				
CP, %	19.6	20.0	19.8	17.1
Ether extract, %	5.7	10.5	5.7	7.8
ME, kcal/lb	1,539	1,576	1,500	1,590

[a]Phase III diets were formulated to 1.15% lysine, .32% methionine, .8% Ca, and .7% P. The common grower diet was formulated to .9% lysine, .7% Ca, and .6% P.
[b]Provided 100, 100, and 50 g/ton of chlortetracycline, sulfathiazole, and penicillin, respectively.
[c]Provided 40 g/ton of tylosin.

Table 4. Effects of Soy Sources on Growth Performance of Early-Weaned Pigs[a]

Item	Soybean meal	Extruded soybeans	Specialty products	CV
d 0 to 7				
ADG, lb[b,c]	.46	.53	.62	10.7
ADFI, lb	1.03	.97	1.03	12.1
F/G[b]	2.23	1.83	1.66	19.0
d 7 to 21				
ADG, lb	.70	.70	.65	14.0
ADFI, lb	1.38	1.53	1.41	7.0
F/G	1.97	2.18	2.17	21.5
d 21 to 35				
ADG, lb	1.16	1.08	1.08	10.9
ADFI, lb	2.27	2.13	2.38	15.9
F/G	1.82	1.97	2.20	15.1
d 0 to 35				
ADG, lb	.77	.77	.78	9.9
ADFI, lb	1.56	1.47	1.60	9.4
F/G	2.03	1.91	2.05	12.2
d 35 to 56				
ADG, lb	1.31	1.37	1.35	9.4
ADFI, lb	3.58	3.66	3.63	6.6
F/G	2.73	2.67	2.69	10.4
d 0 to 56				
ADG, lb	.91	.92	.93	7.3
ADFI, lb	2.06	2.08	2.11	3.5
F/G	2.26	2.26	2.27	6.8
Diet cost/ton, $				
Phase I	752.40	745.49	872.34	--
Phase II	416.80	409.95	558.72	--
Phase III	287.60	275.51	373.84	--
Grower	195.72	195.72	195.72	--
Cost/lb of gain, $				
d 0 to 7[d]	.84	.68	.72	17.6
d 7 to 21[e,f]	.41	.45	.61	24.2
d 21 to 35[e,f]	.26	.27	.41	22.4
d 0 to 35[f]	.39	.39	.52	13.8
d 35 to 56	.27	.26	.26	15.0
d 0 to 56[d,f]	.34	.33	.42	12.8

[a]One hundred and forty four weanling pigs were used (initial body wt of 10.4 lb) with six pigs per pen and eight pens per treatment.
[b,d,e]Soybean meal vs others (P<.001, .01, and .05, respectively).
[c,f]Extruded soybeans vs specialty products (P<.001 and .05, respectively).

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ROASTING AND EXTRUDING AFFECT NUTRIENT UTILIZATION FROM SOYBEANS IN 10- AND 20-LB PIGS

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

Summary

Ninety nursery pigs were used in two metabolism experiments to determine the effects of roasting and extruding on the nutritional value of Williams 82 soybeans with (+K) and without (-K) gene expression for the Kunitz trypsin inhibitor. Treatments for both experiments were: 1) soybean meal; 2) +K roasted; 3) +K extruded; 4) -K roasted; and 5) -K extruded. The roasting and extrusion treatments were accomplished with a Roast-A-Tron® roaster and an Insta-Pro® extruder. Diets were the soybean preparations (96.5% of the diet) with only vitamins and minerals added as needed to meet or exceed NRC requirements. Daily feed allowance was 5% of initial body wt given as three equal meals. In Exp. 1, 50 weanling pigs (10.4 lb average body wt and 21 d average age) were used. Apparent values for N digestibility, biological value (BV), percentage N retention, gross energy (GE) digestibility, and metabolizable energy (ME) were greater for pigs fed extruded soybeans compared to pigs fed roasted soybeans. Also, N digestibility, BV, and percentage N retention were greater for pigs fed -K soybeans compared to those fed +K soybeans. In Exp. 2, 40 pigs (21.4 lb average body wt and 35 d average age) were allowed to adjust to the nursery environment before use in the experiment. In general, the pigs in Exp. 2 (i.e., the older pigs) had greater utilization of nutrients from all of the soybean products than the younger pigs used in Exp. 1. Digestibilities of DM, N, and GE were greater for pigs fed -K soybeans compared to those fed +K soybeans, and extruded soybeans gave greater digestibilities of DM, N, and GE compared to roasted soybeans. Also, percentage N retention and percentage ME were greater for pigs fed extruded soybeans were greater than for pigs fed roasted soybeans. In conclusion, extruded and -K soybeans were of greater nutritional value than roasted and +K soybeans for 10- and 20-lb nursery pigs.

(Key Words: Pig, Soybean, Roast, Extrude, Metabolism, Nitrogen Retention.)

Introduction

The major constituent that is believed to limit the nutritional value of raw soybeans is a group of small proteins collectively called trypsin inhibitors. Previous research at KSU (Reports of Progress No. 610, page 52 and No. 641, page 40) indicated that pigs fed soybeans without the Kunitz trypsin inhibitor grew faster than pigs fed soybeans with the Kunitz trypsin inhibitor. In other experiments, extrusion processing was superior to roasting for maximizing growth performance and nutrient digestibility in weanling pigs. However, the quantitative effects of roasting and dry extrusion on nutrient utilization (e.g., biological value and metabolizable energy) remain to be determined. Thus, the objectives of the experiments reported herein were to determine the effects of roasting and extruding on the nutritional value of Williams 82 soybeans with (+K) or without (-K) gene expression for the Kunitz trypsin inhibitor on nursery pigs of various ages.

Procedures

Williams 82 soybeans with (+K) and without (-K) gene expression for the Kunitz trypsin inhibitor were either roasted or ex-

truded and compared to a soybean meal-based control diet (Table 1). The roasting and extrusion treatments were those deemed usual for soybean processing (i.e., a throughput of approximately 1,000 lb/h and an average exit temperature of 270°F in a Roast-A-Tron® roaster vs a throughput of approximately 1,500 lb/h and an average barrel temperature of 325°F in an Insta-Pro® dry-extruder). Treatments were: 1) soybean meal; 2) +K roasted; 3) +K extruded; 4) -K roasted; and 5) -K extruded. Diets were the soybean preparations with only vitamins and minerals added as needed to meet or exceed NRC (1988) requirements. Chromic oxide was added as .25% of the diets to serve as an indigestible marker.

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

Item	%
Soybean meal[a]	96.49
Monocalcium phosphate	.86
Limestone	1.40
Salt	.30
KSU vitamin premix	.25
KSU mineral premix	.15
KSU selenium premix	.05
Antibiotic[b]	.50
Total	100.00

[a]Roasted and extruded +K and -K soybeans were added in place of soybean meal.
[b]Provided the following per ton of complete diet: 100 g of chlortetracycline, 100 g of sulfathiazole, and 50 g of penicillin.

For Exp. 1, 50 weanling pigs (10.4 lb average body wt) were used in a 10-d metabolism experiment. The pigs were housed in individual cages equipped with woven-wire flooring, and the room was environmentally controlled. The pigs were fed dried skim milk for 3 d of adjustment to the cages and then the experimental diets for 3 d of adjustment before any collections were made. Daily food allowance was 5% of body wt and was divided into three equal feedings given at 7:00 a.m, 1:00 p.m., and 7:00 p.m. Water was consumed on an ad libitum basis. Urine and feces were collected for 4 d. Total urine volume was recorded twice daily and 5% of each collection was kept and frozen for analysis of GE and N. Feces and orts were collected twice daily and frozen. Concentrations of Cr, DM, N, and GE in the feces and diets were determined to allow calculation of apparent digestibilities of DM, N, and GE using the indirect ratio method. Also, concentrations of N and GE in the urine were determined to allow calculation of apparent BV, N retention, and ME. The data were analyzed using the orthogonal comparisons: 1) soybean meal vs extruded and roasted soybeans, 2) -K vs +K soybeans, 3) extruded vs roasted soybeans, and 4) -K vs +K × extruded vs roasted soybeans.

For Exp. 2, the soybean treatments, processing conditions, and animal care were the same as in Exp. 1. However, older pigs (21.4 lb average body wt and 35 d average age) were used in the 10-d metabolism experiment. Analyses of diets, feces, urine samples and the resulting data were as described for Exp. 1.

Results and Discussion

The crude protein and, thus, amino acid concentrations of soybean meal were greater than those of the roasted and extruded soybeans (Table 2). Trypsin inhibitor activities were lower for the -K soybeans than for the +K soybeans, but urease activities were similar among the soybean preparation. Soybean antigenic activity (i.e., for glycinin and β-conglycinin) was less for the heat-treated soybeans compared to soybean meal.

For Exp. 1, pigs fed extruded soybeans had longer villi ($P<.05$) than pigs fed roasted soybeans, but no differences occurred in crypt depth or antisoy titers among pigs fed the various soy products (Table 3). The greater villus height for pigs fed extruded soybeans would tend to increase absorptive surface area and possibly indicates improved functional

status of the small intestine for those pigs compared to pigs fed roasted soybeans.

Digestibilities of DM and N (Table 4) were not different for soybean meal compared to the other treatments (P>.11). However, digestibility of GE from soybean meal tended to be greater (P<.10) than for the full-fat soy products because of the relatively low digestibilities for roasted soybeans. The full-fat soy products supported greater daily retention of N (P<.01) and had 218 kcal/lb more ME than soybean meal. The higher ME would be expected because of the fat content of the full-fat soybean preparation.

The -K soybeans had greater digestibility of N and BV than the +K soybeans (P<.05). Also, percentage N retention, daily retention of ME, and ME of the soy products themselves were greater (P<. 05) for -K compared to +K soybeans.

Extrusion improved nearly all of the response criteria, with 39% greater daily N retention and 490 kcal/lb more ME in the soy products with extrusion processing compared to roasting.

For Exp. 2, digestibilities of DM, N, and GE were greater (P<.05) for soybean meal compared to the full-fat soybean preparations (Table 5). As in Exp. 1, these differences were due to the relatively low digestibilities for the roasted soybeans. The full-fat soy products had 205 kcal/lb more ME than soybean meal (P<.001), as might be expected because of their greater fat content (18.8 vs .9%).

Digestibilities of DM, N, and GE were greater for pigs fed -K soybeans compared to pigs fed +K soybeans (P<.001). Also, the -K soybeans supported greater percentage N retention (P<.01) and percentage ME (P<.05) compared to +K soybeans.

Extrusion improved apparent digestibilities of DM, N, and GE by 11, 8, and 18% compared to roasting (P<.001). Responses for other measurements of nutritional value (i.e., N utilization and ME value) were similar to those for digestibility, with consistently greater utilization of nutrients from extruded soybeans compared to roasted soybeans.

In conclusion, the roasted and extruded soybean preparations were utilized well by the pigs in our experiments. However, as in previous growth assays completed here at KSU, -K soybeans tended to be of greater nutritional value than +K soybeans, and extrusion processing resulted in marked improvements in nutritional value compared to roasting. Finally, our results indicate that the NRC value of 1,644 kcal/lb for full-fat soy products should be revised to indicate the type of processing used. Using our data for conventional (+K) soybeans, NRC overestimates ME of roasted products by 348 kcal/lb in 10-lb pigs and by 50 kcal/lb in 20-lb pigs. In contrast, the ME value of extruded soybeans is underestimated by 293 kcal/lb in 10-lb pigs and 358 kcal/lb in 20-lb pigs.

Table 2. Chemical Composition of Experimental Ingredients (Exp. 1 and 2)[a]

		+ K		- K	
Item	Soybean meal	Roasted	Extruded	Roasted	Extruded
CP, %	45.1	35.8	36.1	36.5	35.8
Gross energy, kcal/lb	1,798	2,200	2,136	2,182	2,144
Indispensable amino acid, %					
Arginine	3.4	2.5	2.5	2.6	2.5
Histidine	1.2	1.0	0.9	1.0	1.0
Isoleucine	2.1	1.6	1.5	1.6	1.7
Leucine	3.7	2.7	2.7	2.7	2.8
Lysine	3.0	2.1	2.1	2.2	2.1
Methionine	0.7	0.5	0.5	0.5	0.5
Phenylalanine	2.4	1.7	1.7	1.9	1.8
Threonine	1.8	1.4	1.4	1.4	1.4
Tryptophan	0.7	0.5	0.5	0.4	0.5
Valine	2.2	1.7	1.7	1.8	1.7
Dispensable amino acid, %					
Alanine	2.0	1.6	1.5	1.6	1.6
Aspartate	5.4	4.0	4.0	4.1	4.0
Cystine	0.8	0.6	0.6	0.6	0.6
Glutamate	8.4	6.0	5.9	6.3	6.2
Glycine	1.9	1.5	1.4	1.6	1.5
Proline	2.5	1.9	1.9	2.1	1.9
Serine	2.3	1.7	1.6	1.8	1.6
Tyrosine	1.7	1.3	1.2	1.3	1.3
Trypsin inhibitor, mg/g	0.9	3.2	2.6	1.3	1.3
Urease activity, Δ pH	0.02	0.12	0.01	0.07	0.01
Glycinin activity, $\log_2$	6	5	4	2	2
β-conglycinin activity, $\log_2$	4	4	2	1	1

[a]Corrected to 90% DM.

Table 3. Intestinal Morphology and Serum Antisoy Titers for Nursery Pigs (10 lb) Fed Conventional (+K) or Low-Trypsin Inhibitor (-K) Soybeans either Roasted or Extruded (Exp. 1)[a]

		+ K		- K		
Item	Soybean meal	Roasted	Extruded	Roasted	Extruded	CV
Villus height, µm[b]	376	354	403	376	413	15.9
Crypt depth, µm	372	356	351	345	336	17.0
Anti-soy titers, $\log_2$	7.0	6.7	6.6	6.5	6.2	18.9

[a]A total of 50 weanling pigs (one pig/pen and ten pens/treatment) was fed from an average initial body wt of 10.4 lb.
[b]Roasted soybeans vs extruded soybeans ($P<.05$).

Table 4. Apparent Nutrient Utilization for Nursery Pigs (10 lb) Fed Conventional (+K) or Low-Trypsin Inhibitor (-K) Soybeans either Roasted or Extruded (Exp. 1)[a]

		+ K		- K		
Item	Soybean meal	Roasted	Extruded	Roasted	Extruded	CV
ADG, lb	.43	.32	.39	.42	.45	37.3
Apparent digestibility, %						
DM[h]	82.3	75.4	80.8	76.3	84.3	6.7
N[dh]	82.6	75.0	81.3	78.5	86.1	7.0
GE[bg]	78.3	70.8	82.8	71.8	83.7	8.3
Biological value, %[de]	63.1	53.8	65.4	67.7	69.9	18.5
N retention, %[df]	47.4	44.6	53.2	53.6	60.4	21.6
N retention, g/d[c]	3.7	3.3	5.4	4.4	5.3	31.1
ME, %[h]	71.0	63.0	78.3	68.1	79.3	8.6
ME retention, kcal/d[dh]	369	347	533	418	549	26.8
ME, kcal/lb[cdi]	1,424	1,296	1,937	1,499	1,837	12.4

[a]A total of 50 weanling pigs (one pig/pen and ten pens/treatment) was fed from an average initial body wt of 10.4 lb.
[bc]SBM vs other treatments (P<.10 and .05, respectively).
[d]-K soybeans vs +K soybeans (P<.05).
[efgh]Roasted soybeans vs extruded soybeans (P<.10, .05, .01, and .001, respectively).
[i]-K vs +K × roasted vs extruded soybeans (P<.05).

Table 5. Apparent Nutrient Utilization for Nursery Pigs (20 lb) Fed Conventional (+K) or Low-Trypsin Inhibitor (-K) Soybeans either Roasted or Extruded (Exp. 2)[a]

		+ K		- K		
Item	Soybean meal	Roasted	Extruded	Roasted	Extruded	CV
ADG, lb[i]	.79	.49	.75	.62	.84	31.7
Apparent digestibility, %						
DM[cgi]	83.2	71.6	81.0	78.1	84.7	4.7
N[bgjk]	86.8	75.6	85.3	84.1	86.4	4.4
GE[cgj]	83.6	68.1	82.8	75.5	86.6	5.5
Biological value, %	73.7	73.5	74.1	75.3	80.9	10.5
N retention, %[fh]	63.9	56.0	64.1	63.2	69.0	11.7
N retention, g/d[b]	16.5	12.4	13.4	13.5	15.0	19.1
ME, %[bej]	81.5	66.2	81.4	73.7	84.7	8.6
ME retention, kcal/d[f]	1,261	1,290	1,480	1,325	1,547	26.8
ME, kcal/lb[djk]	1,618	1,594	2,002	1,759	1,937	12.4

[a]A total of 40 pigs (one pig/pen and eight pens/treatment) was fed from an average initial body wt of 21.4 lb.
[bcd]SBM vs other treatments (P<.05, .01, and .001, respectively).
[efg]-K soybeans vs +K soybeans (P<.05, .01, and .001, respectively).
[hij]Roasted soybeans vs extruded soybeans (P<.05, .01, and .001, respectively).
[k]-K vs +K × roasted vs extruded soybeans (P<.01).

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

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Summary

A total of 150 weanling pigs (14.2 lb avg body wt) was used in a 28-d growth assay to determine the effects of using sodium sulfite as an extrusion enhancer for soy products. Treatments were: 1) soybean meal (SBM), 2) SBM + sodium sulfite, 3) extruded SBM, 4) SBM extruded with sodium sulfite, 5) extruded whole soybeans, and 6) whole soybeans extruded with sodium sulfite. For d 0 to 14, pigs fed SBM had greater average daily feed intake (ADFI), although they had poorer efficiency of gain (F/G) than pigs fed the extruded soy products. Also, pigs fed sodium sulfite showed a trend for greater average daily gain (ADG) and F/G compared to pigs fed diets without sodium sulfite. The positive response to sodium sulfite continued into Phase II (d 14 to 28), where pigs fed sodium sulfite had greater ADG and ADFI compared to those not fed sodium sulfite. Pigs fed extruded soybeans in Phase II had greater ADG than pigs fed extruded SBM. Overall (d 0 to 28), pigs fed diets with sodium sulfite consumed more feed, gained faster, and tended to have improved efficiencies of gain compared to those fed diets without sodium sulfite. Also, pigs fed extruded soybeans had greater rates and efficiencies of gain than pigs fed extruded SBM. Thus, in conclusion, sodium sulfite improved growth performance of weanling pigs. Also, extruded soybeans supported greater growth performance than extruded SBM, but pigs fed extruded soybeans responded less to the use of sodium sulfite as an extrusion enhancement than pigs fed the other treatments.

(Key Words: Sodium Sulfite, Extrusion, Soybeans, Nursery Pigs, Performance.)

Introduction

Soybean meal is the most common protein source used in swine diets. However, soybeans and the meal left after the oil extraction process are also sources of various antinutritional factors such as trypsin inhibitors, lectins, and antigenic proteins (e.g., glycinin and β-conglycinin). Young pigs are especially susceptible to antinutritional factors because of limited feed intake and immature digestive tracts. Heat treatment is the process most commonly used to destroy antinutritional factors. However, the benefits of heating can be negated if the product is overcooked.

During extrusion, high temperature and pressure are used for a brief period to inactivate antinutritional factors without damaging the proteins. However, extrusion is a costly process. Previous experiments here at KSU have shown mixed results in performance of animals fed extruded soybean meal. Part of the inconsistent response may have been caused by overprocessing, i.e., heat treatment with extrusion processing in addition to the heat treatment (toasting) already applied to commercially processed soybean meal. Thus, an extrusion aid that reduces the amount of heat treatment needed to inactivate antinutritional factors could improve the nutritional value of soybean products. Additionally, such an extrusion aid could further increase the consistently good results we have observed with extruded whole soybeans. Sodium sulfite has been suggested as just such an aid for the extrusion process. Thus, the purpose of the experiment described herein was to determine if extrusion of soybean meal and whole soybeans with sodium

sulfite improves growth performance and nutrient digestibility in weanling pigs.

Procedures

One hundred and fifty weanling pigs (average initial wt of 14.2 lb and average age of 21 d) were sorted by sex, weight, and ancestry and used in a 28-d growth assay. There were five pigs per pen with five pens per treatment. The pigs were housed in an environmentally controlled nursery with wire mesh flooring and had ad libitum access to feed and water. Treatments were: 1) soybean meal (SBM), 2) SBM + sodium sulfite, 3) extruded SBM, 4) SBM extruded with sodium sulfite, 5) extruded whole soybeans, and 6) whole soybeans extruded with sodium sulfite. The SBM and whole soybeans used in the experiment were mill-run. For the extrusion treatments, the SBM was mixed with 5% soybean oil prior to extrusion. The average barrel temperature was 290°F for extrusion of both the SBM and soybeans. Sodium sulfite (20 lb per ton) was thoroughly mixed into the SBM or ground whole soybeans before extrusion. As an additional control, 20 lb/ton of sodium sulfite was mixed into unextruded SBM to determine if the beneficial effects of sodium sulfite were caused by enhancement of the extrusion process or simply by addition of the sodium sulfite regardless of extrusion treatment.

The diets for Phase I (d 0 to 14) were formulated to .92% lysine, .9% Ca, and .8% P (Table 1). Diets for Phase II (d 14 to 28) were formulated to .76% lysine, .8% Ca, and .7% P (Table 2). The diets were deficient in lysine to accentuate treatment differences. All diets were formulated to the same digestible energy concentration (1.56 and 1.55 kcal/lb for Phases I and II, respectively) by adding soybean oil.

Pigs and feeders were weighed on d 0, 14, and 28 to allow calculation of ADG, ADFI, and F/G. Data were analyzed as a randomized complete block design. Treatment comparisons were made with the contrasts: 1) no sodium sulfite vs added sodium sulfite, 2) SBM vs extruded products, 3) extruded SBM vs extruded soybeans, 4) SBM vs extruded products × sodium sulfite, and 5) extruded SBM vs extruded soybeans × sodium sulfite.

Results and Discussion

During the initial postweaning phase (d 0 to 14), pigs fed SBM had the greatest ADFI ($P<.02$), but F/G was improved ($P<.03$) for pigs fed extruded SBM and soybeans (Table 3). Pigs fed diets with sodium sulfite tended to have greater rates and efficiencies of gain than pigs fed diets without sodium sulfite ($P<.09$).

For Phase II, pigs fed the diets with sodium sulfite had greater ADG, ADFI, and F/G compared to pigs fed the diets without sodium sulfite ($P<.03$). However, the response was not independent of extrusion treatment, with pigs fed extruded SBM responding to sodium sulfite as an extrusion aid, but pigs fed extruded soybeans not responding to use of sodium sulfite (interaction effect, $P<.04$ and $P<.05$ for ADG and F/G, respectively).

Responses similar to those observed in Phase I and II were noted for the entire experimental period (d 0 to d 28). Pigs fed soy products with added sodium sulfite had greater ADG and ADFI ($P<.002$ and $P<.04$, respectively), and with the exception of extruded soybeans, improved F/G ($P<.03$). Pigs fed soybeans extruded with sodium sulfite tended to have better growth performance than pigs fed soybeans extruded without sodium sulfite. However, as in Phase II, interactions occurred with use of sodium sulfite (i.e., pigs fed SBM but not soybeans responded to use of sodium sulfite as an extrusion aid).

Sodium sulfite is believed to enhance the extrusion process by cross-linking strands of denatured protein that form during extrusion, preventing them from returning to their globular state. The linear form of the proteins would be more accessible to digestive enzymes. The responses we observed to adding sodium sulfite before extrusion of SBM agrees with this theory. However, the response from simply adding sodium sulfite

to the unextruded control diet, and the lack of response to extruded soybeans with sodium sulfite, leave questions about the actual mode of action for this extrusion aid. In conclusion, pigs fed diets with sodium sulfite tended to have improved ADG, ADFI, and F/G compared to pigs fed diets without sodium sulfite. Also, the extruded soybeans treatments tended to be of greater nutritional value than the extruded SBM treatments. However, further research is needed to define a mode of action for this proposed extrusion aid.

Table 1. Diet Composition for Phase I (d 0 to 14), %[a]

Ingredient	SBM	SBM + Na_2SO_3[b]	Extruded SBM[c]	Extruded SBM + Na_2SO_3[bc]	Extruded soybeans	Extruded soybeans + Na_2SO_3[b]
Corn	50.63	50.63	50.63	50.63	50.63	50.63
Soy product	19.40	19.40	20.00	20.00	25.00	25.00
Dried whey	20.00	20.00	20.00	20.00	20.00	20.00
Soybean oil	3.90	3.90	2.90	2.90	---	---
Cornstarch	1.60	1.60	2.00	2.00	---	---
Monocalcium phosphate	1.80	1.80	1.80	1.80	1.67	1.67
Limestone	.87	.87	.87	.87	.90	.90
Salt	.20	.20	.20	.20	.20	.20
Vitamins and minerals[d]	.40	.40	.40	.40	.40	.40
Copper sulfate	.10	.10	.10	.10	.10	.10
Antibiotic[e]	1.00	1.00	1.00	1.00	1.00	1.00
Chromic oxide	.10	.10	.10	.10	.10	.10
Total	100.00	100.00	100.00	100.00	100.00	100.00

[a]All diets were formulated to .92% lysine, .9% Ca, and .8% P.
[b]Sodium sulfite was MX PRO (Triple F Nutrition, Des Moines, IA), added at 20 lb/ton of extruded soy product.
[c]Extruded SBM had 5% soybean oil added before processing.
[d]KSU vitamin and mineral premixes.
[e]Supplied 50 g carbadox/ton of diet.

Table 2. Diet Composition for Phase II (d 14 to d 28), %[a]

Ingredient	SBM	SBM + Na_2SO_3[b]	Extruded SBM[c]	Extruded SBM + Na_2SO_3[bc]	Extruded soybeans	Extruded soybeans + Na_2SO_3[b]
Corn	58.24	58.24	58.24	58.24	58.24	58.24
Soy product	13.60	13.60	14.00	14.00	17.80	17.80
Dried whey	20.00	20.00	20.00	20.00	20.00	20.00
Soybean oil	2.90	2.90	2.20	2.20	---	---
Cornstarch	1.23	1.23	1.53	1.53	---	---
Monocalcium phosphate	1.40	1.40	1.40	1.40	1.30	1.30
Limestone	.83	.83	.83	.83	.86	.86
Salt	.20	.20	.20	.20	.20	.20
Vitamins and minerals[d]	.40	.40	.40	.40	.40	.40
Copper sulfate	.10	.10	.10	.10	.10	.10
Antibiotic[e]	1.00	1.00	1.00	1.00	1.00	1.00
Chromic oxide	.10	.10	.10	.10	.10	.10
Total	100.00	100.00	100.00	100.00	100.00	100.00

[a]All diets were formulated to .76% lysine, .8% Ca, and .7% P.
[b]Sodium sulfite was MX PRO (Triple F Nutrition, Des Moines, IA), added at 20 lb/ton of extruded soy product.
[c]Extruded SBM had 5% soybean oil added before processing.
[d]KSU vitamin and mineral premixes.
[e] Supplied 50 g carbadox/ton of diet.

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

Item	SBM	SBM + Na_2SO_3	Extruded SBM	Extruded SBM + Na_2SO_3	Extruded soybeans	Extruded soybeans + Na_2SO_3	CV
Phase I (d 0 to 14)							
ADG, lb[b]	.45	.46	.44	.51	.43	.48	13.3
ADFI, lb[c]	.93	.86	.85	.83	.71	.82	11.3
F/G[de]	2.07	1.87	1.93	1.63	1.65	1.71	11.3
Phase II (d 14 to 28)							
ADG, lb[fgh]	.78	1.00	.73	.95	.98	.97	13.5
ADFI, lb[i]	1.99	2.21	1.92	2.18	2.02	2.13	10.0
F/G[jkl]	2.56	2.21	2.63	2.29	2.06	2.20	11.0
Overall (d 0 to 28)							
ADG, lb[mno]	.62	.74	.59	.73	.71	.73	10.7
ADFI, lb[p]	1.46	1.53	1.38	1.51	1.37	1.48	8.6
F/G[qrs]	2.35	2.07	2.34	2.07	1.93	2.03	8.9

[a]A total of 150 weanling pigs (five pigs per pen and five pens per treatment) with an average initial body wt of 14.2 lb.

[begiknpr]Effect of sodium sulfite (P<.08, .09, .003, .02, .03, .002, .04, and .03, respectively).

[cd]SBM vs extruded products (P<.02 and .03, respectively).

[fjmq]Extruded SBM vs extruded soybeans (P<.02, .005, .08, and .01, respectively).

[hlos]Extruded SBM vs extruded soybeans × sodium sulfite (P<.04, .05, .07, and .03, respectively).

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ALCOHOL- AND WATER-EXTRACTED SOY PROTEIN CONCENTRATES FOR EARLY-WEANED PIGS

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Summary

A total of 72 weanling pigs (average initial wt of 7 lb and 10 d of age) was used in a 38-d growth assay to determine the nutritional value of alcohol- and water-extracted soy protein concentrates. Pigs were sorted by sex, weight, and ancestry and assigned to 12 pens with six pigs/pen. The soy preparations were fed in a nursery regimen with Phase I (d 0 to 10), Phase II (d 10 to 24), and Phase III (d 24 to 38) diets. Pigs and feeders were weighed at initiation and conclusion of each phase, with fecal samples collected on d 38 for determination of DM and N digestibilities. Pigs fed the alcohol-extracted soy protein concentrate had greater average daily gain (ADG) in all phases, with similar increases in average daily feed intake (ADFI) compared to pigs fed water-extracted soy protein concentrate. However, feed/gain (F/G) was similar throughout the experiment for pigs fed the soy protein treatments. The diets with water-extracted soy protein concentrate had greater digestibility of dry matter (DM) than the diets with the alcohol-extracted product, but N digestibility was similar for both treatments. Although water is an inexpensive solvent compared to alcohol, pigs fed the alcohol-extracted soy protein concentrate had improved growth performance compared to those fed the water-extracted product.

(Key Words: Alcohol Extraction, Water Extraction, Soy Protein Concentrate, Nursery Pigs.)

Introduction

Recent trends for weaning pigs at very young ages (i.e., 14 d or less) has increased the need for highly palatable and digestible diets. For early weaning to be economically viable, the very young pig must adapt to solid feed as soon as possible postweaning. Once these pigs do begin to eat, feed intake is low, so that maximum digestibility is of paramount importance to meet tissue needs for nutrients. Generally, diets for early weaning have a high proportion of animal protein sources such as dried milk and blood products. These protein sources successfully promote growth in this critical phase; however, they are expensive and carry risks of contamination with pathogens not typically found in plant protein sources.

To decrease diet costs, vegetable proteins are preferred protein sources. Soybean meal, although an extremely economical plant protein source, contains antinutritional factors that reduce its value for young pigs. Further refined soy products, such as soy protein isolates and alcohol-extracted soy protein concentrates, are lower in antinutritional factors, but the added processing also increases their cost.

The purpose of the experiment reported herein was to determine if a low-cost water-extracted soy protein concentrate could be used to replace alcohol-extracted soy protein concentrate in diets for early-weaned pigs without reducing growth performance or nutrient digestibility.

Procedures

Seventy-two weanling pigs (7 lb average body wt and 10 d of age) were sorted by weight, sex, and ancestry and allotted to 12 pens, with six pigs per pen and six pens per treatment. Treatments were 1) alcohol-extracted soy protein concentrate and 2) water-extracted soy protein concentrate. The alcohol-extracted concentrate was made by extraction of defatted soy flakes with hot aqueous alcohol. The extraction process concentrates the protein fraction by removal of soluble carbohydrates and is thought to denature biologically active soy proteins (i.e., trypsin inhibitors, glycinin, and β-conglycinin). The water-extracted concentrate was made from whole soybeans that were roasted, cracked, and extracted with water. The initial roasting was used to inactivate the biologically active proteins and reduce protein solubility before extraction with water. The water removes soluble carbohydrates but also may remove some water-soluble proteins. The pigs were housed in an environmentally controlled nursery room with wire mesh flooring and had ad libitum access to feed and water. The diets were fed in pelleted form, with 3/32" pellets in Phase I and 5/32" pellets in Phases II and III. Pigs and feeders were weighed at initiation of the experiment and at the end of Phases I, II, and III (i.e., d 10, 24, and 38, respectively). Fecal samples were collected from four pigs per pen on d 38; dried; and analyzed for concentrations of Cr, DM, and N. Thus, response criteria were ADG, ADFI, F/G, and digestibilities of DM and N.

Results and Discussion

Pigs fed the alcohol-extracted soy protein concentrate had greater ADG in Phases I, II, and III and overall ($P<.06$) compared to pigs fed the water-extracted soy protein concentrate. Similar responses were noted for ADFI, with greater consumption of feed for pigs fed the alcohol-extracted product. No significant differences ($P>.6$) occurred in F/G among pigs fed the two treatments during any phase of the experiment. Digestibility of DM was greater for the diet with water-extracted soy protein concentrate than for the diet with the alcohol-extracted product ($P<.001$), but digestibility of N was similar for the two treatments.

In conclusion, water is an inexpensive, nontoxic, and environmentally friendly solvent compared to alcohol. However, the alcohol-extracted soy protein concentrate was a superior protein source for nursery pigs. This was the first evaluation of the water-extracted product and further research is needed to develop a water-extracted soy protein concentrate equal in nutritional value to the alcohol-extracted product.

Table 1. Diet Composition (Phases I, II, and III)[a]

	Phase I (d 0 to 10)		Phase II (d 10 to 24)		Phase III (d 24 to 38)	
Ingredient, %	Alcohol-extracted	Water-extracted	Alcohol-extracted	Water-extracted	Alcohol-extracted	Water-extracted
Corn	33.76	31.77	49.11	46.42	62.07	59.22
Dried whey	20.00	20.00	20.00	20.00	10.00	10.00
Soy product	11.72	17.18	15.84	23.23	16.44	24.11
Spray-dried plasma protein	10.00	10.00	2.00	2.00	---	---
Lactose	10.00	10.00	---	---	---	---
Fish meal	5.00	5.00	2.00	2.00	---	---
Blood meal	2.00	2.00	2.00	2.00	1.50	1.50
Soybean oil	3.90	.39	4.79	.06	5.15	.24
Monocalcium phosphate	1.86	1.89	2.12	2.15	2.12	2.16
Limestone	.16	.14	.42	.40	.64	.62
Vitamins & minerals[b]	.40	.40	.40	.40	.40	.40
Lysine HCl	---	---	.15	.15	.15	.15
DL-methionine	.13	.15	.09	.11	.05	.08
Antibiotic[c]	1.00	1.00	1.00	1.00	1.00	1.00
Chromic oxide	---	---	---	---	.25	.25
Copper sulfate	.08	.08	.08	.08	.08	.08
Salt	---	---	---	---	.20	.20
Total	100.00	100.00	100.00	100.00	100.00	100.00

[a]The diets were formulated to 1.8% lysine, .9% Ca, and .8% P for Phase I, 1.5% lysine, .9% Ca, and .8% P for Phase II, and 1.2% lysine, .8% Ca, and .7% P for Phase III.
[b]KSU vitamin and mineral premixes.
[c]Supplied 150 g/ton apramycin in Phases I and II and 50 g/ton carbadox in Phase III.

Table 2. Alcohol- and Water-Extracted Soy Protein Concentrates for Early-Weaned Pigs (Phases I, II, and III)[a]

Item	Alcohol-extracted	Water-extracted	CV
d 0 to 10			
ADG, lb[b]	.51	.43	10.4
ADFI, lb[c]	.54	.47	8.3
F/G	1.06	1.09	6.4
d 10 to 24			
ADG, lb[d]	.82	.70	6.2
ADFI, lb	1.19	1.02	21.4
F/G	1.45	1.46	15.9
d 24 to 38			
ADG, lb[e]	1.04	.88	11.9
ADFI, lb	1.61	1.42	12.1
F/G	1.55	1.61	11.6
d 0 to 38			
ADG, lb[f]	.82	.70	4.9
ADFI, lb	1.18	1.02	13.3
F/G	1.44	1.46	12.5
Digestibilities (d 38), %			
DM[g]	87.7	89.7	.6
N	88.2	87.8	.6

[a]A total of 72 pigs (six pigs per pen and six pens per treatment) with an average initial body wt of 7 lb.
[bcdefg]Water-extracted vs alcohol-extracted ($P<.04$, .02, .007, .06, .002, and .001, respectively).

INFLUENCE OF SPRAY-DRIED PLASMA SOURCE ON GROWTH PERFORMANCE OF WEANLING PIGS[1]

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Summary

Six hundred twenty six pigs (initially 9 lb and 13.2 d of age) were used in a 28-d growth trial to determine the effect of spray-dried porcine (SDPP), spray-dried bovine (SDBP), and low-ash porcine plasma (LAPP) on growth performance in the early-weaned pig. Pigs were allotted by weight to one of 10 dietary treatments with 8 to 10 pigs per pen and 7 replicate pens per treatment. The control diet was corn-soybean meal-based and contained 14.44% dried skim milk with no plasma added. Each plasma source (2, 4, and 6%) replaced dried skim milk in the control diet. The LAPP is a similar product to SDPP with the ash component removed. Therefore, the protein content is higher, and slightly lower inclusion rates were required at 1.79, 3.59, and 5.38%. Phase I diets were formulated to contain 1.5% lysine, .42% methionine, .9% Ca, and .8% P. SBM was held constant throughout all the diets at 16.31% with 25% dried whey and 4% fish meal added. On d 14 postweaning, all pigs were switched to a common Phase II milo-SBM based diet. Phase II diets were formulated to 1.25% lysine, .35% methionine, .9% Ca, and .8% P; contained 2.5% spray-dried blood meal and 10% dried whey; and were fed in meal form. Adding any of the plasma sources to the diet from d 0 to 7 after weaning resulted in a linear improvement in average daily gain (ADG) and average daily feed intake (ADFI). Pigs fed diets containing plasma also consumed more feed and were more efficient in feed conversion (F/G) compared to pigs fed the control diet. Adding plasma to the diet also improved ADG and ADFI from d 0 to 14 postweaning. No interactions occurred between level and source; however, pigs fed diets containing SDPP or LAPP had slightly higher ADFI than pigs fed diets containing SDBP d 0 to 14. Feeding a common Phase II diet from d 14 to 28 postweaning had no effect on growth performance. Overall, the pigs fed the plasma sources had greater ADG and ADFI than pigs fed the control diet. These data confirm that feeding spray-dried plasma protein improves growth performance from d 0 to 14 postweaning.

(Key Words: Pigs, Plasma, Growth.)

Introduction

Recent research conducted at Kansas State University determined that porcine plasma is a superior protein source to skim milk in diets of nursery pigs. Also, data in 1992 KSU Swine Day (pages 18 and 24) indicated that the optimum level of porcine plasma in diets of nursery pigs is 7.5%. Several sources of plasma are available to the roducer. Therefore, the objective of this trial was to determine whether a difference occurs in growth performance of pigs fed diets

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[1]Appreciation is expressed to American Protein Corporation for donating feed ingredients and for partial financial support. The authors also wish to thank Steve Eichman, Ellen Johncock and Eichman Brothers, St. George, KS, for the use of facilities and animals in this experiment.

[2]American Protein Corporation, Ames, IA.

containing the three available sources of spray-dried plasma including: SDPP, SDBP, and LAPP. The LAPP is derived from SDPP with the ash portion removed.

Procedures

A total of 626 weanling pigs (initially 9 lb and 13.2 d of age) was allotted by weight to one of 10 experimental treatments with 8 to 10 pigs per pen and seven replicate pens per treatment. Phase I diets were formulated to contain 1.5% lysine, .42% methionine, .9% Ca, and .8% P. SBM was held constant throughout all the diets at 16.31%, with 25% dried whey and 4% fish meal added. Spray-dried plasma sources (0, 2, 4, and 6%) and lactose (0, 2, 4, and 6%) replaced dried-skim milk in order to maintain equal lactose and lysine levels in all diets. The LAPP is a similar product to SDPP with the ash component removed. Therefore, the protein content is higher, and slightly lower inclusion rates were required at 1.79, 3.59, and 5.38%. On d 14 postweaning, all pigs were switched to a common Phase II milo-SBM-based diet. Phase II diets were formulated to 1.25% lysine, .35% methionine, .9% Ca, and .8% P; contained 2.5% spray-dried blood meal and 10% dried whey; and were fed in meal form. Pigs were housed in an environmentally controlled nursery with slatted metal flooring and had ad libitum access to feed and water. Pen sizes were 4 ft × 6 ft. Pigs and feeders were weighed weekly (d 0, 7, 14, and 28) to determine ADG, ADFI, and F/G.

Results and Discussion

During wk 1, ADG ($P<.01$), ADFI ($P<.01$), and F/G ($P<.05$) were improved for pigs fed the plasma diets compared with the control diet. Average daily gain and ADFI increased (linear, $P<.05$), for pigs fed any of the plasma sources.

Average daily gain and ADFI improved ($P<.01$) for pigs fed plasma diets compared to the pigs fed the control diet during Phase I (d 0 to 14 postweaning). No interactions occurred between plasma level and source. However, pigs fed SDPP or LAPP had greater ADFI ($P<.05$) than pigs fed SDBP. Increasing plasma level (regardless of source) increased (linear $P<.05$) ADG and ADFI d 0 to 14 postweaning. Cumulative (d 0 to 28) ADG and ADFI improved for pigs fed diets containing plasma during Phase I compared to pigs fed the control diet ($P<.10$).

In summary, regardless of the origin of spray-dried plasma, feeding plasma as a protein source for weanling pigs results in improved growth performance from d 0 to 14 postweaning. Spray-dried porcine plasma and LAPP performed similarly, but pigs fed either of these plasma sources had greater ADFI d 0 to 14 postweaning than those fed SDBP. Therefore, pig performance can be improved by adding any one of the plasma sources evaluated to a Phase I diet. Secondly, the cost of spray-dried plasma should be a considered to determine the most economical type to feed.

Table 1. Composition of Diets Containing Spray-Dried Porcine and Bovine Plasma

Item	Control	2% Plasma	4% Plasma	6% Plasma
Corn	32.66	32.79	32.93	33.05
SBM	16.31	16.31	16.31	16.31
Dried whey	25.00	25.00	25.00	25.00
Dried skim milk	14.44	9.63	4.81	---
Lactose[a]	---	2.41	4.81	7.22
Plasma[b]	---	2.00	4.00	6.00
Select menhaden fish meal	4.00	4.00	4.00	4.00
Monocalcium phosphate	.71	.92	1.15	1.36
Limestone	.18	.23	.28	.33
Vit/Min[c]	.48	.48	.48	.48
Antibiotic[d]	1.00	1.00	1.00	1.00
Soy oil	5.00	5.00	5.00	5.00
Lysine-HCl	.15	.15	.15	.15
DL-methionine	---	.03	.06	.10
L-cystine	.07	.05	.02	---
Total	100.00	100.00	100.00	100.00

[a]Lactose was added as dried-skim milk was replaced to ensure the diets were isolactose.
[b]Plasma replaced dried skim milk on a lysine basis.
[c]Vit/Min = KSU vitamin and mineral premixes and .08% copper sulfate.
[d]Antibiotic provided by apramycin at 150 g/ton.

Table 2. Composition of Diets Containing Low-Ash Porcine Plasma

Item	Control	2% Plasma	4% Plasma	6% Plasma
Corn	32.66	32.85	33.04	33.23
SBM	16.31	16.31	16.31	16.31
Dried whey	25.00	25.00	25.00	25.00
Dried skim milk	14.44	9.63	4.81	---
Lactose[a]	---	2.41	4.81	7.22
Plasma[b]	---	1.79	3.59	5.38
Fish meal	4.00	4.00	4.00	4.00
Cornstarch	---	.21	.41	.62
Monocalcium phosphate	.71	.81	.93	1.03
Limestone	.18	.28	.39	.48
Vit/Min[c]	.48	.48	.48	.48
Antibiotic[d]	1.00	1.00	1.00	1.00
Soy oil	5.00	5.00	5.00	5.00
Lysine-HCl	.15	.15	.15	.15
DL-methionine	----	.03	.06	.10
L-cystine	.07	.05	.02	---
Total	100.00	100.00	100.00	100.00

[a]Lactose was added as dried-skim milk was removed to ensure the diets were isolactose.
[b]Plasma replaced dried skim milk on a lysine basis.
[c]Vit/Min = KSU vitamin and mineral premixes with .08% copper sulfate.
[d]Antibiotic provided by apramycin at 150 g/ton.

Table 3. Effects of Spray-Dried Plasma Source on Growth Performance of Weanling Pigs[a]

		LAPP, %			SDPP, %			SDBP, %			
Item	Control	2	4	6	2	4	6	2	4	6	CV
d 0 to 7											
ADG, lb[ad]	.20	.27	.27	.32	.27	.30	.33	.24	.31	.32	17.0
ADFI, lb[ad]	.29	.35	.35	.41	.35	.37	.40	.33	.38	.37	12.5
F/G[b]	1.54	1.22	1.33	1.26	1.30	1.27	1.30	1.50	1.21	1.13	18.6
d 0 to 14											
ADG, lb[ad]	.36	.43	.45	.47	.43	.47	.46	.40	.45	.44	11.1
ADFI, lb[ade]	.40	.48	.51	.52	.48	.52	.53	.44	.48	.50	9.4
F/G	1.15	1.12	1.17	1.12	1.18	1.11	1.19	1.15	1.10	1.16	7.1
d 0 to 28[f]											
ADG, lb[c]	.59	.62	.62	.63	.64	.63	.63	.61	.64	.63	7.8
ADFI, lb[c]	.83	.88	.89	.88	.88	.89	.89	.85	.87	.89	7.3
F/G	1.42	1.42	1.47	1.38	1.41	1.43	1.42	1.40	1.37	1.43	4.4

[abc]Control vs all plasma sources (P<.01), (P<.05) and (P<.10), respectively.
[d]Linear effect of plasma level (P<.05).
[e]Plasma source effect, LAPP or SDPP > SDBP (P<.05).
[f]All pigs were fed a common diet from d 14 to 28 postweaning.

THE EFFECT OF SPRAY-DRIED PLASMA SOURCE ON STARTER PIG PERFORMANCE[1]

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

Summary

A total of 416 pigs (initially 9.36 lb and 15 d of age) was used in a 28-d growth assay to evaluate the effects of spray-dried plasma source on starter pig performance. Pigs were blocked by weight and allotted to one of four dietary treatments in a randomized complete block design. Three spray-dried plasma sources were tested: bovine, porcine, and plasma collected from only sows. Plasma sources and lactose replaced skim milk in the control diet to form the experimental diets. Experimental diets were fed during Phase I (d 0 to 14 postweaning), and all pigs were fed a common Phase II (d 14 to 28 postweaning) diet. Phase I diets were formulated to 1.5% lysine and .42 % methionine. Phase II diets were formulated to 1.25% lysine and .36% methionine. Phase I diets were fed in a pellet form and Phase II in a meal form, and all diets were formulated to .9% Ca and .8% P. During Phase I, pigs fed diets containing porcine and sow plasma grew faster than the pigs fed the control and bovine plasma diets. Pigs fed either swine plasma source were more efficient than pigs fed the control diet. During Phase II, when pigs were fed a common diet, pigs that were fed diets containing sow and bovine plasma diets in Phase I had higher feed intakes than pigs that were fed the control diet. Overall (d 0 to 28), pigs fed the porcine plasma diet grew faster and pigs fed the sow plasma diet grew more efficiently than pigs fed the control diet. In conclusion, plasma source affects starter pig performance. Based on our results, plasma of porcine origin promoted greater ADG d 0 to 14 postweaning than bovine plasma.

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

Introduction

Previous research at Kansas State University demonstrated that porcine plasma was superior to bovine plasma in diets for early-weaned pigs. However, subsequent trials conducted at Kansas State University, University of Illinois, and University of Minnesota indicate no differences in performance for pigs fed diets containing porcine or bovine plasma. With these results in mind, the objective of this trial was to determine whether species of origin is important when using spray-dried plasma in diets for early-weaned pigs.

Procedures

A total of 416 pigs (initially 9.36 lb and 15 d of age) was used in a 28-d growth assay to evaluate the effects of plasma source on starter pig performance. Pigs were blocked by weight and allotted to one of four dietary treatments in a randomized complete block design. Three spray-dried plasma sources were tested: bovine, porcine, and plasma collected from sows. Experimental diets were fed during Phase I (d 0 to 14

[1]Appreciation is expressed to American Proteins Corporation for partial funding and donation of spray-dried plasmas. The authors wish to thank Ellen Johncock and Eichman Brothers, St. George, KS, for use of facilities and animals in this experiment.

postweaning) and were formulated by replacing 13.3% dried skim milk in the control diet with 5% plasma and 6.65% purified lactose (Table 1). The corn-soybean meal-based Phase I diets were formulated to 1.5% lysine, .42% methionine, .9% Ca, and .8% P and contained 25% dried whey, 5% select menhaden fishmeal, and 5% soybean oil. The pigs were fed a common corn-soybean-meal-based Phase II (d 14 to 28 postweaning) diet that was formulated to 1.25% lysine, .36% methionine .9% Ca, and .8% P. Phase I diets were pelleted, and Phase II diets were fed in meal form.

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

Results and Discussion

During d 0 to 7 of this trial, pigs fed any of the plasma sources had increased ADG and were heavier on d 7 than pigs fed the control diet ($P<.05$). Also during the first week, pigs fed the two diets containing porcine and sow plasma ate more feed ($P<.05$) than pigs fed the control diet. Pigs fed the diet containing sow plasma were also more efficient than pigs fed the control diet ($P<.05$). During the second week of the trial, pigs fed the diets containing either porcine plasma source grew faster ($P<.05$) than the pigs fed either the control or bovine plasma diets. However, during this period no differences were observed for ADFI or F/G.

For d 0 to 14, pigs fed the diets containing porcine and sow plasma grew faster ($P<.05$) than pigs fed the control and bovine plasma diets and were more efficient ($P<.05$) than pigs fed the control diet. However, feed intake was not affected by dietary treatment. The pigs fed the porcine and sow plasma diets were heavier ($P<.05$) at the end of Phase I than the pigs fed the bovine plasma and control diets.

During Phase II, pigs that were fed the control diet during Phase I ate more feed ($P<.05$) than the pigs fed the bovine and sow plasma diets. No differences were detected during this period for ADG or F/G.

Overall, pigs fed diets containing porcine plasma during Phase I grew faster and were heavier on d 28 than pigs that were fed the control diet ($P<.05$). Pigs fed diets containing sow or bovine plasma were intermediate for ADG. The pigs that were fed the diet containing sow plasma in Phase I were more efficient during the entire trial than the pigs fed the control diet during Phase I. Pigs fed diets containing porcine and bovine plasma had feed efficiencies similar to those of the pigs fed the sow plasma diets.

In conclusion, species source of plasma affects starter pig performance. Pigs fed diets containing porcine and sow plasma grew faster during d 0 to 14 postweaning than pigs fed either the control or bovine plasma diets. The pigs fed the porcine plasma diet were heavier on d 28 and grew faster for the entire trial than pigs fed the control diet. Pigs fed the sow plasma diet were more efficient during the entire trial than pigs fed the control diet. However, an alternative explanation might be that minor differences in processing conditions for plasma at different plants might be affecting pig performance. Plasma sources used in this experiment were processed at different plants. More research must be conducted to evaluate how differences in processing methods and compositional differences of different plasma sources affect starter pig performance.

Table 1. Diet Composition[a]

	Phase I		
Ingredient, %	Control	Spray-dried plasma	Phase II
Corn	32.66	33.68	60.27
Soybean meal, (46.5% CP)	15.01	15.01	22.81
Dried whey	25.00	25.00	10.00
Skim milk	13.30	--	--
Lactose[b]	--	6.65	--
Spray dried plasma source[b]	--	5.00	--
Select menhaden fishmeal	5.00	5.00	--
Spray-dried blood meal	1.75	1.75	2.50
Soybean oil	5.00	5.00	--
Monocalcium phosphate, (21% P)	.65	.94	1.90
Limestone	.11	.41	.84
Antibiotic[c]	1.00	1.00	1.00
Copper sulfate	.08	.08	.08
L-Lysine HCl	--	--	.15
DL-Methionine	.04	.70	.05
Vitamin premix	.25	.25	.25
Trace mineral premix	.15	.15	.15
Total	100.00	100.00	100.00

[a]Phase I (d 0 to 14) diets were formulated to 1.50% lysine and .42% methionine. Phase II (d 14 to 28) diets were for formulated to 1.25% lysine and .36% methionine. All diets were formulated to .9% Ca and .8% P.
[b]Plasma sources were added at 5% to form experimental diets. Purified lactose was added to ensure that experimental diets contained 24.65% lactose.
[c]Provided 150g/ton apramycin in Phase I and 50g/ton carbadox in Phase II.

Table 2. The Influence of Plasma Source on Starter Pig Performance[a]

		Spray-dried plasma source			
Item	Control	Bovine	Porcine	Sow	CV
d 0 to 7					
ADG, lb	.25[b]	.34[c]	.37[c]	.37[c]	20.3
ADFI, lb	.37[b]	.42[bc]	.45[c]	.43[c]	19.8
F/G	1.45[b]	1.25[bc]	1.21[bc]	1.16[c]	15.5
d 7 to 14					
ADG, lb	.58[b]	.58[b]	.65[c]	.66[c]	17.2
ADFI, lb	.75	.74	.75	.74	15.1
F/G	1.30	1.30	1.17	1.15	16.5
d 0 to 14					
ADG, lb	.42[b]	.46[b]	.51[c]	.51[c]	14.5
ADFI, lb	.56[b]	.58[bc]	.60[c]	.59[bc]	12.0
F/G	1.35[b]	1.28[bc]	1.18[c]	1.16[c]	12.0
d 14 to 28					
ADG, lb	.79	.79	.79	.74	14.5
ADFI, lb	1.39[b]	1.30[c]	1.33[bc]	1.28[c]	9.1
F/G	1.77	1.65	1.71	1.76	9.7
d 0 to 28					
ADG, lb	.60[b]	.62[bc]	.65[c]	.63[bc]	12.3
ADFI, lb	.98	.93	.97	.93	8.5
F/G	1.61[b]	1.51[bc]	1.50[bc]	1.50[c]	8.9
Pig weight, lb					
d 0	9.36	9.36	9.36	9.37	13.3
d 7	11.13[b]	11.72[c]	11.94[c]	11.97[c]	12.9
d 14	15.21[b]	15.79[b]	16.52[c]	16.55[c]	12.5
d 28	26.29[b]	26.84[bc]	26.96[bc]	27.52[c]	11.9

[a]A total of 416 pigs (15 ± 3 d) with 9, 10, or 11 pigs/pen with 10 replicate pens/treatment
[bc]Means within a row with different superscripts differ (P<.05).

EVALUATION OF POTATO PROTEIN IN STARTER PIG DIETS[1]

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Summary

In two separate trials, the use of potato protein (75% CP, 5.9% lysine), as a replacement for spray-dried porcine plasma (SDPP) in Phase I and for spray-dried blood meal (SDBM) and select menhaden fish meal (SMFM) in Phase II diets (d 0 to 14 and d 7 to 28 postweaning, respectively), was evaluated. In Exp. 1, 185 weanling pigs (initially 9.7 lb and 15.5 d of age) were blocked by weight and gender and allotted in a randomized complete block design to one of five dietary treatments. The control diet was formulated to 1.5% lysine and .42% methionine and contained 3% SDPP and 25% dried whey. The experimental diets were formulated by substituting, on an equal lysine basis, additional SDPP (2.5 or 5% added; 5.5 or 8% total) or potato protein (2.6% or 5.1%) for soybean meal (SBM) in the control diet. These diets were fed from d 0 to 14 postweaning. From d 14 to 28, all pigs were fed a common Phase II diet. During d 0 to 14 postweaning, pigs fed diets containing 5.5 or 8% SDPP had improved (P<.05) average daily gain (ADG) compared with those fed the control diet or the diet with 5.1% potato protein. No differences were observed in ADG and average daily feed intake (ADFI) of pigs fed the diet with 2.6% potato protein compared with pigs fed the control diet or diets with additional SDPP. Feed intake was increased for pigs fed 8% SDPP and decreased for pigs fed the 5.1% potato protein, when compared to the control group. Feed efficiency (G/F) was not affected by dietary treatment. Overall (d 0 to 28), no differences occurred in ADG, ADFI, and F/G among treatments. In Exp. 2, 270 weanling pigs (initially 13.7 lb and 20 d of age) were used. Pigs were blocked by weight and gender and assigned to each of three dietary treatments at weaning. There were 15 pigs per pen with six replicate pens per treatment. From d 0 to 7 postweaning, all pigs were fed the same diet that was formulated to 1.5% lysine and contained 10% SDPP and 25% dried whey. The Phase II experimental diets contained 10% dried whey and were formulated to 1.25% lysine and .34% methionine. The protein sources, 2.50% SDBM, 4.8% SMFM, or 3.92% potato protein, were substituted on an equal lysine basis, with all diets containing 22.63% SBM. From d 7 to 28 postweaning, pigs fed potato protein had decreased ADG and F/G. No differences occurred between pigs fed either SDBM or SMFM. These results suggest that potato protein as a plant protein should replace these more expensive animal protein sources only in limited amounts.

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

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[1]The authors wish to thank AVEBE America, Inc., Princeton, NJ, for providing the potato protein used in this trial and for partial financial support. We also want to acknowledge Dale Keesecker and Keesecker Agribusiness, Washington, KS; Ellen Johncock; and Eichman Brothers, St. George, KS, for use of animals and facilities in these trials.

Introduction

Spray-dried porcine plasma, spray-dried blood meal, and select menhaden fish meal are the predominate protein sources in starter pig diets. Potato protein is a high-quality plant-protein source that has the potential for application in starter pig diets. However, the actual nutritional value of potato protein in these diets has not yet been established. If potato protein could replace all or part of more expensive protein sources, the cost of starter pig diets could be reduced greatly.

Procedures

Experiment 1: A total of 185 weanling crossbred pigs (initially 9.7 lb and 15.5 d of age) was used in a 28-day growth assay to determine the effects of potato protein on starter pig performance. Pigs were blocked by weight and gender and allotted to six replicates of five dietary treatments. The pigs were fed experimental diets during Phase I (d 0 to 14 postweaning) and a common Phase II diet (d 14 to 28 postweaning). The five experimental diets were pelleted and formulated to contain 1.5% lysine, .42% methionine, .9% Ca, and .8% P. The control diet was a corn-soybean meal-based diet and contained 3% spray-dried porcine plasma (SDPP) and 25% dried whey. The experimental diets were formulated by adding, on an equal lysine basis, more SDPP (2.5 or 5% added; 5.5. and 8% total) or potato protein (2.6% or 5.1%) in place of soybean meal in the control diet. The common Phase II diet was fed as a meal; contained 10% dried whey, 2.5% spray-dried blood meal; and was formulated to 1.25% lysine, .36% methionine, .9% Ca, and .8% P.

The pigs were housed in 5 × 7 ft pens in an environmentally controlled nursery and had ad libitum access to a four-hole self-feeder and nipple waterers. Pigs were weighed and feed disappearance was measured weekly to determine ADG, ADFI, and (F/G).

Experiment 2: Two-hundred seventy crossbred pigs (initially 13.7 lb and 20 d or age) were used in a 28-d growth assay to examine the effect of potato protein in a Phase II starter pig diet. During d 0 to 7 postweaning, a common Phase I diet was fed to all pigs. The Phase I diet was a pelleted corn-soybean meal-based diet that contained 10% spray-dried porcine plasma and 25% dried whey. It was formulated to contain 1.5% lysine, .42% methionine, .9% Ca, and .8% P.

The experimental diets were fed from d 7 to 28. The three Phase II diets all were fed in a meal form; contained 10% dried whey; and were formulated to 1.25% lysine, .34% methionine, .9% Ca, and .8% P. The protein sources examined, select menhaden fish meal (4.87%), spray-dried blood meal (2.5%), and potato protein (3.92%), were substituted on an equal lysine basis, with the soybean level maintained at 22.63% in all diets.

Pigs were blocked by gender and weight and allotted to one of three treatments. There were 15 pigs per pen and six replicate pens per dietary treatment. Each pen contained a six-hole self-feeder and two nipple waterers to allow ad libitum access to feed and water. Pigs were weighed and feed disappearance was measured weekly to determine ADG, ADFI, and F/G.

Results and Discussion

Experiment 1: During d 0 to 14, pigs fed the diets containing 5.5 and 8% SDPP had higher ADG ($P<.05$) than pigs fed the 5.1% potato protein and control diets. However, pigs fed 2.6% potato protein had intermediate ADG: less than those pigs the 5.5 or 8% SDPP and greater than that of pigs fed the control diet. This result suggests that a part of the SDPP in a Phase I diet can be replaced by potato protein. However, the observed differences in ADG and ADFI between pigs fed diets containing 8% SDPP and 5.1% potato protein indicate that this replacement is restricted. During the Phase II portion, when the common diet was fed, no differences occurred in ADG, ADFI, or G/F. Additionally, cumulative results (d 0

to 28) indicate no differences in pig performance from protein source fed d 0 to 14 postweaning.

Experiment 2: During d 7 to 14, no differences were observed in ADG, ADFI, and F/G among treatments. However, at the conclusion of this experiment, the pigs fed the SDBM and SMFM diets outperformed the pigs fed potato protein for ADG and F/G (P<.01). ADFI was lower (P<.01) for pigs fed the potato protein diet than for those fed the diet containing SDBM. Between pigs fed potato protein or SMFM, no differences was observed in ADFI. No differences occurred between pigs fed either SDBM or SMFM diets.

Conclusion

When analyzed, potato protein is a high-quality protein source. However, our results suggest that SDPP, SDBM, and SMFM are superior protein sources in starter pig diets. This conclusion is related to decreased feed intake by pigs fed diets containing 3.9% or more potato protein. Therefore, potato protein as a plant protein should replace these more expensive animal protein sources only in limited amounts.

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

	Porcine plasma, % : Potato protein, %					
Ingredient, %	3 : 0	5.5 : 0	8 : 0	3 : 2.6	3 : 5.1	Phase II
Ground corn	37.24	39.70	42.08	39.66	41.97	60.27
Dried whey	25.00	25.00	25.00	25.00	25.00	10.00
Soybean meal, 48% CP	24.07	18.98	13.97	18.9	13.97	22.81
Soy oil	5.00	5.00	5.00	5.00	5.00	--
Spray-dried porcine plasma	3.00	5.50	8.00	3.00	3.00	--
Spray-dried blood meal	1.75	1.75	1.75	1.75	1.75	2.50
Potato protein	--	--	--	2.63	5.15	--
Monocalcium phosphate	1.62	1.73	1.87	1.75	1.86	1.90
Limestone	.64	.64	.64	.64	.64	.84
Vitamin premix	.25	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15	.15
DL-Methionine	.11	.12	.14	.10	.08	.05
L-Lysine	.10	.10	.10	.10	.10	.15
Copper sulfate	.075	.075	.075	.075	.075	.075
Antibiotic[b]	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]Phase I diets were formulated to contain 1.5% lysine, .42% methionine, .9% Ca, and .8% P and fed d 0 to 14 postweaning. Phase II diets were formulated to contain 1.25% lysine, .36% methionine, .9% Ca, .8% P and fed from d 14 to 28 postweaning.
[b]Provided 150 g/ton of apramycin in Phase I and 50 g/ton carbadox in Phase II.

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

		Experimental protein sources		
Ingredients, %	Phase I	Spray-dried blood meal	Select menhaden fishmeal	Potato protein
Ground corn	37.18	57.47	56.11	56.05
Dried whey	25.00	10.00	10.00	10.00
Soybean meal, 48 % CP	18.69	22.63	22.63	22.63
Spray-dried porcine plasma	10.00	--	--	--
Spray-dried blood meal	--	2.50	--	--
Select menhaden fishmeal	--	--	4.87	--
Potato protein	--	--	--	3.92
Soy oil	5.00	3.00	3.00	3.00
Monocalcium phosphate	1.77	1.945	1.33	2.00
Limestone	.63	.83	.49	.83
Vitamin premix	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15
DL - Methionine	.15	.05	--	--
L - Lysine	.10	.10	.10	.10
Copper sulfate	.075	.075	.075	.075
Antibiotic[b]	1.00	1.00	1.00	1.00
Total	100.00	100.00	100.00	100.00

[a]Phase I diets were formulated to contain 1.5% lysine, .42% methionine, .9% Ca, and .8% P and fed d 0 to 7 postweaning. Phase II diets were formulated to contain 1.25% lysine, .36% methionine, .9% Ca, .8% P and fed from d 7 to 28 postweaning.
[b]Provided 150 g/ton of apramycin in Phase I and 50 g/ton carbadox in Phase II.

Table 3. Effect of Potato Protein on Starter Pig Performance (Exp. 1)[a]

	Porcine plasma, % : Potato protein, %					
Item	3 : 0	5.5 : 0	8 : 0	3 : 2.6	3 : 5.1	CV
D 0 to 14						
ADG, lb	.34[c]	.42[b]	.44[b]	.38[bc]	.33[c]	16.4
ADFI, lb	.47[cd]	.52[bc]	.56[b]	.48[cd]	.42[d]	12.4
F/G	1.38	1.27	1.30	1.25	1.28	10.4
D 0 to 28						
ADG, lb	.64	.67	.65	.67	.64	12.4
ADFI, lb	1.03	1.07	1.06	1.10	1.02	15.2
F/G	1.67	1.56	1.64	1.61	1.59	12.3

[a]One hundred eighty five weanling pigs were used (initially 9.7 lbs 15.5 d of age), with six pens per treatment. Diets fed from d 0 to 14 were formulated to contain 1.5% lysine, .42% methionine, .9% Ca, and .8% P. From d 14 to 28, all pigs were fed the same Phase II diet formulated to contain 1.25% lysine, .36% methionine, .9% Ca, and .8% P.
[b,c,d]Means within the same row without a common superscript differ (P<.05).

Table 4. Effect of Potato Protein on Starter Pig Performance (Exp. 2)[a]

	Experimental protein sources			
Item	Blood meal	Fishmeal	Protein	CV
D 7 to 14				
ADG, lb	.36	.34	.32	22.2
ADFI, lb	.76	.73	.73	8.6
F/G	2.13	2.22	2.33	17.7
D 7 to 28				
ADG, lb	.77b	.79[b]	.64[c]	6.1
ADFI, lb	1.20[b]	1.19[bc]	1.11[c]	4.7
F/G	1.54[b]	1.49[b]	1.72[c]	4.1

[a]Two hundred seventy weanling pigs were used (initially 13.7 lb and 20 d of age), with six replicates per treatment. From day 0 to 7, pigs were fed the same Phase I diet formulated to contain 1.5% lysine, .42% methionine, .9% Ca, and .8% P. Experimental diets fed from d 7 to 28 were formulated to contain 1.25% lysine, .36% methionine, .9% Ca, and .8% P.
[b,c,d]Means within the same row without a common superscript differ (P<.05).

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COMPARISON OF NORSE LT-94 (HERRING MEAL) TO OTHER PROTEIN SOURCES IN EARLY-WEANED STARTER PIG DIETS

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Summary

Two growth trials were conducted to compare Norse LT-94 to other protein sources in starter pig diets. In trial 1, 270 weanling pigs (initially 13.7 lb and 20 d of age) were used to compare Norse LT-94 (herring meal), select menhaden fish meal, and spray-dried blood meal as protein sources in the Phase II diet. Pigs were blocked by weight with six replications of three treatments and 15 pigs per pen. During Phase I (d 0 to 7 postweaning), all pigs were fed the same high nutrient density diet. During Phase II (7 to 28 d postweaning), pigs were fed one of three experimental diets. All Phase II diets contained 10% dried whey and were formulated to 1.25% lysine and .34% methionine. The positive control diet contained 2.5% spray-dried blood meal. Norse LT-94 (herring meal, 4.06%) and select menhaden fish meal (4.87%) replaced blood meal on an equal lysine basis to form the other experimental diets. No differences occurred in pig performance during Phase II, indicating that Norse LT-94, spray-dried blood meal, and select menhaden fish meal are interchangeable as protein sources when substituted on an equal lysine basis.In trial 2, 230 pigs (initially 18 d of age and 11.0 lb) were used to examine the influence of various combinations of spray-dried porcine plasma and Norse LT-94 on starter pig performance. Pigs were allotted by weight to six replicates of five treatments with six to 10 pigs per pen. Pigs were assigned to one of five dietary treatments with no replacement or 25, 50, 75, or 100% of the spray-dried porcine plasma replaced with Norse LT-94 (herring meal) on an equal lysine basis. Therefore, diets contained 8, 6, 4, 2, or 0% spray-dried porcine plasma and 0, 2.14, 4.29, 6.43, or 8.58% Norse LT-94, respectively. All Phase I diets were formulated to contain 20% dried whey, 1.5% lysine, and .44% methionine. These diets were fed from d 0 to 14 postweaning. From d 14 to 28 (Phase II), all pigs were fed a common diet. Replacing spray-dried porcine plasma with Norse LT-94 resulted in a linear decrease in average daily gain (ADG) and average daily feed intake (ADFI) during Phase I and for the overall trial. This response became magnified when greater than 25% of the plasma was replaced with Norse LT-94. Feed efficiency responded in a quadratic manner for the first week of Phase I and for the overall trial, with pigs fed the diet containing 6% spray-dried porcine plasma and 2.14% Norse LT-94 having the best feed efficiency. These trials indicate that Norse LT-94 (herring meal) can replace spray-dried blood meal and select menhaden fish meal in Phase II starter pig diets. However, Norse LT-94 (herring meal) cannot be used as a replacement for spray-dried plasma protein in the Phase I diet.

(Key Words: Starter, Fish Meal, Plasma Protein.)

Introduction

[1]Appreciation is expressed to H.J. Baker and Bro., Little Rock, AR for partial financial support of these research trials, Keesecker Agribusiness, Washington, KS; Ellen Johncock; and Eichman Brothers, St. George, KS, for use of animals and facilities in these experiments.

Recent research at Kansas State University has evaluated several protein sources in diets for early-weaned pigs. These protein sources include spray-dried porcine plasma, spray-dried blood meal, skim milk, and various soy protein concentrates. Norse LT-94 is a high quality herring meal that has the potential to be used in early-weaned starter pig diets. However, Norse LT-94 is a relatively unknown product in the United States. Therefore, the objective of this research was to compare Norse LT-94 to the predominant existing protein sources in starter pig diets. Select menhaden fish meal generally is regarded as one of the highest quality fish meals available to the feed industry, and, thus, trial 1 was designed to directly compare Norse LT-94 with select menhaden fish meal in a manner in which these protein sources would be used by the feed industry. Spray-dried porcine plasma is an expensive, but high quality, protein source used in Phase I diets for the early weaned pig. If Norse LT-94 could be substituted for a portion of the porcine plasma in the diet without affecting pig performance, diet cost would be decreased. Therefore, the second trial was designed to answer this objective.

Procedures

Trial 1. A total of 270 pigs (initially 20 d and 13.7 lb) was used in this 28-d growth trial to compare Norse LT-94, select menhaden fish meal, and spray-dried blood meal as protein sources for the early-weaned pig. Pigs were blocked by weight and allotted to each of three dietary treatments with a total of 15 pigs per pen and six replicate pens per treatment.

The trial was divided into two phases. During Phase I (day 0 to 7 postweaning), all pigs were fed a common diet. This diet contained 10% spray-dried porcine plasma and 25% dried whey and was formulated to 1.6% lysine, .44% methionine, .9% Ca, and .8% P (Table 1).

The Phase II experimental diets were fed from d 7 to 28 postweaning. These diets contained 10% dried whey and were formulated to 1.25% lysine, .34% methionine, .9% Ca, and .8% P (Table 1). The control diet contained 2.5% spray-dried blood meal. Norse LT-94 (4.06%) and select menhaden fish meal (4.87%) replaced spray-dried blood meal on an equal lysine basis to form the other experimental diets. Soybean meal was maintained constant (22.63%) in all diets.

Pigs were housed in an environmentally controlled nursery in 4 × 8 ft pens. Pigs were allowed ad libitum access to feed and water. Pigs were weighed and feed disappearance was measured on d 7, 14, 21 and 28 after weaning to determine average daily gain (ADG), average daily feed intake (ADFI) and feed efficiency (G/F).

Data were analyzed as a randomized complete block design. General linear model procedures of SAS were used with initial weight serving as the blocking factor. Single degree of freedom contrasts were used to separate treatment means. Pig weight at the end of Phase I (d 7) was used as a covariate for Phase II growth performance.

Trial 2. A total of 230 pigs (initially 18 d and 11.0 lb) was used in this 28-d trial to compare Norse LT-94 and spray-dried porcine plasma in the Phase I starter pig diet. Pigs were blocked by weight and allotted to each of five dietary treatments with a total of six to 10 pigs per pen and six replicate pens per treatment.

Similar to trial 1, trial 2 was divided into two phases. The experimental diets were only fed during Phase I (d 0 to 14 postweaning). All pigs received a common diet during Phase II (d 14 to 28 postweaning). The Phase I, experimental diets were formulated to contain 1.5% lysine, .44% methionine, .9% calcium, and .8% phosphorus (Table 2). The control diet was corn-soybean meal-based and contained 8% spray-dried porcine plasma (SDPP) and 25% dried whey. Norse LT-94 was absent or replaced 25, 50, 75, or 100% of the porcine plasma on an equivalent lysine basis to form the experimental diets. Therefore, diets contained 8, 6, 4, 2, or 1% spray-dried porcine plasma and 0, 2.14, 4.29, 6.43, or 8.58% Norse LT-94,

respectively. Soybean meal level remained constant in all diets.

On d 14, all pigs were switched to a common Phase II diet containing 10% dried whey and 2.5% spray-dried blood meal and formulated to 1.25% lysine (Table 2). Pigs were fed this diet for the remainder of the experiment.

Pigs were housed in an environmentally controlled nursery in 4 × 6 ft pens. Pigs were allowed ad libitum access to feed and water. Pigs were weighed and feed disappearance was measured on d 7, 14, 21, and 28 after weaning to determine average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (G/F).

Data were analyzed as a randomized complete block design. General linear model procedures of SAS were used with initial weight serving as a blocking factor. Linear and quadratic polynomials were used to detect the response to replacing spray-dried porcine plasma with Norse LT-94.

Results and Discussion

Trial 1. When all pigs consumed the same diet during Phase I, pigs gained .32 lb/d, consumed .45 lb/day, and had a feed to gain (F/G) ratio of 1.51. During Phase II, no differences (P>.21) occurred in ADG, ADFI, or F/G among pigs fed diets containing Norse LT-94, select menhaden fish meal or spray-dried blood meal for any week of the trial (Table 3). These results indicate that Norse LT-94 can replace select menhaden fish meal and spray-dried blood meal on an equal lysine basis in starter pig diets with no influence on performance.

Trial 2. Replacing spray-dried porcine plasma with Norse LT-94 resulted in linear reductions (P<.006) in ADG and ADFI during Phase I (d 0 to 14) and for the overall trial. The depression in performance became more evident when greater than 25% of the spray-dried porcine plasma was replaced with Norse LT-94. Feed to gain increased in a linear (P<.01) fashion during Phase I and for the overall trial as the level of Norse LT-94 increased in the diet. Feed efficiency improved with the first substitution of Norse LT-94 for spray-dried porcine plasma (6% plasma, 2.4% Norse LT-94); however, as larger portions of plasma were replaced, F/G increased rapidly.

Although small differences in ADG and ADFI occurred from d 14 to 21, no differences were observed between the five experimental treatments for the entire Phase II period (d 14 to 28). Thus, any difference in performance at the end of Phase I was maintained for the duration of the experiment. In summary, Norse LT-94 can replace only a small portion of the spray-dried porcine plasma in the Phase I diet without causing large reductions in pig performance.

In conclusion, these trials indicate that Norse LT-94 can replace spray-dried blood meal and select menhaden fish meal in Phase II starter pig diets. However, Norse LT-94 cannot be used as a replacement for spray-dried plasma protein in the Phase I diet.

Table 1. Composition of Diets (Trial 1)

		Experimental protein sources[a]		
Ingredient, %	Phase I[b]	Blood meal	Norse LT-94	Menhaden fish meal
Corn	37.18	57.47	56.32	56.11
Soybean meal (48% CP)	18.69	22.63	22.63	22.63
Porcine plasma	10.0	—	—	—
Spray-dried blood meal	—	2.5	—	—
Norse LT-94	—	—	4.056	—
Select menhaden fish meal	—	—	—	4.872
Soybean oil	5.0	3.0	3.0	3.0
Dried whey	25.0	10.0	10.0	10.0
Monocalcium phosphate	1.77	1.95	1.95	1.33
Limestone	.63	.82	.82	.49
Antibiotic[c]	1.0	1.0	1.0	1.0
Copper sulfate	.08	.08	.08	.08
L-lysine HCl	.10	.10	.10	.10
DL-methionine	.15	.05	—	—
Vitamin premix	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15
Total	100.0	100.0	100.0	100.0

[a]All Phase II diets were formulated to contain 1.25% lysine, .9% Ca, .8% P, and .36% methionine.
[b]The Phase 1 diet was formulated to contain 1.6% lysine, .44% methionine, .9% Ca, .8% P.
[c]150 g/ton apramycin in Phase I and 50 g/ton carbadox in Phase II.

Table 2. Composition of Experimental Diets (Trial 2)[a]

	Plasma protein, % : Norse LT-94, %					
Ingredient, %	8:0	6:2.14	4:4.29	2:6.43	0:8.58	Phase II
Corn	38.63	38.72	38.81	38.86	38.92	57.47
Soybean meal (48% CP)	19.28	19.28	19.28	19.28	19.28	22.63
Porcine plasma	8.0	6.0	4.0	2.0	—	—
Norse LT-94	—	2.14	4.29	6.43	8.58	—
Spray-dried blood meal	—	—	—	—	—	2.5
Soybean oil	5.0	5.0	5.0	5.0	5.0	3.0
Dried whey	25.0	25.0	25.0	25.0	25.0	10.0
Monocal. phos., 21% P	1.74	1.58	1.43	1.27	1.11	1.95
Limestone	.64	.60	.56	.52	.48	.83
Antibiotic[b]	1.0	1.0	1.0	1.0	1.0	1.0
Copper sulfate	.08	.08	.08	.08	.08	.08
L-lysine	.10	.10	.10	.10	.10	.10
DL-methionine	.13	.09	.06	.06	.05	.05
Vitamin premix	.25	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15	.15
Total	100.0	100.0	100.0	100.0	100.0	100.0

[a]All Phase I diets were formulated to contain 1.5% lysine, .9% Ca, .8% P, and .44% methionine. Experimental diets were fed from d 0 to 14 postweaning. All pigs received the Phase II diet from d 14 to 28 postweaning. The Phase II diet was formulated to 1.25% lysine, .9% Ca, and .8% P.
[b]150 g/ton apramycin in Phase I and 50 g/ton carbadox in Phase II.

Table 3. Comparison of Protein Sources in the Phase II Diet (Trial 1)

	Protein source				
Item	Spray-dried blood meal	Norse LT-94 (herring meal)	Select menhaden fish meal	CV	P value
d 7 to 14					
ADG, lb	.36	.29	.34	22.5	.39
ADFI, lb	.75	.71	.73	8.2	.53
F/G	2.25	2.73	2.63	25.9	.48
d 14 to 21					
ADG, lb	.86	.96	.87	11.5	.26
ADFI, lb	1.08	1.09	1.06	6.01	.80
F/G	1.28	1.12	1.32	18.5	.38
d 21 to 28					
ADG, lb	1.09	1.08	1.14	8.2	.59
ADFI, lb	1.72	1.75	1.70	4.9	.63
F/G	1.58	1.62	1.51	7.0	.34
d 7 to 28					
ADG, lb	.76	.77	.78	5.7	.89
ADFI, lb	1.18	1.18	1.16	4.3	.74
F/G	1.54	1.52	1.49	2.6	.11

[a]Means represent 6 pens/treatment with 15 pigs/pen. All pigs were fed a common Phase I diet from d 0 to 7 postweaning. Pig weight at d 7 was used as a covariate for Phase II growth performance.

Table 4. Effect of Replacing Plasma Protein with Norse LT-94 (herring meal) on Starter Pig Performance (Trial 2)[a]

	Plasma Protein, % : Norse LT-94, %						P Values	
Item	8:0	6:2.14	4:4.29	2:6.43	0:8.58	CV	Linear	Quadratic
d 0 to 7								
ADG, lb	.34	.32	.28	.17	.17	23.6	.001	.41
ADFI, lb	.44	.38	.38	.35	.32	13.6	.001	.81
F/G	1.28	1.18	1.40	2.23	2.00	23.5	.001	.06
d 0 to 14								
ADG, lb	.51	.48	.43	.37	.31	16.7	.001	.56
ADFI, lb	.57	.50	.48	.46	.42	11.8	.001	.58
F/G	1.11	1.06	1.12	1.25	1.46	18.5	.006	.10
d 14 to 21								
ADG, lb	.72	.70	.84	.71	.76	9.8	.41	.25
ADFI, lb	1.12	1.10	1.14	1.12	1.11	6.4	.94	.70
F/G	1.57	1.59	1.38	1.63	1.46	8.1	.26	.58
d 14 to 28								
ADG, lb	.93	.93	.96	.90	.90	6.9	.36	.34
ADFI, lb	1.44	1.43	1.43	1.39	1.39	4.9	.11	.75
F/G	1.56	1.54	1.50	1.55	1.54	4.4	.73	.32
d 0 to 28								
ADG, lb	.72	.70	.70	.64	.61	8.1	.001	.36
ADFI, lb	1.00	.97	.96	.93	.90	5.5	.002	.93
F/G	1.40	1.38	1.38	1.46	1.50	8.7	.01	.10

[a]Means represent 6 pens per treatment with 6 to 10 pigs/pen depending on block. Pigs were fed one of the experimental diets d 0 to 14 postweaning, and all pigs were fed a common Phase II diet d 14 to 28 post-weaning.

EVALUATION OF MODIFIED POTATO STARCH IN DIETS FOR THE EARLY-WEANED PIG[1]

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Summary

Two growth trials were conducted to compare the effectiveness of replacing either corn or lactose with modified potato starches in diets for conventionally and early-weaned pigs. In Exp. 1, 198 pigs (initially 9.4 lb and 19 d of age) were used to determine if modified potato starch (potato starch 1) can replace a portion of the lactose in a high nutrient dense diet. Pigs were allotted by weight, gender, and ancestry to each of six dietary treatments with either five or six pigs per pen and six pens per treatment. The control diet contained 10% dried whey (7.2% lactose), 7.5% spray-dried porcine plasma, 2.5% select menhaden fish meal, and 1.75% spray-dried blood meal. Additional treatments were formulated by adding 7 or 14% modified potato starch or lactose in place of corn. A positive control diet also was formulated containing 29% dried whey (providing the same amount of lactose as the 10% dried whey plus 14% lactose diet). All diets were formulated to contain 1.5% lysine, and .90% Ca, .80% P, and 17.88% soybean meal and were fed in a meal form. From day 0 to 14 postweaning, increasing dietary lactose tended to linearly improve ADG and ADFI. Added potato starch did not improve ADG compared with pigs fed the control diet, but ADFI increased linearly with increasing potato starch. In Exp. 2, 180 pigs (8.5 lb and 14 d of age) were used to evaluate the effects of two modified potato starches (potato starch 1 or potato starch 2 a further hydrolyzed potato starch with a greater percentage of sugars as either glucose or maltose as a replacement for either corn or lactose in a segregated early-weaning diet (SEW). Pigs were fed a control diet containing 15% dried whey, 12% added lactose, 6% porcine plasma, and 6% select menhaden fish meal. Modified potato starch 1 or 2 (12%) replaced either corn or the added lactose on an equal weight basis. From d 0 to 7 postweaning, pigs fed the modified potato starch 1 had greater ADG and ADFI than those fed modified potato starch 2. Pigs fed diets with either starch substituted for corn had greater ADG than those fed diets with either starch substituted for lactose. From d 0 to 14 and d 0 to 21, pigs fed diets containing either modified potato starch substituted for corn tended to have greater ADG than those fed the control diet. This appeared to be the result of greater feed intake of pigs fed the diets containing either starch substituted for corn compared with those fed the control diet or diets containing either starch substituted for lactose. Pigs fed diets with either modified starch substituted for lactose had similar ADG as those fed the control diet. In conclusion, these results suggest that potato starch can improve growth performance of pigs when substituted for corn and can replace a portion of the lactose in an SEW diet without adversely affecting performance.

Introduction

Previous research (KSU Swine Day Report of Progress 641, p 63) has indicated that modified potato starch substituted for

[1]The authors would like to thank Avebe America, Inc. for donating the modified starches used in these experiments.

corn in a Phase I diet increased ADG and ADFI of pigs weaned at 21 d of age. The modified potato starch used in this previous trial was treated enzymatically to break the carbohydrate molecules into individual glucose molecules and spray-dried. It had a dextrose equivalent (relative sweetness compared with pure dextrose) of 20. Unfortunately, the positive influence on growth performance of this modified starch is overshadowed by its hydroscopic nature and difficulties in flowing through feed handling systems. In addition, at this time, modified starches are not likely to be cost competitive as a replacement for corn. Therefore, the objective of these experiments was to evaluate the use of modified starches as replacements for either corn or lactose in diets for conventionally and segregated early-weaned pigs.

Procedures

A total of 198 pigs (initially 9.4 lb and 19 d of age) was used in a 35-d growth trial. Pigs were allotted by weight and ancestry to one of six dietary treatments for a total of five to six pigs per pen and six pens per treatment. The trial was divided into two phases. Experimental diets were fed during Phase I (d 0 to 14 postweaning). All pigs were fed a common Phase II diet from d 14 to 35 postweaning.

Dietary treatments were based on level of lactose plus casein or modified potato starch 1 plus casein added to the Phase I diet in replacement of dietary corn. Potato starch 1 was enzymatically hydrolyzed to contain approximately 1.5% glucose, 4.5% maltose, and 8.5% maltotriose, with the remaining 85.5% sugars as higher glucose polymers. It had a dextrose equivalent of 20. The control diet was soybean meal-based containing 10% dried whey, 1.75% spray-dried blood meal, 2.5% fish meal, and 7.5% spray-dried porcine plasma. Lactose (7 or 14%) and potato starch 1 (7 or 14%) replaced corn in the control diet. The sixth treatment was a positive control diet with 29% dried whey. This diet contained the same amount of lactose as the diet containing 14% added lactose and 10% dried whey. All Phase I diets were formulated to 1.5% lysine, .42% methionine, .9% calcium, and .8% phosphorus. The common Phase II diet contained 10% dried whey and 2.5% spray-dried blood meal. It was formulated to contain 1.25% lysine, .36% methionine, .9% calcium, and .8% phosphorus. Both Phase I and Phase II diets were fed in a meal form.

In Exp. 2, a total of 180 pigs (initially 8.5 lb and 14 d of age) was used in a 21-d growth trial. Pigs were allotted by sex, weight, and ancestry and placed in pens containing six pigs each. Pens were assigned randomly to one of five treatments in a randomized complete block design. Pigs were fed the five experimental diets from d 0 to 21 postweaning. All diets were formulated to contain 1.7% lysine, .48% methionine, .90% Ca, and .80% P. The control diet contained 10% spray-dried porcine plasma, 1.75% spray-dried blood meal, and 15% dried whey. Modified potato starch 1 (same as in Exp. 1) or a further modified potato starch (potato starch 2) replaced 12% of either corn or lactose to provide the four additional treatments. Potato starch 2 was obtained by enzymatic hydrolysis to provide 3% glucose, 10% maltose, 12.5% maltotriose, with the remaining 74.5% of sugars as higher glucose polymers. It has a dextrose equivalent of 30. All diets were fed in a pelleted form.

In both experiments, pigs were housed in an environmentally controlled nursery with slotted-metal flooring and were allowed ad libitum access to feed and water. Pigs were weighed and feed disappearance was measured weekly to determine ADG, ADFI, and F/G.

Results and Discussion

Experiment 1. From d 0 to 14 postweaning, increasing dietary lactose tended to improve (linear, $P<.11$) ADG and ADFI. Added potato starch 1 did not improve ADG compared with pigs fed the control diet, but ADFI increased (linear, $P<.05$) with increasing added starch. Pigs fed the diet containing 29% dried whey had the greatest ADG, which was not different from that of pigs fed the diet containing 14% added lac-

tose. However, pigs fed the diet containing 29% dried whey had greater ADG (P<.05) than those fed 14% added potato starch. No differences occurred in ADG of pigs fed the 10% dried whey control diet compared with pigs fed the diets with added starch or with 7% added lactose. Feed efficiency was not affected by dietary treatment. During Phase II when pigs were fed a common diet, no differences were observed in ADG. Pigs fed the diet containing 29% dried whey had greater ADFI than those fed the diet containing 14% added starch during Phase I. However, pigs previously fed diets containing added starch tended to have improved F/G (linear, P<.11) compared with those pigs fed the diet containing 10% dried whey. Overall results (d 0 to 35) showed improved ADG (linear, P<.05) and ADFI (quadratic, P<.10) with increasing lactose fed during Phase I, but no linear improvement with added starch. However, the mean ADG of pigs fed diets containing added starch during Phase I was greater than that of pigs fed the control diet (P<.05). Pigs fed the diet containing 29% dried whey had greater ADFI compared with those fed the diet with 14% added starch. In summary, ADG and ADFI increased with increasing lactose from 7.2 to 21% of the diet. Although no differences occurred in growth performance of pigs fed 29% dried whey (21% lactose) and those fed 14% added lactose (21% total lactose), pigs fed the 29% dried whey diet tended to have better ADG and F/G. Pigs fed 14% added starch had decreased ADG compared with those fed 29% dried whey, suggesting that modified starch is not a complete replacement for lactose in starter diets for pigs weaned at 21 d of age.

Experiment 2. From d 0 to 7 postweaning, pigs fed the diets containing modified potato starch 1 had greater ADG and ADFI (P<.10) than those fed diets containing modified potato starch 2. Pigs fed diets with either starch substituted for corn had greater ADG (P<.05) than those fed diets with starch substituted for lactose. In addition, pigs fed the diet containing either modified starch substituted for corn had greater ADG compared with pigs fed the control diet (P<.05). From d 0 to 14 and d 0 to 21, pigs fed diets containing either modified starch substituted for corn tended to have greater ADG (P<.10) and ADFI (P<.05) than those fed the control diet. Pigs fed diets with starch substituted for corn had greater ADFI than those fed diets containing starch substituted for lactose (P<.05). Pigs fed modified potato starch 1 had greater ADFI and improved F/G than those fed modified potato starch 2 (P<.10). Pigs fed diets with either starch substituted for lactose had similar ADG to those fed the control diet. Therefore, substituting modified starches for corn improves ADG and ADFI of early-weaned pigs, with the greatest benefits observed for pigs fed modified potato starch 1.

These results suggest that modified potato starch can improve growth performance of pigs when substituted for corn and can replace a portion of the lactose in an SEW diet without adversely affecting performance. However, currently, the hydroscopic nature of modified potato starch prohibits regular application in starter pig diets, because it causes major problems in manufacturing and feed handling.

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

Item	10% Dried whey	Lactose, %		Potato starch, %		29% Dried whey	Phase II[b]
		7%	14%	7%	14%		
Corn	53.25	45.67	38.06	45.67	38.06	35.05	58.76
Soybean meal (46.5% CP)	17.88	17.88	17.88	17.88	17.88	17.88	21.26
Potato starch 1	--	--	--	7.00	14.00	--	--
Lactose	--	7.00	14.00	--	--	--	--
Dried whey	10.00	10.00	10.00	10.00	10.00	29.00	10.00
Spray dried plasma	7.50	7.50	7.50	7.50	7.50	7.50	--
Soy oil	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Fish meal menhaden	2.50	2.50	2.50	2.50	2.50	2.50	--
Spray-dried blood meal	1.75	1.75	1.75	1.75	1.75	1.75	2.5
Monocalcium phosphate (21% P)	1.77	1.84	1.92	1.84	1.92	1.32	1.97
Antibiotic[c]	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Casein	--	.55	1.16	.55	1.16	--	--
Limestone	.61	.57	.53	.57	.53	.41	.83
KSU vitamin premix	.25	.25	.25	.25	.25	.25	.25
KSU trace minerals	.15	.15	.15	.15	.15	.15	.15
Methionine	.104	.103	.100	.103	.100	.100	.05
Copper sulfate	.075	.075	.075	.075	.075	.075	.075
L-lysine HCL	.150	.128	.103	.128	.103	--	.15
Total	100	100	100	100	100	100	100

[a]Diet was formulated to contain 1.5% lysine, .44% methionine, .9% Ca, and .8% P and was fed from d 0 to 7 postweaning.
[b]Diet was formulated to contain 1.25% lysine, .35% methionine, .9% Ca, and .8% P and was fed from d 7 to 1 postweaning.
[c]Provided 150 g/ton apramycin in Phase I and 50 g/ton carbadox in Phase II.

Table 2. Diet Composition (Exp. 2)[a]

		Potato starch substituted for	
Item	Control	Corn	Lactose
Corn	30.54	18.33	30.53
Soybean meal (46.5% CP)	14.97	14.97	14.97
Potato starch 1 or 2	--	12.00	12.00
Lactose	12.00	12.00	--
Dried whey	15.00	15.00	15.00
Spray-dried plasma protein	10.00	10.00	10.00
Soy oil	6.00	6.00	6.00
Menhaden fish meal	6.00	6.00	6.00
Spray-dried blood meal	1.75	1.75	1.75
Monocalcium phosphate (21% P)	1.47	1.65	1.48
Antibiotic[b]	1.00	1.00	1.00
Zinc oxide	.38	.38	.38
Limestone	.21	.14	.21
KSU vitamin premix	.25	.25	.25
KSU trace minerals	.15	.15	.15
DL-methionine	.12	.15	.12
Isoleucine	--	.043	--
L-lysine HCL	--	.035	--
Salt	.15	.15	.15
Total	100	100	100

[a]Diets were formulated to contain 1.7% lysine, .48% methionine, and .90% Ca, and .8% P and fed from d 0 to 21 postweaning.
[b]Provided 150 g/ton carbadox.

Table 3. Effect of Added Potato Starch or Lactose on Starter Pig Performance (Exp. 1)[a]

Item	10% Dried whey	Potato starch, %		Lactose, %		29% Dried whey	CV
		7%	14%	7%	14%		
D 0 to 14							
ADG, lb[bc]	.64	.66	.67	.67	.71	.77	13.2
ADFI, lb[de]	.92	1.02	1.05	1.02	1.07	1.13	9.1
G/F	1.47	1.54	1.57	1.50	1.52	1.45	10.8
D 14 to 35							
ADG, lb	1.08	1.15	1.15	1.19	1.15	1.16	7.3
ADFI, lb[f]	2.10	2.13	2.08	2.17	2.12	2.21	6.2
G/F[g]	1.95	1.85	1.81	1.83	1.83	1.9	7.0
D 0 to35							
ADG, lb[b]	.90	.96	.96	.98	.98	1.00	6.6
ADFI, lb[cdh]	1.62	1.69	1.67	1.71	1.69	1.78	5.5
G/F	1.82	1.76	1.74	1.75	1.72	1.76	6.7

[a]One hundred ninety eight weanling pigs were used (initially 9.41 lb and 19 d of age +/- 3 d of age), with 5 pigs per pen in three reps and 6 pigs per pen in three reps. Day 0 to 14 diets were formulated to contain 1.5% lysine, .42% methionine, .9% Ca, and .8% P. Day 14 to 35 diets contained 1.5% lysine.
[bd]Linear effect of lactose (P<.11 and P<.05), respectively.
[cf]14% starch vs 29% dried whey (P<.05 and P<.11), respectively.
[eg]Linear effect of starch (P<.05 and P<.11), respectively.
[h]Quadratic effect of lactose (P<.10).

Table 4. Effect of Added Potato Starch Substituted for Corn or Lactose on Starter Pig Performance (Exp. 2)[a]

Item	Control	Starch substituted for corn		Starch substituted for lactose		CV
		Potato starch 1	Potato starch 2	Potato starch 1	Potato starch 2	
D 0 to 7						
ADG, lb[bc]	.41	.48	.43	.43	.40	12.8
ADFI, lb[d]	.41	.50	.42	.49	.41	17.1
F/G	1.00	1.03	.94	1.16	1.01	19.0
D 0 to 14						
ADG, lb[e]	.54	.62	.59	.55	.56	11.1
ADFI, lb[dfg]	.62	.73	.67	.71	.59	9.5
F/G[d]	1.15	1.18	1.14	1.30	1.06	11.7
D 0 to 21						
ADG, lb[e]	.67	.74	.72	.68	.70	9.3
ADFI, lb[dfg]	.80	.94	.87	.90	.78	9.8
F/G[d]	1.20	1.27	1.20	1.33	1.12	7.6

[a]One hundred eighty weanling pigs were used (initially 8.6 lb and d of age), 6 pigs/pen, 5 pens per treatment. Experimental diets were fed from d 0 to 21 postweaning.
[bd]Mean of pigs fed MD20 vs SPG (P<.10 and P<.01), respectively.
[cg]Mean of pigs fed starch substituted for corn vs lactose (P<.05 and P<.10), respectively.
[ef]Mean of pigs fed starch substituted for corn vs control (P<.10 and P<.05), respectively.

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INFLUENCE OF OATS AND OAT PRODUCTS IN PHASE I AND II DIETS ON GROWTH PERFORMANCE OF WEANLING PIGS

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Summary

Two experiments were conducted to determine the nutritional value of oats and oat products in diets of weanling pigs. In Exp. 1, 115 weanling pigs (avg initial body wt of 12.4 lb and avg age of 19 d) were used in a 38-d growth assay. Treatments were 1) a corn-soybean meal-based control, 2) ground oats, 3) oat groats, and 4) oat flour. Phase I diets were formulated to 1.55% lysine, and at d 10 postweaning the pigs were switched to a Phase II diets formulated to 1.3% lysine. At d 24 postweaning, all pigs were changed to a sorghum-based Phase III diet. The diets were fed in pelleted form. For Phase I, pigs fed the oat products tended to have greater efficiencies of gain compared to pigs fed corn. Pigs fed the reduced fiber oat products (groats and flour) were more efficient than pigs fed ground whole oats, and the most refined oat product (oat flour) tended to support the greatest efficiencies of gain (8% greater ADG and 13% greater F/G than the corn control). These same trends for pigs fed oat flour were noted in Phase II and for the overall experiment (i.e., d 0 to 38). In Exp. 2, 172 weanling pigs (avg initial body wt of 12.5 lb and avg age of 19 d) were used in a second 38-d growth assay. Treatments were 1) a corn-soybean meal-based control, 2) ground oats, 3) roasted oats, 4) oat groats, 5) steam-flaked oat groats, and 6) oat flour. The data indicated that roasting decreased the nutritional value of ground oats. However, steam-flaking improved the nutritional value of oat groats. Feeding diets formulated with processed oat products (i.e., steam-flaked oat groats and oat flour) improved F/G through Phase II (e.g., 6% greater efficiency of gain compared to the corn-based control), but much of that advantage was lost during Phase III while the pigs were fed the same sorghum-based diet. In conclusion, the most refined oat products (steam-flaked oat groats and oat flour) supported better F/G than corn in Phases I and II. However, cost must be continuously balanced against the improved performance to ensure that use of these oat products is economically viable.

(Key Words: Pigs, Carbohydrate, Starter, Oat, Growth.)

Introduction

Oats is a popular field crop grown throughout much of the United States. During the past decade, researchers at KSU have developed and promoted a three-phase diet regimen (depending on age at weaning) for feeding nursery pigs. In the 1981 KSU Swine Day (page 26), it was stated that pigs fed a corn-sorghum meal-based diet gained 5% slower than pigs fed diets with steam-rolled or ground oats. However, in that experiment, simple diets were fed to pigs weaned at 6 wk of age. Therefore, two experiments were conducted to determine the effects of various oat products in Phase I (d 0 to 10) and II (d 10 to 24) complex nursery diets on growth performance of pigs weaned at 3 weeks of age or less.

Procedures

In Exp. 1, 115 weanling pigs (avg body wt of 12.4 lb and avg age of 19 d) were allotted by weight, sex, and ancestry with six pigs per pen and five pens per treatment. Treatments were 1) a corn-soybean meal-based control, 2) ground oats, 3) oat groats,

and 4) oat flour. The ground oat treatment was a "full-fiber" ingredient. Oat groats were the dehulled portions of the whole oats, and the oat flour was further refined with the oat bran removed. Phase I diets were formulated to 1.55% lysine, .9% Ca, and .8% P. At d 10, the pigs were switched to Phase II diets with 1.3% lysine, .9% Ca, and .8% P, using the same carbohydrate sources as in Phase I. At d 24, all pigs were put on a sorghum-based Phase III diet formulated to 1.15% lysine, .9% Ca, and .8% P. All diets were fed in pelleted form. In Exp. 2, 172 weanling pigs (avg body wt of 12.5 lb and avg age of 19 d) were allotted by weight, sex, and ancestry with six pigs per pen and five pens per treatment. Treatments were 1) a corn-soybean meal-based control, 2) ground oats, 3) roasted oats, 4) oat groats, 5) steam-flaked oat groats, and 6) oat flour. Phase I, II, and III diets were formulated to the same nutrient concentrations as in Exp. 1. All carbohydrate sources were ground through a hammermill using an 1/16" screen. The roasted oats were ground through a hammermill and then reconstituted to 30% moisture. This product was pelleted and passed through a Jet-Pro® roaster with an exit temperature of 260°F. For steam-flaked oat groats, the product was heated and softened with steam and rolled flat through a steam flaker with an exiting temperature of approximately 200°F.

All 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 to 5, respectively. Each pen had a self-feeder and nipple waterer to allow ad libitum consumption of fed and water. The pigs and feeders were weighed on d 0, 10, 24, and 38 to allow calculations of average daily gain (ADG), average daily feed intake (ADFI), and feed to gain ratio (F/G).

Results and Discussion

Experiment 1. No differences were detected for ADG or ADFI during Phase I (d 0 to 10) of the experiment. However, pigs fed the diet with corn tended to have poorer F/G ($P<.06$) than those fed the oat products. Also, pigs fed the diet with ground oats had poorer F/G ratio ($P<.02$) than those fed diets with oat groats and oat flour. The removal of fiber (hulls and bran) for the oat groats and flour treatments probably was the reason for improved efficiency of gain.

For Phase II (d 10 to 24), ADFI was greater ($P<.02$) for pigs fed the ground oats compared to pigs fed diets with oat groats and oat flour. Diets with ground whole oats would have lower energy concentrations and, thus, pigs would eat more to consume similar amounts of energy. Pigs fed diets with oat flour had improved ADG and F/G ($P<.01$) compared to those fed diets with oat groats.

Data from the combined Phases I and II periods (d 0 to 24) indicated that pigs fed ground oats consumed more feed ($P<.08$) and had poorer F/G ($P<.02$) than pigs fed oat groats and oat flour. Pigs fed oat flour had improved ADG and F/G compared to those fed oat groats ($P<.02$).

During Phase III (d 24 to 38), no differences occurred for ADG, ADFI, or F/G among pigs fed the various carbohydrate sources in Phases I and II. However, overall data (d 0 to 38) indicated that pigs initially fed diets with ground oats tended to consume more feed ($P<.07$) and converted feed to gain with less efficiency than those fed oat groats and oat flour. Also, pigs initially fed diets with oat flour tended to have improved F/G ($P<.08$) compared to those fed oat groats.

Experiment 2. During Phase I, pigs fed diets with reduced fiber (groats- and flour-based diets) had greater ADG and ADFI than those fed ground oats and roasted oats ($P<.01$). Also, pigs fed ground oats had greater ADG and ADFI ($P<.04$) than pigs fed roasted oats. Thus, it appeared that heat treatment (roasting) of the whole oats reduced their nutritional value.

During Phase II, pigs fed roasted oats continued to have poorer ADG and ADFI ($P<.02$) compared to pigs fed ground oats. Pigs fed diets with ground oats and roasted oats had poorer F/G ($P<.01$) compared to pigs fed reduced-fiber treatments, and pigs fed steam-flaked oat groats had better F/G ($P<.001$) than those fed ground oat groats.

The combined data from Phases I and II indicated that pigs fed ground oats and roasted oats had poorer ADG and F/G (P<.03) than pigs fed reduced fiber treatments. Pigs fed ground oats had improved ADG and ADFI (P<.01) compared to pigs fed roasted oats. Also, pigs fed steam-flaked oat groats had improved F/G (P<.001) compared to those fed ground oat groats. The improvement in nutritional value with heat treatment (steam flaking) of the oat groats probably can be attributed to denaturation of protein and gelatinization of starch. Perhaps the lack of response to heat treatment (roasting) for whole oats was because of overprocessing. A slightly dark appearance for the roasted oats product was noted when the diets were mixed.

Overall (d 0 to 38), pigs initially fed corn tended to have greater ADG and ADFI (P<.08 and <.09, respectively) compared to pigs fed oat products. Pigs initially fed ground oats had improved ADG and ADFI (P<.02) compared to those fed roasted oats. Also, pigs initially fed steam-flaked oat groats tended to have improved F/G (P<.06) compared to pigs given ground oat groats.

In summary, oat products are suitable substitutes for corn in diets for weanling pigs. Further processing of oat products, especially steam-flaking and removal of fiber to yield oat flour, resulted in improved nutritional value of Phases I and II nursery diets (e.g., equal ADG but 6% greater efficiency of gain compared to the ground corn control diet). Thus, depending on cost, processed and refined oat products can be used to improve F/G of weanling pigs during Phases I and II (d 0 to 24) postweaning. However, their generally greater price dictates careful comparison of diet costs before oat products are used.

Table 1. Diet Composition, [ab]

Ingredient	Phase I[c] (d 0 to 10)	Phase II[d] (d 10 to 24)	Phase III[e] (d 24 to 38)
Corn	38.70	51.87	---
Sorghum	---	---	60.22
Soybean meal	15.00	20.00	33.60
Dried whey	20.00	20.00	---
Lactose	10.00	---	---
Spray dried plasma protein	8.00	---	---
Spray dried blood meal	2.00	2.00	---
Soybean oil	2.00	2.00	2.00
Monocalcium phosphate	1.88	1.55	1.97
Limestone	.68	.78	.92
Vit/Min/Ab[f]	1.47	1.58	1.29
DL-methionine	.17	.08	---
Lysine-HCl	.10	.14	---
Total	100.00	100.00	100.00

[a]For Exp. 1, ground oats, oat groats, and oat flour were used to replace corn, lysine-HCl, monocalcium phosphate, and limestone in Phases I and II.
[b]For Exp. 2, ground oats, roasted oats, oat groats, and oat flour were used to replace corn, lysine-HCl, monocalcium phosphate, and limestone in Phases I and II.
[c]Phase I diets were formulated to 1.55% lysine, .9% Ca, and .8% P.
[d]Phase II diets were formulated to 1.3% lysine, .9% Ca, and .8% P.
[e]Phase III diets were formulated to 1.15% lysine, .9% Ca, and .8% P. This diet was fed from d 24 to 38 of both trials.
[f]Vit/Min = KSU vitamin and trace mineral premixes. Antibiotic (Ab) was 150 g/ton apramycin in Phase I and 50 g/ton carbadox in Phases II and III.

Table 2. Effects of Oat Products on Performance of Nursery Pigs (Exp. 1)[a]

						Contrasts[bc]		
Item	Corn	Ground oats	Ground oat groats	Oat flour	CV	1	2	3
Phase I (d 0 to 10)								
ADG, lb	.60	.60	.66	.65	12.6	--	--	--
ADFI, lb	.67	.67	.68	.64	13.3	--	--	--
F/G	1.12	1.10	1.03	.98	7.0	.06	.02	--
Phase II (d 10 to 24)								
ADG, lb	.98	1.00	.84	1.04	8.1	--	--	.01
ADFI, lb	1.42	1.49	1.29	1.34	8.7	--	.02	--
F/G	1.45	1.49	1.51	1.29	7.0	--	--	.01
Phases I and II (d 0 to 24)								
ADG, lb	.82	.84	.77	.88	7.8	--	--	.02
ADFI, lb	1.11	1.15	1.03	1.04	9.1	--	.08	--
F/G	1.35	1.37	1.34	1.20	5.1	--	.02	.01
Overall (d 0 to 38)								
ADG, lb	.86	.88	.80	.89	12.4	--	--	--
ADFI, lb	1.38	1.45	1.29	1.33	9.7	--	.07	--
F/G	1.61	1.65	1.61	1.50	6.1	--	--	.08

[a]A total of 115 pigs (six pigs/pen and five pens/treatment) with an average initial body wt of 12.4 lb and an average final body wt of 70 lb.
[b]Contrasts were: 1) corn vs oat products; 2) ground oats vs reduced fiber oat products (groats and flour); and 3) oat groats vs oat flour (oat bran removed).
[c]Dashes indicate P>.10.

Table 3. Effects of Oat Products on Performance of Nursery Pigs (Exp 2)[a]

								Contrasts[bc]			
Item	Corn	Ground oats	Roasted oats	Ground oat groats	Steam-flaked oat groats	Oat flour	CV	1	2	3	4	5
Phase I (d 0 to 10)												
ADG, lb	.53	.53	.47	.54	.54	.55	7.7	--	.01	.04	--	--
ADFI, lb	.48	.47	.43	.49	.49	.47	4.6	--	.001	.01	.05	--
F/G	.91	.90	.90	.90	.92	.86	7.4	--	--	--	--	--
Phase II (d 10 to 24)												
ADG, lb	1.11	1.12	1.00	1.08	1.10	1.10	6.5	--	--	.02	--	--
ADFI, lb	1.49	1.54	1.37	1.49	1.34	1.41	7.1	--	--	.02	--	.04
F/G	1.33	1.37	1.37	1.38	1.22	1.29	4.2	--	.01	--	--	.001
Phases I and II (d 0 to 24)												
ADG, lb	.87	.87	.78	.86	.87	.87	7.0	--	.03	.001	--	--
ADFI, lb	1.07	1.09	.97	1.07	.99	1.02	8.6	--	--	.01	--	.06
F/G	1.23	1.25	1.24	1.24	1.14	1.17	4.6	--	.001	--	--	.001
Overall (d 0 to 38)												
ADG, lb	1.07	1.05	.98	1.05	1.06	1.01	10.0	.08	--	.02	.08	--
ADFI, lb	1.56	1.57	1.46	1.55	1.50	1.47	8.2	.09	--	.01	--	--
F/G	1.45	1.49	1.49	1.48	1.42	1.46	5.0	--	.01	--	--	.06

[a]A total of 172 pigs (six pigs/pen and five pens/treatment) with an avg initial body wt of 12.5 lb.
[b]Contrasts were: 1) corn vs oat products; 2) ground oats and roasted oats vs reduced fiber oat products (ground/steam-flaked groats and flour); 3) ground oats vs roasted oats; 4) dehulled oat products (groats and steam-flaked groats) vs refined oat flour (oat bran removed); and 5) ground oat groats vs steam-flaked oat groats.
[c]Dashes = P>.10.

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THE EFFECT OF NOVEL CARBOHYDRATE SOURCES ON NURSERY PIG GROWTH PERFORMANCE

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Summary

Two growth assays were conducted to determine the effects of novel carbohydrate sources in Phase I and II starter diets on growth performance. In Exp. 1, 90 weanling pigs (avg initial body wt of 12.4 lb and 18 d of age) were used in a 38-d trial evaluating three carbohydrate sources: corn, tapioca, and rice flour. The carbohydrate sources were substituted for corn in diets formulated to 1.55 and 1.3% lysine for Phase I (d 0 to 10) and Phase II (d 10 to 24), respectively. All pigs were fed the same sorghum-soybean meal-based diet from d 24 to 38 postweaning. For the overall experiment, pigs fed rice flour had greater average daily gain (ADG) compared with those fed tapioca, with those fed the diet containing corn having intermediate ADG. Pigs fed rice flour had improved feed to gain ratio (F/G) compared with those fed either corn or tapioca. In Exp. 2, 60 weanling pigs (avg initial body wt of 8.6 lb and 17 d of age) were used in a similar study to evaluate corn, ground sorghum, and roasted sorghum as the primary carbohydrate sources in Phase I and II diets. During d 0 to 10 postweaning, pigs fed the corn diet had greater average daily feed intake (ADFI) than those fed the sorghum-based diets; however, no other differences in growth performance were observed during the experiment. These results suggest similar growth performance of starter pigs fed tapioca, sorghum, and roasted sorghum compared with those fed corn-based diets. However, pigs fed rice flour had improved F/G compared with those fed either corn or tapioca. Therefore, decisions on the use of novel carbohydrate sources in Phase I and II starter diets should be based on their price and availability relative to corn.

(Key Words: Starter, Pigs, Tapioca, Sorghum, Rice, Roasting, Performance.)

Introduction

Corn is a traditional carbohydrate source used in diets of nursery pigs. However, swine producers may have access to alternative carbohydrate products. Therefore, the objective of the two experiments reported herein was to examine the nutritional value of novel carbohydrate sources in diets for nursery pigs.

Procedures

In Exp. 1, 90 weanling pigs (initial body wt of 12.4 lb and 18 d of age) were allotted by weight, sex, and ancestry, with six pigs per pen and five pens per treatment. Dietary treatments included a corn-soybean meal-based control diet or diets in which the corn was replaced by either tapioca or rice flour (Table 1). In Exp. 2, 60 weanling pigs (initial body wt 8.6 lb and 17 d of age) were allotted by weight, sex, and ancestry, with five pigs per pen and four pens per treatment. Dietary treatments included the same corn-based control diet used in Exp. 1 or diets in which the corn was replaced by either ground sorghum or roasted sorghum. To obtain the roasted sorghum, sorghum grain was ground and reconstituted to 30% moisture. The product then was pelleted and passed through a Jet-Pro® roaster with an exit temperature of 260°F.

Both experiments were conducted as 38-d growth assays. At initiation of the experiments, pigs were given a Phase I diet (d 0 to 10 postweaning) formulated to 1.55% lysine, .9% Ca, and .8% P. Phase II diets (d 10 to 24) were formulated to 1.3% lysine, .9% Ca, and .8% P. On d 24 postweaning, all pigs were switched to the same sorghum-based Phase III diet with 1.15% lysine, .9% Ca, and .8% P. All diets were fed in pelleted form.

Pigs were housed in 4-ft × 5-ft pens with woven-wire flooring. Room temperatures were 90, 87, 84, 80, and 79°F for wk 1 to 5, respectively. Each pen had a self-feeder and nipple waterer to allow ad libitum consumption of feed and water. The pigs were weighed on d 0, 10, 24, and 38 of the experiment to determine ADG, ADFI, and F/G.

Results and Discussion

Experiment 1. No differences were observed for for ADG, ADFI, or F/G (Table 2) during the Phase I feeding period (d 0 to 10 postweaning). However, pigs fed the corn treatment showed a trend for greater ADFI (P<.09) compared to pigs fed tapioca and rice flour. In Phase II (d 10 to 24 postweaning), pigs fed rice flour and tapioca had improved F/G compared to pigs fed corn (P<.01), and pigs fed rice flour tended to have improved F/G compared to pigs fed tapioca (P<.09). Phase I and II combined data indicated that pigs fed rice flour and tapioca had better F/G compared to pigs fed corn primarily because of the superior F/G for pigs fed the diet with rice flour (P<.01). Data from the overall trial (d 0 to 38 postweaning) suggested that pigs fed rice flour had improved F/G compared to pigs fed corn and tapioca (P<.01).

Experiment 2. Pigs fed the diet with corn during Phase I (d 0 to 10 postweaning) had greater ADFI (P<.04) compared with those fed the sorghum treatments (Table 3). No differences occurred in ADG or F/G in the Phase I period. During Phases II, III, and for the overall feeding period, no differences occurred in growth performance among pigs fed the three carbohydrate sources.

In summary, novel carbohydrate sources, other than corn, are viable alternatives in phase-feeding programs for nursery pigs. In Exp. 1, pigs fed rice flour were the most efficient. In Exp. 2, pigs fed either sorghum source had similar performance to those fed the corn diet. Therefore, if carbohydrate quality is good, these sources can be substituted for corn depending on price and availability. However, the added expense of roasting sorghum did not result in improved performance of weaned pigs.

Table 1. Diet Composition, %

Ingredient	Phase I[ab] (d 0 to 10)	Phase II[c] (d 10 to 24)	Phase III[d] (d 24 to 38)
Corn	38.05	49.87	---
Sorghum	---	---	60.22
Soybean meal	15.00	20.00	33.60
Dried whey	20.00	20.00	---
Lactose	10.00	---	---
Spray-dried plasma protein	8.00	---	---
Spray-dried blood meal	2.00	2.00	---
Soybean oil	2.00	2.00	2.00
Monocalcium phosphate	2.16	1.88	1.97
Limestone	.57	.64	.92
Vit/Min/Ab[e]	1.87	3.33	1.29
Lysine-HCl	.18	.21	---
DL-methionine	.17	.07	---
Total	100.00	100.00	100.00

[a]For Exp. 1, tapioca and rice flour were used to replace corn, lysine-HCl, monocalcium phosphate, and limestone so that all Phase I diets had 1.55% lysine, .9% Ca, and .8% P.
[b]For Exp. 2, sorghum and roasted sorghum were used to replace corn, lysine-HCl, monocalcium phosphate, and limestone so that all Phase I diets had 1.55% lysine, .9% Ca, and .8% P.
[c]Phase II diets were formulated to contain 1.3% lysine, .9% Ca, and .8% P using the same carbohydrate sources that were in Phase I diets.
[d]The common Phase III diet was formulated to 1.15% lysine, .9% Ca, and .8% P. This diet was fed from d 24 to 38 of both experiments.
[e]Vit/Min = KSU vitamin and mineral premixes. Ab = antibiotic (150 g apramycin/ton of diet in Phase I, 50 g carbodox/ton of diet in Phase II, and 50 g carbadox/ton of diet in Phase III).

Table 2. Novel Carbohydrate Sources for Weanling Pigs (Exp. 1)[a]

					Contrasts[b]	
Item	Corn	Tapioca	Rice flour	CV	1	2
Phase I (d 0 to 10)						
ADG, lb	.60	.53	.55	13.8	--[c]	--
ADFI, lb	.67	.61	.59	10.9	.09	--
F/G	1.12	1.15	1.07	10.3	--	--
Phase II (d 10 to 24)						
ADG, lb	.98	.98	1.06	8.4	--	--
ADFI, lb	1.42	1.34	1.38	7.5	--	--
F/G	1.45	1.37	1.30	4.5	.01	.09
Phases I and II (d 0 to 24)						
ADG, lb	.82	.79	.84	6.2	--	--
ADFI, lb	1.11	1.04	1.05	7.2	--	--
F/G	1.35	1.32	1.25	2.5	.01	.01
Overall (d 0 to 38)						
ADG, lb	.86	.82	.90	6.1	--	.04
ADFI, lb	1.38	1.30	1.35	5.7	--	--
F/G	1.60	1.59	1.50	2.5	.01	.01

[a]A total of 90 weanling pigs (six pigs/pen and five pens/treatment) with an average initial body wt of 12.4 lb and an average final body wt of 45 lb.
[b]Contrasts were: 1)corn vs tapioca and rice flour; and 2) tapioca vs rice flour.
[c]Dashes = P>.10.

Table 3. Novel Carbohydrate Sources for Weanling Pigs (Exp. 2)[a]

					Contrasts[b]	
Item	Corn	Ground sorghum	Roasted sorghum	CV	1	2
Phase I (d 0 to 10)						
ADG, lb	.62	.57	.53	14.4	--[c]	--
ADFI, lb	.57	.53	.50	6.0	.04	--
F/G	.92	.93	.94	11.0	--	--
Phase II (d 10 to 24)						
ADG, lb	.84	.86	.80	12.1	--	--
ADFI, lb	1.14	1.18	1.12	10.9	--	--
F/G	1.36	1.37	1.40	4.5	--	--
Phases I and II (d 0 to 24)						
ADG, lb	.75	.74	.69	10.7	--	--
ADFI, lb	.90	.91	.86	9.1	--	--
F/G	1.20	1.23	1.25	5.1	--	--
Overall (d 0 to 38)						
ADG, lb	.92	.91	.89	7.2	--	--
ADFI, lb	1.28	1.33	1.29	7.5	--	--
F/G	1.39	1.46	1.45	5.6	--	--

[a]A total of 60 weanling pigs (five pigs/pen and four pens/treatment) with an average initial body wt of 8.6 lb and an average final body wt of 44.5 lb.
[b]Contrasts were: 1) corn vs sorghum sources; and 2) ground sorghum vs roasted sorghum.
[c]Dashes = P>.10.

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EFFECTS OF INTERACTION BETWEEN ZINC OXIDE AND COPPER SULFATE ON STARTER PIG PERFORMANCE[1]

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Summary

Two experiments were conducted to examine the effects of supplementing starter pig diets with zinc oxide and (or) copper sulfate on starter pig performance. In experiment 1, two hundred forty pigs were used in a 28-day growth assay. Four dietary treatments were used: 1) control (165 ppm zinc and 16.5 ppm copper), 2) 3,000 ppm zinc, 3) 250 ppm copper, and 4) 3,000 ppm zinc + 250 ppm copper. The pigs were blocked by weight and allotted to each of the four dietary treatments in a 2 × 2 factorial design with 9, 10, or 11 pigs per pen and 6 replicate pens per treatment. Diets were formulated in two phases: Phase I (d 0 to 14 postweaning) and Phase II (d 14 to 28 postweaning) with 1.6 and 1.25% lysine, respectively. Pigs were fed the same experimental mineral level during the entire 28-d growth assay. During Phase I, feeding 3,000 ppm zinc from zinc oxide, with or without 250 ppm copper, improved average daily gain (ADG) and feed efficiency (F/G) compared with pigs fed the control or added-copper diets. Surprisingly, no improvement occurred in ADG or F/G for pigs fed the diet with 250 ppm copper from copper sulfate as compared with pigs fed the control diet. In Phase II, a zinc × copper interaction occurred. Pigs fed the diet with only added zinc grew faster, ate more, and were more efficient than pigs fed the control diet. Pigs fed diets with added copper had intermediate ADG and average daily feed intake (ADFI). Pigs fed diets with added zinc and (or) copper had similar F/G. For the entire 28-day trial, pigs fed the diets with added zinc had improved ADG, ADFI, and F/G compared to pigs fed the control diet. In the second experiment, pigs were fed a common Phase I diet supplemented with zinc oxide (3000 ppm zinc). On d 14, pigs were switched to the diets containing experimental mineral levels. Phase II experimental diets were identical to those of the first experiment. Similar to Phase II in Exp. 1, a zinc × copper interaction occurred for ADG. Zinc oxide improved ADG when added to the control diet, but not when added to the copper diet. Feeding high levels of zinc oxide in the Phase I diets may have had a carryover effect in Phase II, because we found no improvement in pig performance when high levels of copper were added to the Phase II diet. The results from these experiments indicate that feeding 3,000 ppm of zinc from zinc oxide is a viable means of increasing starter pig performance, but optimum response occurs when the diet does not contain supplemental copper from copper sulfate.

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

Introduction

Recently, researchers at Kansas State University, University of Illinois, and other institutions have investigated the use of supplemental zinc in starter pig diets. The research at Kansas State University showed no advantage to feeding 3,000 ppm of zinc in combination with 250 ppm of copper. How-

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

ever, research at the University of Illinois demonstrated a positive effect of feeding 3,000 ppm zinc from zinc oxide over a control diet that did not contain growth promoting levels of copper sulfate. Therefore, the objectives of these experiments were to evaluate the effects of supplementing starter pig diets with high levels of zinc and (or) copper on performance and to determine whether the presence of high levels of copper in the diet influenced the response to zinc oxide.

Procedures

Experiment 1: A 28-day growth assay used a total of 240 pigs (initially 9.8 lb and 15 d of age) to examine the effect of supplementing starter pig diets with zinc oxide and (or) copper sulfate. Each pen contained 9, 10, or 11 pigs with six replicate pens per treatment. The pigs were blocked by weight and assigned to one of four dietary treatments in a 2 × 2 factorial design. Pigs were fed the same experimental mineral treatments throughout the entire 28-day trial, and the treatments were as follows: 1) control (165 ppm zinc and 16.5 ppm copper), 2) 3,000 ppm zinc, 3) 250 ppm copper, and 4) 3,000 ppm zinc + 250 ppm copper. 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 porcine plasma, 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 and (or) copper sulfate were added to achieve the appropriate levels of zinc and copper. The zinc oxide used contained 72% zinc; therefore, .393% (7.9 lb/ton) was added to the diets with 3000 ppm zinc, and .093% copper sulfate (1.86 lb/ton) was added to the diets containing 250 ppm copper. Feed samples were collected and analyzed for crude protein (CP), zinc, copper, iron, and manganese.

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.

Experiment 2: Two hundred sixty four pigs were used in another 28-d growth assay to evaluate the effects of supplementing Phase II starter pig diets with zinc oxide and (or) copper sulfate on pig performance after all pigs received a common Phase I diet containing 3000 ppm zinc from zinc oxide. This experiment used 10, 11, or 12 pigs per pen. Procedures for this experiment were the same as those used in Exp.1. Phase I and II diets were formulated to the same nutrient contents as those used in the first experiment; however, the duration of mineral supplementation was different. Pigs were fed a common Phase I diet that contained 3000 ppm zinc from zinc oxide. On d 14, pigs were allotted randomly to one of the four dietary treatments, which were the same Phase II diets used in Exp. 1.

Results and Discussion

Experiment 1: Mineral analysis confirmed that zinc and copper levels were similar to the values the diets were formulated to contain, except for the zinc content in the copper-supplemented diet (Table 2). The zinc level was considerably higher than the formulated amount, especially in the Phase II diet. The high zinc analysis may have been due to sampling error or possible carryover in diet manufacturing. The potential for carryover in diet manufacturing must be analyzed further.

In this trial, feeding 3,000 ppm zinc from zinc oxide, with or without copper, increased growth performance and feed utilization in the Phase I period (Table 3). Surprisingly, no improvement occurred in performance for pigs fed the diet supplemented with 250 ppm copper from copper sulfate. This is in direct contrast to data collected in previous research with starter pigs. This lack of response may have been due to an age-related response to

copper. Very young pigs were used in this trial (14 d) compared to 28-d-old pigs in most of the previous experiments that have demonstrated a response to copper sulfate.

In the Phase II portion of this trial, zinc × copper interactions were detected for ADG, and F/G (P<.01 and .05, respectively). A tendency for a zinc × copper interaction also was detected for ADFI (P<.08). Pigs fed the diet with only added zinc grew faster, ate more, and were more efficient than pigs fed the control diet. Unlike Phase I, the pigs fed the copper and zinc + copper diets performed more similarly, with intermediate values for ADG, ADFI, and F/G. The response to copper supplementation agrees with previous research and provides further support for an age-related response to copper, because the pigs were 28 d of age at the initiation of Phase II.

For the entire 28-day growth assay, zinc × copper interactions were found for ADG and F/G (P<.01 and .05, respectively). Adding high levels of zinc oxide to the diet improved performance when growth-promoting levels of copper sulfate were not included in the diet. Also, the pigs maintained on the zinc and zinc + copper diets had higher ADFI (P<.01) than the pigs fed the control diet. Even though the Phase I performance of the pigs fed the copper diet was similar to that of the pigs fed the control diet, their overall performance was higher than that of the pigs fed the control diet. The increased performance of the pigs fed the zinc and zinc + copper diets can be explained in part by the increased ADFI.

The performance of the pigs fed the zinc + copper diet explains previous research conducted with zinc oxide at Kansas State University. In that research, both experimental diets contained 250 ppm copper. The pigs fed the diet with supplemental zinc oxide performed the same as the pigs fed the control diet with 250 ppm copper. This is the same response found during Phase II of the current trial when zinc oxide was added to a diet already containing 250 ppm copper.

It is important to note the importance of using zinc oxide to provide the supplemental zinc. Research at the University of Illinois comparing zinc methionine, zinc lysine, zinc oxide, and zinc sulfate showed that zinc oxide is needed to illicit a zinc response. However, lower levels of zinc methionine, zinc lysine, and zinc sulfate were needed to achieve the same plasma levels of zinc. The high cost of the amino acid chelates and the lower performance of the pigs fed zinc sulfate make supplementation with these products less economical than using zinc oxide.

An economic analysis was conducted for the entire 28-d trial using diet costs of $650.63 and $244.11 per ton for control Phase I and II diets, respectively, with $.574 and $.536 per lb for zinc oxide and copper sulfate, respectively (Table 5). The analysis of Phase I revealed that feeding the zinc diet cost $.36 per lb of gain, whereas feeding the copper diet cost $.37 per lb of gain. During Phase II, feeding the zinc diet cost $.19 per lb of gain, and feeding the copper diet cost $.18 per lb of gain. When analyzing the entire 4-week trial, feeding both the zinc and copper diets cost $.25 per lb of gain; however, the pigs fed the zinc diet were more than 2 lb heavier than the pigs fed the copper diet at the end of the 28-day trial.

In conclusion, feeding zinc oxide at 3,000 ppm improves growth performance in the weanling pig. Because the pigs fed the zinc diet grew faster through the entire trial and more efficiently in the Phase II portion, the additional $ 3.27 per ton for the zinc oxide diet compared to a diet containing copper sulfate can be justified in both Phase I and II starter pig diets.

Experiment 2: During Phase I, when a common diet was fed, pigs had an ADG of .50 lb and a F/G of 1.29. When pigs were fed the experimental mineral levels in Phase II, a zinc × copper interaction (P>.05) was detected for ADG (Table 4). When the control diet was supplemented with zinc oxide, ADG numerically improved; however, when zinc was added with copper, ADG was depressed, showing the importance of using zinc oxide alone and not in combination with

copper. During the same period, pigs fed the diet supplemented with only zinc oxide ate more feed, but adding copper to either the control or zinc diets reduced ADFI (P<.05). Overall, the pigs fed the diets with added copper, with or without zinc, had lower growth rates (P<.01) and depressed feed intakes (P<.05).

The copper response in this experiment can be explained by the excellent performance of the pigs fed the control diet. The pigs fed the control diet in this experiment grew better than the pigs fed the control diet in Exp. 1. This improved performance indicates a possible carryover or storage effect from feeding high levels of zinc in Phase I diets. Although not shown, feeding zinc in Phase II in this experiment had an economic advantage.

In conclusion, both experiments indicate that supplementing starter pig diets with 3000 ppm zinc from zinc oxide does improve growth performance during the first 4 weeks postweaning. However, further research is needed to examine possible interaction with copper in later stages of growth and to determine the optimum level of zinc supplementation. The effect of diets containing high levels of zinc oxide on feeders and flooring is another area that needs examination. Overall, adding zinc to Phase I and II diets is recommended to improve growth performance.

Table 1. Composition of Diets[a]

Ingredient, %	Phase I	Phase II
Corn	36.96	57.16
Soybean meal (48% CP)	19.30	22.49
Dried whey	25.00	10.00
Spray-dried porcine plasma	7.50	--
Spray-dried blood meal	1.75	2.50
Soybean oil	5.00	3.00
Monocalcium phosphate	1.74	1.95
Limestone	.62	.82
Antibiotic[b]	1.00	1.00
Cornstarch[c]	.49	.49
DL-methionine	.13	.04
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 (.393%) and copper sulfate (.093%) replaced cornstarch to form the experimental diets.

Table 2. Mineral and Crude Protein Analysis of Experimental Diets (Exp. 1)

Item	Control diet	Zinc diet	Copper diet	Zinc + copper diet
Phase I				
CP, %	22.8	22.8	22.9	22.2
Zinc, ppm	245	3051	406	2951
Copper, ppm	26	24	235	240
Iron, ppm	617	576	529	590
Manganese, ppm	62	77	72	70
Phase II				
CP, %	19.24	19.91	19.72	20.02
Zinc, ppm	235	2824	1396	2569
Copper, ppm	24	20	167	177
Iron, ppm	459	640	580	536
Manganese, ppm	83	85	74	75

Table 3. Influence of Zinc Oxide and Copper Sulfate on Starter Pig Performance (Exp. 1)[a]

Item	Control	Zn	Cu	Zn + Cu	CV
d 0 to 14					
ADG, lb[b]	.53	.58	.52	.59	14.2
ADFI, lb	.62	.63	.58	.64	10.5
F/G	1.22	1.08	1.13	1.08	10.7
d 14 to 28					
ADG, lb[c]	.65	.92	.82	.83	12.2
ADFI, lb[d]	1.15	1.38	1.21	1.29	8.3
F/G[e]	1.85	1.52	1.47	1.56	14.8
d 0 to 28					
ADG, lb[c]	.59	.75	.67	.71	10.9
ADFI, lb[b]	.86	1.01	.89	.96	10.2
F/G[e]	1.54	1.35	1.34	1.36	6.9

[a]Two hundred forty weanling pigs were used (initially 9.8 lb and 15 d of age) with 9, 10, or 11 pigs/pen and 6 pens/treatment.
[b]Zinc effect (P<.01).
[cde]Zinc × copper interaction (P<.01, .08, and .05, respectively).

Table 4. Influence of Zinc Oxide and Copper Sulfate on Starter Pig Performance (Exp. 2)[a]

Item	Control	Zn	Cu	Zn + Cu	CV
d 14 to 28					
ADG, lb[b]	.81	.87	.77	.75	5.6
ADFI, lb[c]	1.39	1.47	1.33	1.33	7.2
F/G	1.74	1.71	1.73	1.82	7.2
d 0 to 28					
ADG, lb[d]	.66	.69	.63	.62	5.4
ADFI, lb[c]	1.01	1.06	.97	.98	5.6
F/G	1.56	1.55	1.55	1.61	6.9

[a]Two hundred sixty four weanling pigs were used (initially 9.2 lb and 12 d of age) with 10, 11, or 12 pigs/pen and 6 pens/treatment. A common Phase I (d 0 to 14) diet (3000 ppm zinc) was fed to all pigs. Experimental mineral levels were fed during Phase II (d 14 to 28).
[b]Zinc × copper interaction (P<.05).
[cd]Copper effect (P<.05, and .01, respectively).

Table 5. Influence of Zinc Oxide and Copper Sulfate on Feed Cost per Pig and Feed Cost per Pound of Gain (Exp. 1)

Item	Control	Zinc	Copper	Zinc + copper
d 0 to 14				
Total feed, lb/pig	8.69	8.78	8.12	8.90
Diet cost, $/cwt[a]	$ 32.53	$ 32.74	$ 32.58	$ 32.79
Feed cost, $/pig	$ 2.83	$ 2.87	$ 2.65	$ 2.92
Total gain, lb/pig	7.46	8.12	7.23	8.32
Feed cost, $/lb gain	$ .38	$ .35	$ .37	$ .35
d 14 to 28				
Total feed, lb/pig	16.06	19.38	16.94	18.10
Diet cost, $/cwt[a]	$ 12.21	$ 12.41	$12.25	$ 12.46
Feed cost, $/pig	$ 1.96	$ 2.41	$ 2.08	$2.26
Total gain, lb/pig	9.04	12.86	11.52	11.65
Feed cost, $/lb gain	$ .22	$ .19	$ .18	$ .26
d 0 to 28				
Total feed, lb/pig	24.20	28.16	25.02	27.00
Diet cost, $/cwt[a]				
Feed cost, $/pig	$ 4.79	$ 5.29	$ 4.73	$ 5.18
Total gain, lb/pig	16.49	20.98	18.76	19.97
Feed cost, $/lb gain	$ .29	$ .25	$ .25	$ .26

[a]Diet cost based on $2.30/bu corn, $200/ton SBM, $.574/lb zinc oxide, and $.536/lb copper.

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EFFECT OF CHELATED TRACE MINERALS ON NURSERY PIG GROWTH PERFORMANCE[1]

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Summary

A total of 442 weanling pigs (inital age and wt of 22 d and 14.4 lb, respectively) was used on a commercial farm in northeast Kansas to evaluate growth performance with diets containing a chelated trace mineral premix or an inorganic trace mineral premix. Minerals evaluated in the premixes provided 16.5 ppm Cu, 165 ppm Fe, 40 ppm Mn, and 165 ppm Zn. For the inorganic trace mineral treatment, the mineral sources were copper sulfate, ferrous sulfate, manganous oxide, and zinc oxide. The chelated trace mineral premix had the following fractions of these minerals provided as amino acid chelates: 109.7% of Cu, 75.8% of Fe, 78.1% of Mn, and 47.0% of Zn with the balance coming from the previous inorganic sources to make diets similar in added trace mineral content. All diets also contained copper sulfate, providing an additional 188 ppm Cu. Pigs fed the chelated trace mineral had increased average daily gain (ADG), average daily feed intake (ADFI), and lower feed efficiency (F/G) from d 0 to 7 postweaning. No differences occurred between treatments in ADG or ADFI from d 7 to 14. For this same period, pigs fed the inorganic trace minerals had lower F/G than pigs fed the chelated trace minerals. For the entire Phase I period (d 0 to 14), pigs fed the chelated trace minerals had greater ADFI with no difference in ADG or F/G. No differences occurred in ADG or F/G for the Phase II period (d 14 to 28). However, pigs fed the inorganic trace minerals had increased ADFI (P>.02). For the entire nursery period (d 0 to 28), no differences occurred in ADG, ADFI, and F/G between pigs fed either chelated or inorganic trace minerals. Based on the improved performance observed, chelated trace minerals may have been more available, which benefitted the weanling pig during the stressful first week postweaning. However, for the entire nursery period, based on this single study, no significant differences occurred in growth performance for pigs fed either trace mineral source.

(Key Words: Starter, Minerals, Performance.)

Introduction

Chelated minerals previously have been demonstrated to have greater availability compared to traditional inorganic mineral sources for livestock. Additionally, research has linked chelated minerals with enhanced immune function, improved reproduction, changes in the lean to fat ratio. Therefore, this trial was designed to directly compare a standard industry level of inorganic trace minerals (Fe, Cu, Mn, and Zn) with a chelated trace mineral premix in diets for early-weaned starter pigs.

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[1]Appreciation is expressed to Albion Laboratories, Inc., 1005 East 7th, Suite 203, Atlantic, IA 50022, for partial financial support of this research project and Keesecker Agribusiness, Washington, KS, for use of animals and facilities.

[2]Albion Laboratories, Inc., Atlantic, IA.

Procedures

A total of 442 weanling pigs averaging 22 d of age with an average initial weight of 14.4 lb was used on a commercial farm in northeast Kansas to evaluate the use of a chelated trace mineral premix or a traditional inorganic trace mineral premix. Crossbred pigs (Pig Improvement Company) were blocked by weight and sex and allotted to one of two dietary treatments. Pigs were housed with 14 or 15 pigs per pen. Each pen was 4 × 8 ft, had woven wire flooring, and contained two nipple waters and a six-hole self-feeder.

Pigs were fed a high nutrient density Phase I diet from d 0 to 14 (Table 1), which was formulated to 1.5% lysine, .42% methionine, .9% Ca, and .8% P. The Phase I diet also contained 7.5% spray-dried porcine plasma, 1.75% spray-dried blood meal, and 25% dried whey. On day 14, all pigs were switched to the Phase II diets (Table 1). The Phase II diets were corn-soybean meal-based and contained 10% dried whey and 2.5% spray-dried blood meal. Phase II diets were formulated to 1.25% lysine, .35% methionine, .9% Ca, and .8% P. All diets were pelleted through a 5/32 inch die.

Minerals evaluated in the premixes provided 16.5 ppm Cu, 165 ppm Fe, 40 ppm Mn, and 165 ppm Zn from copper sulfate, ferrous sulfate, manganous oxide, and zinc oxide for the inorganic trace mineral treatment. The following fractions of these inorganic trace minerals were replaced with an amino acid chelate: 109.7% of Cu, 75.8% of Fe, 78.1% of Mn, and 47.0% of Zn. All diets contained additional copper sulfate providing another 188 ppm Cu.

Pigs and feeders were weighed weekly to determine pen ADG, ADFI, and F/G.

Results and Discussion

Pigs fed chelated trace minerals had increased ADG ($P<.03$), ADFI ($P<.07$), and lower F/G ($P<.11$) for d 0 to 7 (Table 2). The proposed increased availability of the chelated trace minerals may have improved week 1 pig growth performance.

For week 2 of the experiment, no difference occurred in ADG or ADFI ($P>.18$) between pigs fed chelated and inorganic trace mineral premixes. However, for d 7 to 14, pigs fed inorganic trace minerals had lower F/G ($P<.02$) than pigs fed the chelated trace minerals. This response may have been due to the pigs reaching a critical level of gut maturation and improved absorption of inorganic trace minerals, stimulating a partial compensatory efficency response.

For the entire Phase I period (d 0 to 14), no differences occurred in ADG ($P>.39$) or F/G ($P>.97$) between the treatments. However, pigs fed the chelated trace minerals had greater ADFI ($P<.07$).

For the Phase II period (d 14 to 28), no differences occurred in ADG ($P<.22$) or F/G ($P>.87$) between the trace mineral treatments. In contrast to Phase I, pigs fed the inorganic trace minerals had greater ADFI ($P<.02$) for the Phase II period. The possible reasons for this have been discussed above.

Average daily gain, ADFI, and F/G for the entire experiment (d 0 to 28) were not different ($P>.18$) between the pigs fed the diets containing chelated or inorganic trace minerals. Final average weights were similar ($P>.60$) for pigs receiving the diets with chelated and inorganic trace minerals (29.8 vs 30.0 lb, respectively).

In conclusion, chelated trace minerals may have provided increased trace mineral absorption and tissue levels that benefitted the weanling pig during the first week post-weaning. However, based on this particular experiment, for the entire nursery trial, feeding the chelated trace mineral premix to nursery pigs provided no sustained benefit.

Table 1. Experimental Diet Composition

	Phase I diets[a]		Phase II diets[b]	
Item, %	Inorganic	Chelate	Inorganic	Chelate
Corn	40.90	40.90	57.73	57.73
SBM, (48% CP)	15.58	15.58	22.21	22.21
Dried whey	25.00	25.00	10.00	10.00
Soybean oil	5.00	5.00	3.00	3.00
Spray-dried porcine plasma	7.50	7.50	—	—
Spray-dried blood meal	1.75	1.75	2.50	2.50
Monocalcium phosphate	1.81	1.81	1.96	1.96
Limestone	.64	.64	.83	.83
Vitamin premix	.25	.25	.25	.25
Inorganic trace mineral premix[c]	.15	—	.15	—
Chelated trace mineral premix[d]	—	.25	—	.25
Lysine	.10	.10	.15	.15
Methionine	.15	.15	.05	.05
Copper sulfate	.075	.075	.075	.075
Soy isolate	.072	—	.072	—
Cornstarch	.028	—	.028	—
Medication[e]	1.00	1.00	1.00	1.00
Totals	100.0	100.0	100.0	100.0

[a]Phase I diets were formulated to contain; 1.5% lysine, .42% methionine, .9% Ca, .8% P.
[b]Phase II diets were formulated to contain; 1.25% lysine, .35% methionine, .9% Ca, .8% P.
[c]Inorganic trace mineral premix: each lb provided 12 g Mn; 50 g Fe; 50 g Zn; 5 g Cu; 90 mg I; 90 mg Se from manganous oxide, ferrous sulfate, zinc oxide, copper sulfate, calcium iodate, and sodium selenite.
[d]Chelated trace mineral premix: each lb provided 7.2 g Mn; 30 g Fe; 30 g Zn; 3 g Cu; 54 mg I; 54 mg Se from a blend of manganese amino acid chelate, iron amino acid chelate, zinc amino acid chelate, copper amino acid chelate, manganous oxide, ferrous sulfate, zinc oxide, copper sulfate, calcium iodate, and sodium selenite.
[e]Medication provided 150 g/ton apramycin during Phase I and 50 g/ton carbadox during Phase II.

Table 2. Effect of Trace Mineral Source on Growth Performance of Weanling Pigs[a]

Item	Chelated mineral	Inorganic mineral	CV	P value
d 0 to 7				
ADG, lb	.337	.272	24.56	.031
ADFI, lb	.399	.373	9.25	.071
F/G	1.24	1.43	18.22	.110
d 7 to 14				
ADG, lb	.563	.592	10.11	.196
ADFI, lb	.665	.644	6.29	.187
F/G	1.19	1.10	8.47	.019
d 0 to 14				
ADG, lb	.450	.432	12.99	.394
ADFI, lb	.532	.509	6.12	.066
F/G	1.19	1.19	9.58	.972
d 14 to 28				
ADG, lb	.648	.682	10.84	.224
ADFI, lb	1.042	1.106	6.20	.020
F/G	1.62	1.62	6.98	.873
d 0 to 28				
ADG, lb	.549	.557	7.55	.629
ADFI, lb	.787	.807	5.10	.189
F/G	1.44	1.45	4.15	.453

[a]A total of 442 pigs were used with 14 or 15 pigs per pen and 15 pens per treatment. Average intitial weight of pigs was 14.4 lb. Average final weights by treatment were 29.8 lb for pigs fed chelated trace minerals and 30.0 lb for pigs fed inorganic trace minerals.

Swine Day 1994

THE EFFECTS OF ADDED SALT IN THE PHASE II STARTER PIG DIET[1]

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Summary

A total of 178 pigs (initially 10.5 lb and 19 d of age) was used to compare the effects of added salt in the Phase II (d 14 to 28 postweaning) diet. Pigs were alloted by sex and inital weight and placed in pens containing either nine or 10 pigs. All pigs were fed the same Phase I diet for the first 14 d postweaning. The Phase I diet contained 20% dried whey, 7.5% spry-dried porcine plasma (SDPP), and 1.75% spray-dried blood meal (SDBM) and was formulated to contain 1.5% lysine and .42% methionine. On day 14, pigs were assigned to one of three diets that contained either 3.5 or 7 lb/ton added salt or no salt. The Phase II diet was corn-soybean meal-based, contained 10% dried-whey and 2.5% SDBM, and was formulated to contain 1.25% lysine and .34% methionine. During Phase I (d 0 to 14 postweaning), average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G) were .52 lb, .63 lb, and 1.2, respectively. During Phase II (d 14 to 28 postweaning), ADG and F/G tended to improve with increasing added salt (8 and 9%, respectively). For the cumulative period (d 0 to 28 postweaning), numerical increases also occurred in both ADG and F/G. These results suggest that up to 7 lb/ton of added salt in a Phase II diet containing 10% dried whey improves ADG and F/G of starter pigs.

(Key Words: Starter, Performance, Salt.)

Introduction

Sodium and chlorine (salt) are responsible for maintaining the cation-anion balance of cells. Perhaps more important is the role that salt plays in stimulating appetite and feed intake. Generally, 5 to 7 lb of salt are added per ton in diets for growing-finishing pigs and approximately 10 lb per ton in gestation and lactation diets. However, little, if any salt is added to diets for starter pigs containing dried whey and spray-dried plasma protein. This is because these ingredients generally contain moderate levels of salt (approximately 3% salt in good quality dried whey and 5 to 2.9% sodium in spray-dried plasma protein). However, with recent changes in the sodium content of spray-dried porcine plasma and the increased use of lactose in place of dried whey, the need for added salt in starter pigs diets becomes a concern. Therefore, the objective of this experiment was to determine if added salt in a starter pig diet containing 10% dried whey would improve pig growth performance.

Procedures

A total of 178 pigs (initially 10.5 lb and 19 d of age) was used in a 28-d growth trial. Pigs were alloted by sex, weight, and ancestry and placed in pens containing nine or 10 pigs each. A common Phase I diet was fed for the first 14 d postweaning. The Phase I diet contained 20% dried whey, 7.5%

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

SDPP, and 1.75% SDBM and was formulated to contain 1.5% lysine and .42% methionine. After the Phase I period, pens were assigned randomly to one of three treatments in a randomized complete block design. During Phase II (d 14 to 28 postweaning), pigs were fed diets that contained 3.5 or 7 lb/ton added salt or no salt. The Phase II diet contained 10% dried-whey and 2.5% SDBM and was formulated to contain 1.25% lysine and .34% methionine and fed in a meal form.

Pigs were housed in 5 ft × 5 ft pens (9 to 10 pigs per pen) in an environmentally-controlled nursery facility on a commercial farm in northeast Kansas. Each pen contained two nipple waterers, and pigs were allowed ad libitum access to feed and water. Pigs and feeders were weighed on d 7, 14, 21, and 28 to calculate ADG, ADFI, and F/G.

Results and Discussion

During Phase I, ADG, ADFI, and F/G were .52 lb, .63 lb, and 1.2, respectively. From d 14 to 28 postweaning, pigs fed added salt had a numerical increase in ADG ($P<.12$) and were more efficient ($P<.07$). This trend also held true for the cumulative period (d 0 to 28 postweaning). In conclusion this growth assay suggests that salt typically obtained from the 10% added whey is not enough to maximize pig performance. Adding up to 7 lb/ ton of salt to the Phase II diet improved ADG and F/G 8 and 9%, respectively.

Table 1. Diet Composition,[a] %

Item	Phase I	Phase II[b]
Corn	45.29	59.26
Soybean meal, (48% CP)	16.13	21.26
Dried whey, edible grade	20.00	10.00
Spray-dried porcine plasma	7.50	--
Spray-dried blood meal	1.75	2.50
Soybean oil	5.00	3.00
Moncalcium phosphate	1.91	1.97
Limestone	.69	.83
Antibiotic[c]	1.00	.50
Trace mineral premix	.15	.15
Vitamin premix	.25	.25
DL-methionine	.15	.05
L-lysine HCL	.10	.15
Copper sulfate	.075	.075
Total	100	100

[a]Phase I diets were fed from d 0 to 14 postweaning, and Phase II diets were fed from d 14 to 28 postweaning.
[b]Salt levels of 3.5 and 7 lb/ton were added in place of corn.
[c]Provided 150 g/ton of apramycin in Phase I and 50 g/ton of carbodox in Phase II.

Table 2. Effect of Added Salt in Phase II Starter Diets[a]

	Added salt, lb/ton				Probability, P <	
Item	0	3.5	7	CV	linear	quadratic
D 0 to 14[b]						
ADG, lb	.52	.53	.50	9.5	.62	.46
ADFI, lb	.61	.64	.63	8.5	.56	.57
F/G	1.18	1.19	1.23	5.7	.15	.65
D 14 to 28[c]						
ADG, lb	.85	.88	.92	8.9	.12	.94
ADFI, lb	1.35	1.33	1.32	6.4	.66	.93
F/G	1.58	1.52	1.43	8.6	.07	.93
D 0 to 28						
ADG, lb	.68	.71	.71	7.8	.39	.71
ADFI, lb	.98	.98	.97	6.7	.57	.90
F/G	1.43	1.39	1.37	4.7	.13	.83

[a]One hundred seventy-one weanling pigs were used (initially 10.5 lb and 19 +/- 3 d of age) with 10 pigs per pen in three replications and 9 pigs per pen in three replications.
[b]All pigs received a common diet from d 0 to 14 after weaning.
[c]Day 14 wt was used as a covariant for d 14 to 28 period.

Swine Day 1994

INFLUENCE OF BUFFERED PROPIONIC AND FUMARIC ACIDS ON STARTER PIG PERFORMANCE[1]

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Summary

A 28 d growth trial was conducted to determine the effects of adding organic acids to a Phase I starter diet on pig performance. At weaning (13 ± 2 d of age and 8.86 lb), 300 pigs were blocked by weight and allotted to each of five diets. The control diet was corn-soybean meal based; contained 20% dried whey, 7.5% spray-dried porcine plasma, and 1.75% spray-dried blood meal; and was formulated to 1.5% lysine, .9% Ca, and .8% P. Luprosil NC (.4%; a buffered liquid propionic acid), Luprosil salt (.4%; a buffered dry propionic acid), fumaric acid (1.5%), and a combination of Luprosil NC (.4%) and fumaric acid (1.5%) replaced corn in the control diet to provide the four additional experimental treatments. Pigs fed diets containing any of the acid sources had improved average daily gain (ADG) and feed efficiency (F/G) during Phase I (d 0 to 14 postweaning) compared with those fed the control diet. No differences occurred in ADG among pigs fed any of the acid sources; however, pigs fed the diet containing fumaric acid had improved F/G when compared to those fed Luprosil salt during Phase I. No differences occurred in growth performance when pigs were fed a common diet during Phase II (d 14 to 28 postweaning), but ADG and F/G were improved during the overall 28 d trial when the pigs were fed acidified diets during Phase I. These results suggest that adding organic acids (buffered propionic or fumaric acid) to a diet containing 20% dried whey and 7.5% porcine plasma enhances growth performance from d 0 to 14 postweaning.

(Key Words: Starter, Acid, Diet, Performance.)

Introduction

Previous research at Kansas State University demonstrated that adding fumaric acid to a Phase I starter diet (containing 20% dried whey and 10% porcine plasma) resulted in tendencies for improved ADG and F/G. Buffered propionic acid (Luprosil NC) has also been shown to improve growth performance in swine and offers the advantages of having lower inclusion rate and corrosion potential than nonbuffered propionic acid. Luprosil NC, which contains 53.5% propionic acid, 9.5% ammonia, 11.5% propylene glycol, and 25.5% water, is a liquid preservative of processed feedstuffs. Buffered propionic acid is also available in a dry form, known as Luprosil salt, also a feed preservative. This is a fine, nearly white powder that contains 77% propionic acid and 21% calcium.

The inclusion of acids in starter diets has not been as beneficial when the diets contained higher levels of milk products. However, with the increased use of spray-dried

[1]Appreciation is expressed to BASF Corporation, 100 Cherry Hill Rd., Parsippany, NJ for donating the Luprosil NC and Luprosil Salt, as well as providing partial financial support for this experiment. Appreciation also is expressed to Steve Eichman, Ellen Johncock and Eichman Brothers, St. George, KS, for providing the pigs and facilities.

blood meal and plasma protein to replace a portion of the milk products in high nutrient density starter diets, a re-evaluation of organic acids and their impact on starter pig performance is necessary. The purpose of this trial was to compare fumaric acid, Luprosil NC, and Luprosil salt as acidifiers in high nutrient density diets (HNDD) for early-weaned pigs.

Procedures

A total of 300 pigs (initially 13 ± 2 d of age and 7 to 13.7 lb) was used in a 28 d growth trial. Pigs were blocked by weight and allotted to one of five diets, with a total of 10 pigs/pen and six pens/treatment. The five diets were: 1) control diet (without acid), 2) .4% Luprosil NC 3) 1.5% fumaric acid, 4) .4% Luprosil NC and 1.5% fumaric acid (combined), and 5) .4% Luprosil salt.

This trial was divided into two phases. During Phase I (d 0 to 14 postweaning), a pelleted diet containing 20% dried whey, 7.5% porcine plasma, and 1.75% spray-dried blood meal and formulated to contain 1.5% lysine, .9% Ca, and .8% P was fed (Table 1). The Luprosil NC, Luprosil salt, fumaric acid, and the combination of Luprosil NC and fumaric acid each replaced corn to achieve the five experimental diets. During Phase II (d 14 to 28 postweaning), all pigs were fed a common diet without acid. This diet contained 10% dried whey and 2.5% spray-dried blood meal and was formulated to 1.25% lysine, .9% Ca, and .8% P (Table 1).

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

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

Results

During d 0 to 7 postweaning, pigs fed acidified diets had improved ADG ($P<.01$) compared with pigs fed the control diet (Table 2). Pigs fed the diet containing Luprosil NC had improved ADG ($P<.06$) when compared with those fed the diet containing the combination of Luprosil NC and fumaric acid. Pigs fed either of the other acid sources had intermediate ADG. The addition of acid to the diet had mixed effects on ADFI. Pigs fed Luprosil NC had the greatest ADFI, which was different from that of pigs fed either the fumaric acid diet or Luprosil salt diet ($P<.02$). Pigs fed the control diet or other acid sources had intermediate ADFI. Feeding pigs acidified diets improved F/G ($P<.01$), when compared with feeding pigs the control diet; however, no differences in F/G occurred among the pigs fed the various acid sources.

During Phase I (d 0 to 14 postweaning), ADG ($P<.02$) was greatest for pigs fed diets containing acid compared with those fed the control diet. Pigs fed the diets containing Luprosil NC or fumaric acid had numerically the greatest ADG of pigs fed acidified diets. Although no differences occurred in ADFI, F/G ($P<.01$) was improved for pigs fed acidified diets. Among the acid sources, the greatest improvement in F/G resulted from feeding the diet containing fumaric acid, when compared with pigs fed the diet containing Luprosil salt ($P<.03$).

During Phase II (d 14 to 28 postweaning), when all pigs were fed a common diet, no differences occurred in growth performance. Thus, for the overall 28 d trial, ADG ($P\leq.13$) and F/G ($P<.10$) tended to be improved by feeding an acidified diet during d 0 to 14 postweaning.

Discussion

The results of this trial agree with previous research regarding the inclusion of organic acids in starter diets. Although the inclusion of acids in diets containing high

levels of milk products (40%) does not affect pig performance, including acids in lower milk product HNDD, such as those used in this trial tends to improve pig performance.

How organic acids improve pig performance is not quite clear. Research conducted at Purdue University indicated that stress associated with weaning often causes an undesirable shift in digestive tract microflora, which results in increased gut pH and reduced nutrient digestion and absorption. Most organic acids seem to prevent this undesirable shift by indirectly reducing gut pH, which improves nutrient digestion, absorption, and overall pig performance.

Although all of the organic acids used in this trial improved pig performance during Phase I, differences between the acids were observed. The data from this trial seem to suggest that fumaric acid improves ADG primarily by increased feed utilization, whereas the Luprosil increases ADG by stimulating feed intake.

Fumaric acid, Luprosil NC, and Luprosil salt can be obtained for about $.26, $.61, and $.56 per lb, respectively. With a corn price of $2.36/bu and the inclusion rates used in this trial, additional costs are $6.69 (fumaric), $4.56 (Luprosil NC), or $4.16 (Luprosil salt) per ton of complete feed.

Although a slight increase in feed cost/ton is associated with adding an acid to a Phase I starter diet, the improvement in ADG and F/G result in lower feed cost per pig. Based on the Kansas State recommendation of feeding a Phase I diet to pigs from 11 to 15 lb, the improvement in F/G (.16) from adding an acid to the diet in this trial would reduce total feed cost per pig by $.16 in addition to the improvement in ADG.

In conclusion, the organic acids tested in this trial resulted in an economical improvement in ADG and F/G when added to the Phase I diet. However, no additive effects resulted from adding different organic acids in combination.

Table 1. Composition of Diets[a]

Ingredient, %	Phase I	Phase II
Corn	44.32[b]	60.27
Soybean meal (46.5% CP)	16.81	22.81
Dried whey	20.00	10.00
Spray dried plasma	7.50	—
Spray dried blood meal	1.75	2.50
Soybean oil	5.00	—
Monocalcium phosphate (21% P)	1.90	1.90
Limestone	.69	.84
Antibiotic[c]	1.00	1.00
Zinc oxide (72%)	.38	—
Copper sulfate	—	.08
L-lysine HCl	.10	.15
DL-methionine	.15	.05
Vitamin premix	.25	.25
Trace mineral premix	.15	.15
Total	100.00	100.00
Calculated analysis, %		
CP	21.57	19.38
Lysine	1.50	1.25
Methionine	.45	.36
Ca	.90	.90
P	.80	.80

[a]Pigs were fed the Phase I and II diets from d 0 to 14 and d 14 to 28, respectively.
[b]Luprosil NC (.4%), Luprisil salt (.4%), fumaric acid (1.5%), and Luprosil NC (.4%) with fumaric acid (1.5%) each replaced corn to form the four additional Phase I experimental diets.
[c]Provided 150 g/ton apramyacin in Phase I and 50 g/ton carbadox in Phase II.

Table 2. Influence of Fumaric Acid, Luprosil NC, Fumaric Acid and Luprosil NC in Combination, and Luprosil Salt on Starter Pig Performance[a]

		Organic acid				
Item	Control	Fum. acid	Lup. NC	Combined	Lup. salt	CV
d 0 to 7						
ADG, lb[bc]	.28	.33	.36	.32	.35	11.1
ADFI, lb[d]	.42	.40	.47	.41	.44	9.8
F/G[be]	1.52	1.22	1.30	1.30	1.27	9.7
d 0 to 14						
ADG, lb[f]	.46	.52	.53	.49	.49	7.8
ADFI, lb	.63	.59	.64	.59	.63	8.5
F/G	1.36	1.14	1.20	1.20	1.27	8.8
d 0 to 28						
ADG, lb[g]	.58	.61	.63	.61	.62	8.4
ADFI, lb	.97	.97	1.02	.98	1.00	7.8
F/G[g]	1.69	1.61	1.61	1.61	1.61	5.0

[a]Means represent 10 pigs per pen with 6 replications per treatment. Pigs were weaned at 13 ± 2 d of age and 8.86 lb.
[b]Mean of pigs fed acidified diets vs control (P<.01).
[c]Luprosil NC vs combined (P<.06).
[d]Fumaric acid vs Luprosil NC (P<.05).
[e]Fumaric acid vs Luprosil salt (P<.05).
[f]Mean of pigs fed acidified diets vs control (P<.05).
[g]Mean of pigs fed acidified diets vs control (P≤.13).

Swine Day 1994

THE EFFECT OF DIETARY L-CARNITINE ON GROWTH PERFORMANCE AND TISSUE ACCRETION RATES IN THE EARLY-WEANED PIG[1]

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Summary

A total of 216 pigs (initially 11.7 lb and 21 d of age) was used in a 35-d growth trial to determine the effect of dietary L-carnitine on growth performance and tissue accretion rates for the early-weaned pig when fed a porcine plasma-based diet. Pigs were blocked by weight, ancestry, and sex in a randomized complete block design, resulting in six pigs per pen (three barrows and three gilts) and six pens per treatment. Experimental diets were fed in two phases from d 0 to 35 postweaning. During Phase I (d 0 to 14 postweaning), the control diet was corn-soybean meal based; included 7.5% spray-dried porcine plasma, 25% dried whey, and 1.75% spray-dried blood meal; and was formulated to contain 1.6% lysine; and .44% methionine. On d 14, all pigs were switched to a Phase II (d 14 to 35 postweaning) diet that contained 10% dried whey and 2.5% spray-dried blood meal and was formulated to contain 1.25% lysine and .36% methionine. L-carnitine replaced corn in the Phase I and II control diets to provide dietary L-carnitine levels of 250, 500, 750, 1,000, and 1,250 ppm. On d 35, three barrows and three gilts per treatment (one pig per block) were slaughtered to determine carcass composition. From d 0 to 14 postweaning, increasing L-carnitine had no effect on growth performance. From d 14 to 35 and d 0 to 35, no differences occurred in average daily gain (ADG) and average daily feed intake (ADFI); however, pigs fed 1,000 ppm L-carnitine were more efficient (F/G) over the entire trial and were 1.94 lb heavier on d 35 than pigs on the positive control treatment. Plasma carnitine levels taken on day 14 increased as dietary carnitine increased. Percentage carcass CP, lipid, and daily protein accretion were not influenced by dietary L-carnitine on d 35. However, daily fat accretion was reduced, with pigs on the 750 ppm L-carnitine having the lowest daily fat accretion. Based on these results, L-carnitine addition reduces daily fat accretion and improves F/G when fed during the nursery phase.

(Key Words: Early-Weaned Pigs, L-Carnitine, Growth, Pigs.)

Introduction

Previous research at Kansas State University has shown that feeding high levels of L-carnitine in the nursery phase (from d 0 to 35 postweaning) had no effect on growth performance. However, pigs receiving high levels of L-carnitine (1,000 ppm) had significantly lower lipid, moisture, and ash accretion rates when compared to pigs offered diets with no added carnitine. This reduction of lipid accretion rates by carnitine supplementation has been observed previously in even earlier work conducted at KSU. This research demonstrated that pigs fed diets containing high levels of dietary L-carnitine during the first 2 weeks postweaning were more efficient during the Phase II period.

[1]Appreciation is expressed to Lonza, Inc., Fairlawn, NJ, for partial financial assistance and for providing the L-carnitine used in this trial.

[2]Lonza, Inc., Fairlawn, NJ.

Additionally, pigs fed dietary L-carnitine had lower lipid accretion rates. However, the exact requirement of L-carnitine needed in this nursery phase has not been determined. Therefore, the objective of this experiment was to determine the appropriate level of L-carnitine needed in nursery diets containing spray-dried blood products to enhance growth performance and tissue accretion rates.

Procedures

A total of 216 (21-d old) pigs was blocked by initial weight, ancestry, and sex and allotted to each of six dietary treatments. There were six pigs per pen (three barrows and three gilts) and six pens per treatment. Phase I consisted of d 0 to 14 postweaning, and Phase II was from d 14 to 35 post-weaning. Added L-carnitine levels were fed during the entire nursery phase (d 0 to 35 postweaning). A basal diet was formulated to contain 7.5% spray dried porcine plasma, 1.75% spray-dried blood meal, and 25% dried whey (Table 1). Experimental treatments fed during Phase I were achieved by adding increasing levels of L-carnitine to the basal diet to achieve dietary carnitine levels of 250, 500, 750, 1,000, and 1,250 ppm. The Phase I diet was formulated to contain 1.5% lysine and .42 % dietary methionine. During Phase II (d 14 to 35 postweaning), the basal diet was corn-soybean meal-based and contained 2.5% spray-dried blood meal and 10% dried whey. During Phase II, pigs were fed the same dietary carnitine level as in Phase I. All Phase I diets were fed in a pelleted form. The Phase II diet was fed in a meal form.

Pigs were housed in an environmentally controlled nursery. Temperature was maintained at approximately 90°F for the first week of the trial and lowered by approximately 5°F per week to maintain pig comfort. Pigs were offered ad libitum access to food and water. Pigs were weighed and feed disappearance was determined on d 7, 14, 21, 28, and 35 postweaning to calculate ADG, ADFI,and F/G. Pigs were bled on d 14 to evaluate plasma L-carnitine levels. Four males and four females were slaughtered at the start of the study for determining initial carcass composition. On d 35, six pigs per treatment (three females and three males per treatment) were selected randomly and slaughtered to determine daily accretion rates (protein and lipid) for the 35-d nursery phase.

Results and Discussion

From d 0 to 14 postweaning, increasing L-carnitine had no influence (P>.10) on growth performance (Table 2). From d 14 to 35 and d 0 to 35, no differences occurred in ADG and ADFI; however, pigs fed the 1,000 ppm L-carnitine were more efficient (P=.07) over the entire trial and were 1.94 lb heavier on d 35 compared with pigs fed the control diet.

Increasing dietary L-carnitine raised the level of carnitine in the plasma. This allows us to conclude that the biological activity of L-carnitine was increased; hence, all effects seen in this experiment were due to increasing levels of dietary L-carnitine.

Percentage carcass CP and daily protein accretion were not influenced by dietary L-carnitine on d 35. Although percentage carcass lipid was not influenced, daily fat accretion was reduced (quadratic, P=.09) with increasing dietary L-carnitine, and pigs fed 750 ppm L-carnitine had the lowest fat accretion rates. These results are similar to those previously reported at Kansas State University (1990 and 1993 Swine Day reports).

Based on the results of this experiment, L-carnitine addition reduces daily fat accretion and improves F/G when fed during the nursery phase. However, L-carnitine is not currently available in the U.S. for use in swine diets.

Table 1. Phase I and II Basal Diet Composition, %[a]

Ingredient	Phase I	Phase II
Corn[b]	41.65	58.76
Dried whey	25.00	10.00
Soybean meal, (48% CP)	14.91	21.26
Spray-dried porcine plasma	7.50	
Soybean oil	5.00	3.00
Spray-dried blood meal	1.75	2.50
Monocalcium phosphate (21% P)	1.82	1.97
Antibiotic[c]	1.00	1.00
Limestone	.64	.83
Vitamin premix	.25	.25
Mineral premix	.15	.15
DL-methionine	.15	.05
Copper sulfate	.075	.075
L-lysine	.10	.08
Total	100.00	100.00

[a]Phase I basal diet was formulated to contain 1.5% lysine, .42% methionine, .90% Ca, and .80% P; the Phase II basal diet was formulated to contain 1.25% lysine, .35% methionine, .90% Ca, and .80% P.
[b]L-Carnitine replaced corn on a lb per lb basis to achieve the 250, 500, 750, 1,000, and 1,250 ppm dietary carnitine experimental diets.
[c]Provided 50 g per ton carbodox.

Table 2. Performance of Pigs Fed Increasing Levels of L-Carnitine from d 0 to 35 Postweaning[a]

	Added carnitine, ppm						
Item	0	250	500	750	1,000	1,250	CV
d 0 to 14							
ADG, lb	.76	.75	.76	.77	.81	.80	10.8
ADFI, lb	.87	.89	.90	.88	.90	.91	11.0
F/G	1.15	1.17	1.19	1.16	1.11	1.14	6.1
d 14 to 35							
ADG, lb	1.17	1.19	1.22	1.20	1.23	1.22	7.2
ADFI, lb	2.14	2.11	2.21	2.14	2.12	2.22	6.7
F/G	1.83	1.78	1.81	1.79	1.74	1.83	5.8
d 0 to 35							
ADG, lb	1.00	1.01	1.04	1.03	1.06	1.05	7.4
ADFI, lb	1.63	1.62	1.69	1.64	1.63	1.69	7.0
F/G[e]	1.62	1.60	1.63	1.60	1.55	1.62	4.6
d 35							
PA, g per d[f]	58.0	56.3	55.8	53.1	54.6	56.3	11.8
FA, g per d[bg]	42.9	41.9	41.8	37.0	42.3	45.1	15.2
PC, nmole per mL[h]	13.7	34.9	42.2	50.2	51.6	50.2	14.6
d 35 wt	46.95	47.25	48.09	47.59	48.88	48.59	5.9

[a]Two hundred and sixteen weanling pigs were used (initially 11.7 lb and 21 d of age), 6 pigs per pen with 6 pens per treatment.
[b]Quadratic effect of dietary L-carnitine (P=.09).
[c]Linear effect of dietary L-carnitine (P<.01).
[d]Quadratic effect of dietary L-carnitine (P<.01).
[e]Control vs 1,000 ppm L-carnitine (P=.07).
[f]PA = protein accretion rates.
[g]FA = fat accretion rates.
[h]PC = plasma carnitine.

Swine Day 1994

INFLUENCE OF β-GLUCAN ON NONSPECIFIC IMMUNITY AND GROWTH PERFORMANCE IN WEANLING PIGS[1]

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Summary

Three experiments, using 344 pigs, were conducted to evaluate the influence of β-glucan (MacroGard™-S) on neutrophil and macrophage function, resistance to *Streptococcus suis* challenge, and growth performance in weanling pigs. β-glucan, when fed at inclusion rates of .05 and .1%, did not influence neutrophil or macrophage function or increase overall growth performance. Similarly, .025% β-glucan did not alter neutrophil or macrophage bactericidal activity or production of superoxide anion. However, diets containing .025% β-glucan increased average daily gain, average daily feed intake, and pigs weights and decreased plasma haptoglobin levels on d 21. Unfortunately, pigs fed a diet containing .025% that exhibited increased growth performance were more likely to die after challenge with *S. suis.* These data suggest the existence of a complex interaction involving growth performance and resistance to *S. suis* in pigs fed .025% β-glucan. The interaction should be investigated further.

(Key Words: Starter Pigs, β-glucan, Growth.)

Introduction

Increasing innate immunity in young pigs is one means of decreasing disease susceptibility and presumably increasing growth performance. Glucans from a variety of bacterial, yeast, and plant cell walls have been shown to stimulate both specific (vaccine adjuvants) and nonspecific immune responses. When one considers the mechanisms responsible for the positive results obtained from feeding β-glucan to weaned pigs, several possibilities exist. First, is the response evoked by eliciting specific immune reactions? If weaned pigs were vaccinated close to the time that β-glucan was administered in the feed, it is conceivable that immunity to specific vaccine immunogens could result. However, unless the animals were exposed to the particular vaccine pathogens during the nursery phase, it is difficult to imagine an increase in growth performance from the generation of specific immunity to vaccine antigens. Second, is the positive growth response evoked by enhancement of nonspecific immunity? Primary targets of β-glucan activity are phagocytic cells of the immune system, such as neutrophils and macrophages. It is conceivable that increasing phagocytic cell function could lower the innate pathogen load in young pigs and act

[1]Appreciation is expressed to Provesta Corp., Bartlesville, OK, for partial financial support and provision of the β-glucan. We also thank Eichman Farms, St. George, KS, for animals and facilities used in Exp. 2 and Danielle Goodband for her excellent technical assistance.

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much like a low-level antibiotic feed additive. Finally, because delayed-type hypersensitivity (DTH) is an immune response capable of being modulated, one could imagine a mechanism whereby feeding an immunomodulator in the nursery diet might abate soybean-induced DTH by enhancing tolerance to soybean proteins. We conducted three experiments feeding β-glucan to weaned pigs to address some of these possibilities. In Exp. 1, we evaluated the influence of diet (all milk protein vs soybean meal) and .1% β-glucan on growth performance and neutrophil function in weaned pigs. In Exp. 2, the influence of .1% β-glucan on growth performance was evaluated in weaned pigs in a large-scale on-farm trial. In Exp. 3, we evaluated the influence of .025 and .05% β-glucan on growth performance, neutrophil and macrophage function, acute phase protein production, and resistance to a *Streptococcus suis* infection in weaned pigs.

Procedures

Experiment 1: One hundred forty-four crossbred pigs were weaned at 3 wk of age and allotted by weight, gender, and ancestry to four treatment groups in a 2 × 2 factorial arrangement of nursery diet and β-glucan treatment. Pigs were housed in an environmentally controlled nursery with woven-wire flooring. Each pen contained a self-feeder and a nipple waterer to provide ad libitum access to feed and water. Six pigs were housed per pen (4 ft × 5 ft) with six replicate pens per treatment. From weaning to d 7 postweaning, all pigs were fed a common milk-protein-based diet (Table 1). On 7 d postweaning, 72 pigs were switched to a soybean-meal-based diet. The remaining pigs were fed a milk-protein-based diet that did not contain any soybean meal. Within dietary treatments, pigs were assigned to control or .1% β-glucan treatments. Pig weights and feed consumption were collected weekly postweaning to calculate average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G).

Starting on d 7 postweaning, whole-blood samples were collected weekly from six pigs on each treatment for assessment of neutrophil function. Neutrophils were isolated and evaluated for generation of reactive oxygen intermediates, antibody-dependent cellular cytotoxicity, and bactericidal activity. In addition, a whole-blood flow cytometric assay for neutrophil oxidative burst was conducted. Superoxide anion production and bactericidal activity against *Streptococcus suis* were evaluated only in pigs on the milk-based diet.

Experiment 2: One hundred forty pigs were weaned at 14 d of age and assigned to control or .1% β-glucan diets. Pigs were housed in an environmentally-controlled nursery with slotted-metal flooring on a commercial farm in northeast Kansas. Each pen contained a self-feeder and two nipple waterers to provide ad libitum access to feed and water. Six, seven, or nine pigs were housed per pen (4 ft × 6 ft) with nine replicate pens per treatment. Pigs were fed Phase I diets from weaning to d 14 postweaning and then switched to Phase II diets from d 14 to 28 postweaning (Table 1). Pigs were fed their respective control or β-glucan treatment for the entire 28-d study. Pig and feeder weights were collected weekly postweaning to calculate ADG, ADFI, and F/G.

Experiment 3: Sixty crossbred pigs were weaned at 3 weeks of age and allotted by weight, gender, and ancestry to three dietary treatment groups: 0, .025, and .05% β-glucan (Table 1). Pigs were housed in an environmentally controlled, isolation facility in polyethylene pens. Each pen contained a self-feeder and a nipple waterer to provide ad libitum access to feed and water. Four pigs were housed per pen with five replicate pens per treatment. Pig weights and feed consumption were collected weekly postweaning to calculate ADG, ADFI, and F/G.

On d 14 and 28, alveolar macrophages were collected from five pigs on each treatment by bronchoalveolar lavage. Macrophage functions evaluated included generation of superoxide anion production and bactericidal activity. Additionally, macrophage expression of the membrane antigen CD14, a receptor for lipopolysaccharide (LPS), was evaluated on d 14 and 28. On d 26, neutrophils were collected (five pigs/treatment) and

assayed for superoxide anion production and bactericidal activity. At d 0, 7, 14, 21, 28, and 35 plasma was collected from two pigs per pen for analysis of the acute phase protein, haptoglobin.

After 4 wk on the experimental diets, all pigs were injected intravenously with 6.5×10^8 colony forming units of a log-phase culture of *S. suis*, serotype 2. Pigs were observed daily following challenge and the following clinical signs were recorded: dyspnea, depression, lameness, and CNS disorders. Scoring of clinical signs was 0 to 3 (normal to severe) for dyspnea, depression, and CNS disorders and 0 to 4 (normal to down) for lameness. A pooled clinical score was calculated for each pig. Rectal temperatures were monitored daily. All pigs were euthanitized by electrocution at 12 d after infection.

Data were analyzed according to the General Linear Models procedure of the Statistical Analysis System. Mortality data were analyzed by Fisher's Exact Test. Haptoglobin levels were analyzed using repeated measures analysis of variance with a Satterthwaite error correction for comparisons of treatments within day postweaning.

Results

Inclusion of β-glucan at .1% of the diet did not increase growth performance in nursery pigs (Table 2). Conversely, pigs fed the milk-based diet containing β-glucan had numerically decreased growth performance during the first 2 weeks on the diet. Pigs fed the soybean-meal-based diet had depressed growth performance in comparison to pigs fed the milk-based diet; however, adding .1% β-glucan to the diet did not abate this depression. Because β-glucan did not produce the expected increase in growth performance, a second experiment was conducted with a different lot of β-glucan. However, feeding .1% β-glucan-supplemented diets for 4 weeks to nursery pigs did not influence growth performance (Table 3).

Inclusion of β-glucan at rates less than .1% may be more effective in enhancing growth performance. Based on data that became available to us after the conclusion of the first two experiments, β-glucan inclusion rates of .025 and .05% were evaluated in Exp. 3. Average daily gain was increased in pigs fed a diet supplemented with .025% β-glucan for 4 wk (Table 4). This increased gain was the result of increased feed intake and resulted in approximately a 5 lb weight advantage after 4 wk on the diet. Numerically, ADG, ADFI, and pig weights were greater in pigs fed .05% β-glucan than pigs fed the control diet. However, after *S. suis* challenge on d 28 postweaning, ADG was threefold less in pigs fed β-glucan than in pigs fed the control diet.

In general, oral β-glucan had no consistent effects on peripheral blood neutrophil generation of reactive oxygen intermediates, antibody-dependent cellular cytotoxicity, or bactericidal activity. Macrophage and neutrophil production of superoxide anion and bactericidal activity against *S. aureus* were not influenced by diets containing .025 and .05% β-glucan. Similarly, macrophage expression of the LPS receptor, CD14, was not influenced by inclusion of β-glucan in diets.

An interaction occurred between dietary treatments and day postweaning on plasma haptoglobin concentration (Figure 1). The interaction resulted in lower concentrations of haptoglobin produced on d 14 and 21 postweaning in the pigs fed .025% β-glucan.

Inoculation of pigs with 6.5×10^8 colony forming units of *S. suis*, caused a rapid expression of streptococcal disease in all pigs. However, pigs that displayed the best growth performance, i.e., pigs fed the .025% β-glucan diet, were more susceptible to the streptococcal infection than pigs fed the control diet (Figure 2). This finding was evident in rectal temperatures and clinical signs of the disease and was most clearly demonstrated by the 50% mortality rate in pigs fed .025% β-glucan.

Discussion

Three points are clear from these β-glucan experiments. First, with three different dietary regimens, we observed no benefit of supplementing nursery-pig diets with .1% β-glucan. Second, nursery-pig diets supplemented with .025% β-glucan increased growth performance. Third, pigs that exhibited increased growth performance caused by a diet containing .025% β-glucan were more likely to die after challenge with *S. suis*.

Our data suggest that a discrete dose relationship exists between dietary levels of β-glucan, growth performance, and resistance to streptococcal disease. In our first experiment using .1% β-glucan, growth performance was decreased during the first 2 wk of the study; however, this finding was not observed in the second trial using .1% β-glucan. It is known that β-glucan can augment interleukin-1 secretion in macrophages that are activated by LPS. If immune activation does limit growth performance, perhaps the data from Exp. 1 reflect this concept. However, why was the growth depression observed only during the first 14 d in Exp. 1 and not in Exp. 2? Because of disease problems (*S. suis*), pigs in Exp 1. were water medicated at about wk 2 of the trial. The water medication may have reduced the pathogen load and, thus, the degree of immune activation and may have decreased any interleukin-1 priming-effect of β-glucan on activated immune cells. Although β-glucan has been shown to augment interleukin-1 secretion in activated macrophages, it is also known that β-glucan can preferentially cause the secretion of a competitive inhibitor of interleukin-1. If feeding β-glucan alters the balance of interleukin-1 and the competitive inhibitor of interleukin-1 such that the inhibitor is preferentially secreted, then one would expect less activation of the immune system during the feeding period, which might result in increased growth performance. This is further supported by the data indicating decreased production of acute phase proteins in the pigs fed .025% β-glucan. Interleukin-1 and other cytokines are critical for the production of the acute phase proteins of the immune response. Thus, the decreased level of acute phase proteins could indicate suppression of cytokine production. However, because interleukin-1 is a pivotal cytokine in an animals' resistance to bacterial disease, one would expect an individual with lower interleukin-1 capabilities to be at a disadvantage during a bacterial infection. Indeed, this scenario may explain our findings of increased growth performance prior to challenge with *S. suis* and increased disease susceptibility after *S. suis* challenge in pigs supplemented with .025% β-glucan.

In conclusion, our findings suggest that supplementing nursery-pig diets with .025% β-glucan increased growth performance. However, because this treatment also increased disease susceptibility to *S. suis*, our data suggest that a complex interaction exists between growth performance and disease susceptibility in pigs fed β-glucan. The implications of this last finding are extremely important, and we recommend that further studies be conducted to confirm or refute the involvement of β-glucan in the interaction of growth performance and disease susceptibility.

Table 1. Diet Composition[a]

	Exp. 1			Exp. 2 Phase 1	Exp. 2
Item	Phase 1	Milk	Soy	and Exp. 3	Phase 2
Corn	42.13	52.14	42.31	37.45	56.44
Dried whey	25.00	20.00	10.00	25.00	10.00
Soybean meal (48.5% CP)	--	--	38.47	19.14	23.54
Dried skim milk	10.00	5.00	--	--	--
Casein	4.82	4.32	--	--	--
Spray-dried porcine plasma	7.50	7.50	--	7.50	--
Soybean oil	5.00	5.00	5.00	5.00	3.00
Spray-dried blood meal	1.75	1.75	--	1.75	2.50
Monocalcium phosphate (21% P)	1.60	1.90	1.69	1.74	1.93
Antibiotic[b]	1.00	1.00	1.00	1.00	1.00
Limestone	.53	.66	.78	.63	.82
Vitamin premix	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15
DL-methionine	.10	.04	.02	.173	.90
Copper sulfate	.075	.075	.075	.075	.075
L-lysine HCl	.10	.10	--	.10	.10
Cornstarch[c]	--	.10	.10	.05	.10
Total	100	100	100	100	100

[a]Diets in Exp. 1, Exp. 2 Phase 1 (d 0 to 14 postweaning) and Exp. 3 were formulated to contain 1.6% lysine and .46% methionine. Diets in Exp. 2 Phase 2 (d 14 to 28) were formulated to contain 1.25% lysine and .35% methionine. All diets were formulated to contain .9% calcium and .8% phosphorus. Exp. 1 Phase 1 was fed from d 0 to 7 postweaning, and soy or milk diets were fed from d 7 to 35 postweaning.
[b]To provide 50 g/ton carbadox.
[c]β-glucan was substituted for cornstarch to provide .1% β-glucan in Exp. 1 and 2 and .025% and .05% β-glucan in Exp. 3.

Table 2. Effects of Diet and β-Glucan on Growth Performance of Weanling Pigs (Exp. 1)[a]

	Milk		Soybean meal		
Item	Control	.1% β-glucan	Control	.1% β-glucan	CV
d 7 to 14 postweaning					
ADG, lb[b]	.76	.63	.40	.40	15.3
ADFI, lb[b,c]	.92	.73	.73	.65	10.1
F/G[b]	1.13	1.27	1.97	1.74	19.1
d 7 to 35 postweaning					
ADG, lb[b]	1.04	1.02	.75	.75	10.1
ADFI, lb	1.39	1.29	1.32	1.30	7.2
F/G[b]	1.32	1.29	1.76	1.76	11.2
Pig weight, lb					
d 35[b]	44.9	43.7	36.3	36.7	6.3

[a]A total of 144 pigs was used (initially 11.1 lb and 21 d of age), six pigs/pen, six pens/treatment. All pigs were fed a common diet (milk) from d 0 to 7 postweaning. Dietary treatments were fed from d 7 to 35 postweaning. Values are means of six pens adjusted using average weight on d 7 as a covariate.
[b]Diet main effect ($P<.01$).
[c]Glucan main effect ($P<.01$).

Table 3. Effects of β-Glucan on Growth Performance of Weanling Pigs (Exp. 2)[a]

Item	Control	.1% β-Glucan	CV
d 0 to 14 postweaning			
ADG, lb	.51	.53	12.5
ADFI, lb	.60	.59	11.9
F/G	1.19	1.15	6.8
d 14 to 28 postweaning			
ADG, lb	.76	.76	10.3
ADFI, lb	1.29	1.23	7.1
F/G	1.73	1.63	7.4
d 0 to 28 postweaning			
ADG, lb	.63	.64	10.6
ADFI, lb	.94	.91	8.1
F/G	1.51	1.44	6.0

[a]A total of 140 pigs was used (initially 8.7 lb and 14 d of age) with six, seven, or nine pigs/pen and nine pens/treatment. Pigs were fed Phase I diets from d 0 to 14 postweaning and then switched within treatment to Phase II diets from d 14 to 28 postweaning. No treatment effects.

Table 4. Effects of β-Glucan on Growth Performance of Weanling Pigs (Exp. 3)[a]

Item	Control	.025% β-Glucan	.05% β-Glucan	CV
d 0 to 14 postweaning				
ADG, lb	.71[b]	.83[c]	.73[b]	12.0
ADFI, lb	.68[b]	.82[c]	.70[b]	11.4
F/G	.97	.99	.97	2.2
d 14 to 28 postweaning				
ADG, lb	1.11[b]	1.34[c]	1.23[b]	8.4
ADFI, lb	1.15[b]	1.41[c]	1.28[b]	13.7
F/G	1.20	1.22	1.24	10.1
d 0 to 28 postweaning				
ADG, lb	.91[b]	1.09[c]	.98[b]	11.9
ADFI, lb	.95[b]	1.17[c]	1.06[b]	13.2
F/G	1.06	1.08	1.08	5.9
d 28 to 35 postweaning[d]				
ADG, lb	.31	.08	.02	389
Pig weight, lb				
d 14 postweaning	20.8[e]	22.4[f]	20.9[e]	6.0
d 28 postweaning	36.3[b]	41.1[c]	38.1[b]	6.4

[a]Total of 60 pigs was used (initially 10.8 lb and 18 d of age) with four pigs/pen on d 0 to 14, three pigs/pen on d 15 to 28, and two pigs per/pen on d 29 to 35. There were five pens/treatment.
[b,c]Means lacking a common superscript differ (P<.05).
[d]ADG after *S. suis* challenge.
[e,f]Means lacking a common superscript differ (P<.10).

Figure 1. Plasma Haptoglobin Concentrations in Pigs Fed β-Glucan and Challenged with *S. suis*. (Pigs were fed diets supplemented with .025 and .05% β-glucan for 4 wk and inoculated intravenously with *S. suis* serotype 2 (6.5×10^8 CFU) at d 28. Values are means ± SEM, n=10. Means within day lacking a common superscript differ, $^{a,b}P<.07$ and $^{c,d}P<.14$.)

Figure 2. Survival Rates of Pigs after *S. suis* Challenge. (Pigs were fed diets supplemented with .025 and .05% β-glucan for 4 wk and inoculated intravenously with *S. suis* serotype 2 (6.5×10^8 CFU) at d 28. Ten pigs were on each diet. Values within day lacking a common superscript differ, P<.04.)

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NURSERY GROWTH PERFORMANCE OF INTACT MALES AND BARROWS

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

Summary

A total of 100 weanling pigs with an average initial body wt of 11.8 lb and average age of 17 d was used in a 38-d growth assay to determine the effect of castration on growth performance of nursery pigs. All pigs were fed the same Phase I, II, and III diets formulated to 1.6, 1.4, and 1.35% lysine, respectively. Data indicated no differences in growth performance between intact males and barrows in the first 38 d postweaning (12 to 48 lb).

(Key Words: Starter, Performance, Boars, Barrows.)

Introduction

Intact males have greater average daily gain and are more feed efficient than barrows when fed in the finishing phase. The point at which these differences in performance begin is unclear. Therefore, the objective of this experiment was to determine if intact males have greater growth performance than barrows in the nursery phase.

Procedures

A total of 100 male pigs (initial body wt of 11.8 lb and an average age of 17 d) was used in a 38-d growth assay. Half of the pigs were castrated at 7 d of age. Pigs were allotted by weight, sexual condition, and ancestry, with five pigs per pen and 10 replicate pens per treatment. Intact males and barrows were housed in separate pens. At the start of the experiment, all pigs were fed the same corn-soybean meal-based Phase I diet formulated to 1.6% lysine, .9% Ca, and .8% P with 20% dried whey, 5% dried skim milk, 1% fish meal, and 10% plasma protein. On d 10 postweaning, all pigs were switched to a corn-soybean meal-based Phase II diet formulated to 1.4% lysine, .9% Ca, and .8% P with 15% dried whey, 1.5% blood meal, and 3% fish meal. On d 24 postweaning, all pigs were switched to a corn-soybean meal Phase III diet formulated to 1.35% lysine, .9% Ca, and .8% P. All diets were fed in pelleted form.

Pigs were housed in 4-ft × 5-ft pens with woven-wire flooring. Room temperatures were 90, 87, 84, 80, and 75°F for weeks 1 to 5, respectively. Each pen had a self-feeder and a 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 determine average daily gain (ADG), average daily feed intake (ADFI), and feed/gain (F/G).

Results and Discussion

Intact males and barrows had similar ADG and ADFI (Table 1). Although there were trends ($P<.10$) for differences in F/G, the differences were small and inconsistent (i.e., barrows were more efficient in Phase I and intact males were more efficient overall). In summary, castration had little effect on growth performance during the first 38 days postweaning.

Table 1. Growth Performance of Intact Males vs Castrates in the Nursery[a]

Item	Intact males	Barrows	CV
Phase I (d 0 to 10)			
ADG, lb	.67	.69	11.3
ADFI, lb	.63	.61	6.1
F/G[b]	.94	.88	6.8
Phase II (d 10 to 24)			
ADG, lb	.79	.80	14.6
ADFI, lb	1.11	1.13	10.3
F/G	1.41	1.41	6.5
Phase III (d 24 to 38)			
ADG, lb	1.36	1.40	11.2
ADFI, lb	1.98	2.12	12.2
F/G	1.46	1.51	5.6
Overall (d 0 to 38)			
ADG, lb	.97	.99	9.6
ADFI,lb	1.30	1.36	10.4
F/G[b]	1.34	1.37	2.0

[a]A total of 100 weanling pigs (five pigs/pen and 10 pens/treatment) with an average initial weight of 11.8 lb and an average final wt of 48 lb.
[b]Significant trend (P<.10).

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THE USE OF GROWTH MODELS TO EVALUATE THE CHANGING RESPONSE TO DIGESTIBLE LYSINE IN HIGH-LEAN GROWTH GILTS

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Summary

Conventional response criteria for amino acid research include mean live weight gain and tissue accretion rates over a given weight interval. However, these methods fail to characterize the changing response of tissue accretion to dietary amino acids as body weight increases. For this reason, growth modeling was used to characterize the response to digestible lysine in two experiments (114 gilts each) from 80 to 160 lb and 160 to 300 lb, respectively. Corn-soybean meal diets were formulated to assure that lysine (.54 to 1.04% and .54 to .94% digestible lysine for Exp 1 and 2, respectively) was the first limiting amino acid. Analysis of variance was used to test linear and quadratic responses in cumulative weight gain on test as digestible lysine increased. A time by digestible lysine interaction was detected, indicating that a separate regression equation for each lysine level was necessary. In Exp. 1, ADG and carcass CP accretion were maximized for gilts fed 1.04, .94, and .84% digestible lysine from 80 to 100 lb, 100 to 120 lb, and 120 to 160 lb, respectively. Lipid accretion was minimized for gilts fed .74 to .84% digestible lysine. In Exp. 2, ADG was maximized by feeding .84% from 160 to 205 lb and .74% from 205 to 300 lb. Carcass CP accretion was maximized by feeding .94% digestible lysine, and lipid accretion was minimized for gilts fed .84% digestible lysine from 160 to 300 lb. If feeding graded levels of digestible lysine resulted in parallel lines for carcass protein accretion, mean values would result in accurate data evaluation. However, responses to digestible lysine changed over the feeding period. Therefore, the use of BW and compositional growth curves offers an innovative approach to more accurately characterize the growing pig's response to increased digestible lysine.

(Key Words: Pigs, Gilts, Growth, Carcass Composition, Growth Modeling.)

Introduction

Currently, nutrient requirements for growing-finishing pigs are based on mean growth performance or lean tissue accretion rates over a given time period (ARC, 1981; NRC, 1988). These static estimates of nutrient requirements limit the flexibility to accurately formulate diets for the daily changes in nutrient needs as well as genotype, environment, and health status. Previous research from the University of Illinois indicated that mean ADG and G/F overestimate the methionine requirement for growing finishing pigs compared to mathematical modeling techniques. Therefore, these data suggest a need for improved techniques to determine nutrient requirements. An approach to model body weight gain has been developed at Purdue University to accurately characterize total body weight and tissue weight gain over time. This modeling approach can conceptually improve the estimates for nutrient requirements to maximize carcass protein accretion. The objective of our research was to use these mathematical techniques to characterize the changing response to digest-

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ible lysine in high-lean growth gilts fed from 75 to 160 lb and 160 to 300 lb.

Procedures

Animals and Housing. One-hundred fourteen high-lean growth gilts from a terminal sire line (Pig Improvement Co., L326, Franklin, KY, USA) were used in each of two experiments to determine the digestible lysine requirement to maximize average daily gain (ADG) and carcass protein accretion from 75 to 160 lb (Exp. 1) and from 160 to 300 lb (Exp. 2). The carcass CP and lipid contents for these gilts are given in Table 1. The gilts in Exp. 1 (66 lb body weight) were delivered to the Kansas State University Swine Teaching and Research Center and fed a .90% total lysine diet until they reached a mean weight of 80 lb. In Exp. 2, the gilts were fed a 1.15% total lysine diet from 70 to 160 lb before the experiment was initiated. Three gilts were housed per pen (4 ft × 15 ft pens with solid flooring) in an open-fronted building with six replicate pens per treatment. Each pen contained a single-hole feeder and nipple waterer to provide ad libitum access to feed and water, respectively.

Diet Formulation. Digestible lysine treatments were .54, .64, .74, .84, .94, and 1.04% (.75, .78, .96, 1.03, 1.17, 1.28% total lysine, respectively) for Exp. 1 and .54, .64, .74, .84, and .94% (.73, .87, 1.05, 1.07, and 1.13% total lysine, respectively) for Exp. 2. The corn-soybean meal ratio was adjusted to provide the desired digestible lysine levels. Then, digestible tryptophan, threonine, methionine + cystine, and isoleucine were set using an ideal amino acid ratio. The dietary ME content was increased to 1,550 kcal/lb by adding 3% soybean oil. All other nutrients were formulated in excess of NRC (1988) estimates for the 44- to 110-lb and 110- to 240-lb pig for Exp. 1 and 2, respectively.

Tissue Accretion Rates. Six gilts were selected randomly for slaughter at 80 and 160 lb for Exp. 1 and 2, respectively, and the right side of each eviscerated carcass was ground to determine the percentage moisture, CP, lipid, and ash. When the pen mean weight was approximately 120 and 160 lb (Exp. 1) and 230 and 300 lb (Exp. 2), one pig from each pen (six pigs per treatment) was slaughtered for carcass analyses. The head, leaf fat, and viscera were removed at slaughter and were not included in tissue accretion rate determination. At 24 h postmortem, the right side of each carcass was ground once through a .4-in plate, once through a .25-in plate, and homogenized for 3 min in a ribbon-paddle mixer. Proximate analyses were conducted on each carcass sample. From the chemical analyses, the amounts of CP, lipid, ash, and DM were determined for each carcass based upon cold carcass weight. Moisture content was determined by subtracting the percentage of DM from 100%. Thus, initial composition, determined from chemical composition of carcass weight, was subtracted from chemical composition determined at 120 and 160 lb (Exp. 1) and 230 and 300 lb (Exp. 2). Tissue accretion rates were determined from the difference between final and initial composition, divided by the days on test. These means then were used to test linear and quadratic effects of digestible lysine.

Weight Interval Performance Analyses. Analysis of variance with the GLM function of SAS was used to obtain the least square means for ADG and carcass CP and lipid accretion from 80 to 160 lb and 160 to 300 lb. Linear and quadratic polynomials were used to evaluate the effect of digestible lysine. Break-point analysis was used to determine the inflection point at 95% of maximal response when the quadratic function was significant. The inflection point for a lysine requirement was determined for ADG and carcass protein and lipid gain, from 80 to 160 lb. From 160 to 300 lb, the inflection point was not estimated for ADG and carcass protein and lipid gain, because no significant quadratic response was observed.

Regression Analyses. Two functions, one relating live weight to time and a second relating the body component mass to live weight, were used to establish the body component accretion rates at each age or weight. Regression analysis was used first to determine the relationship between live weight gain and days on test by using the

following equation to solve for regression coefficients:

$$\textbf{Cumulative live weight gain on test} = b_o + b_1(\text{day}) + b_2(\text{day}^2).$$

An allometric equation then was used to determine the coefficients of carcass CP and lipid accretion relative to live weight:

$$Y = aX^b$$

where Y = carcass CP or lipid, a = scale constant, X = body weight, and b = relative growth coefficient. The equation was linearized as log Y = log a + b log X to utilize least squares regression analyses. Component (carcass CP or lipid) gain then was related to live weight gain by multiplying the derivative of live weight over time by the derivative of component weight over live weight.

Results

The initial body weight (b_o) for the relationships between the change in live weight gain over time were similar for all digestible lysine levels at 80 lb (Exp 1.) and 160 lb (Exp 2.; Table 1). The linear (b_1) and quadratic (b_2) terms were different (P<.001) for each digestible lysine level in both Exp. 1 and 2. The b_1 term increased as digestible lysine level increased from .54 to 1.04% , resulting in greater ADG for gilts fed increased digestible lysine (Figure 1.). The b_2 values were positive for gilts fed .54, .74, and .84%, indicating increased ADG as body weight or time increased. The negative b_2 terms for gilts fed .64, .94, and 1.04% suggest reduced ADG as body weight increased. For Exp 2, the b_1 and b_2 terms were different (P<.001) for each digestible lysine level. The b_1 term increased as digestible lysine increased from .54 to .94%, resulting in greater ADG (P<.001). Average daily gain (Figure 2) was reduced as body weight increased, as reflected by the negative b_2 terms for each digestible lysine level. These b_2 terms were influenced (P<.001) by digestible lysine for gilts fed .64, .84, and .94% digestible lysine.

The intercepts (a) developed for the carcass CP allometric functions from 80 to 160 lb decreased (P<.001) as digestible lysine increased (Table 2). Growth coefficients (b) were greater (P<.001) as digestible lysine increased from .54 to 1.04%, peaking at .74%. The intercept for carcass lipid accretion was influenced (P<.001) by digestible lysine. Carcass lipid growth functions (b) were reduced (P<.001) as a result of increased digestible lysine. Similarly, carcass CP and lipid intercepts were influenced (P<.001) as digestible lysine increased in Exp. 2 (Table 6). The growth coefficients for carcass CP increased (P<.001), whereas carcass lipid coefficients decreased (P<.001).

The data in Fig. 1 represent weight interval performance analyses and the corresponding regression analyses for ADG and carcass CP and lipid accretion from 80 to 160 lb. Weight interval performance analyses for ADG (Panel A) indicated greater (linear, P<.01) gains as a result of increased digestible lysine. Average daily gain appears to be maximized for high-lean growth gilts fed .84 to .94% (18 g/d digestible lysine or 22 g/d total lysine intake) digestible lysine. Live weight growth curve analyses of ADG (Panel B) indicated maximum ADG (P<.001) for high-lean growth gilts fed 1.04, .94, and .84% digestible lysine from 75 to 100 lb, 100 to 120 lb, and 120 to 160 lb, respectively. These diets would provide 16, 18, and 18 g/d digestible lysine intake (19, 21, and 21 g/d total lysine intake, respectively) for the specified weight periods. Weight interval performance analyses indicated increased (quadratic, P<.05) CP accretion as digestible lysine increased (Panel C). The inflection point for 95% of the maximum response was .79 g/kg (14 g/d) digestible lysine (9.4 g/kg or 17 g/d total lysine). Regression analyses (Panel D) showed that carcass CP accretion was maximum (P<.001) for gilts fed 1.04, .94, and .84% digestible lysine from 75 to 100 lb, 100 to 120 lb, and 120 to 160 lb. The analysis of CP accretion would result in identical lysine estimates (digestible and total) as did the ADG analysis. Carcass lipid accretion decreased (quadratic, P<.10) as digestible lysine increased (Panel E). The inflection point for minimum carcass lipid

gain was calculated at .71% (13 g/d) digestible lysine (.84% or 15 g/d total lysine). The regression of carcass lipid accretion over body weight indicated a linear increase (P<.001) in lipid gain for all dietary treatments, except gilts fed 10.4 g/kg (Panel F).

Weight interval performance analyses from 160 to 300 lb indicated that digestible lysine did not influence (P>.10) ADG (Figure 2.; Panel A). Numerically, ADG apparently is maximized for gilts fed .74% (22 g/d) digestible lysine or .88% (27 g/d) total lysine. Regression analyses of body weight gain over time (Panel B) indicated maximum (P<.001) ADG for gilts fed .84 and .74% digestible lysine from 160 to 205 lb and 205 to 300 lb, respectively. These estimates would provide 25 and 22 g/d digestible lysine intake (30 and 26 g/d total lysine intake). Carcass CP accretion (Panel C) was greater (linear, P<.10) as digestible lysine increased. This increase in CP accretion would require .94% (28 g/d) digestible lysine or 1.12% (33 g/d) total lysine. Regression analyses of carcass CP accretion over body weight (Panel D) was maximum (P<.001) for gilts fed .94% (28 g/d) digestible lysine or 1.12% (33 g/d) total lysine. However, as body weight increased, carcass CP accretion continually decreased (P<.001). Carcass lipid accretion (Panel E) was not influenced (P>.10) by digestible lysine in high-lean growth gilts fed from 160 to 300 lb. The regression analyses of carcass lipid accretion (Panel F) indicated increased lipid accretion for gilt fed all diets, except .84% digestible lysine.

Discussion

These results indicate that the response to digestible lysine changes as body weight increased from 80 to 300 lb. Traditionally, nutrient requirement estimates are established by using mean performance over a given weight period. These estimates are determined for mean performance from 110 to 280 lb in the National Research Council's (1988) amino acid requirements for finishing pigs. Use of these techniques obviously limits practical diet formulation because of differences in the pigs' genetic potential, health status, environmental conditions, and gender, which will change the shape of the growth curves.

The data from Figure 1 suggest that ADG and carcass protein were limited by lysine intake. Thus, as digestible lysine was increased from .54 to .94%, the rates of total live weight gain and carcass protein gain increased dramatically. Gilts fed deficient levels of dietary lysine (.54%) attained only 67% of their genetic potential for carcass protein gain from 80 to 160 lb. The differences in the regression lines represent the influence of digestible lysine on the body weight where peak carcass protein gain was attained. These differences could be explained by previous nutrient intake that may influence the shape of the compositional curves, offering the potential for compensatory gain. Our data suggest that the .74% digestible lysine diet fed prior to the first experiment limited carcass protein gain. Thus, feeding greater levels of digestible lysine resulted in large increases in carcass protein gain, potentially as compensatory gain, as well as meeting the lysine need for maximum carcass protein gain. Secondly, the resulting decrease in carcass protein gain for gilts fed 1.04% digestible lysine may be related to decreased net energy for gain because of increased excess amino acid degradation. Lipid accretion increased as body weight increased from .54 to 1.04% digestible lysine. However, it increased to a lesser extant for gilts fed .84 to .94% digestible lysine compared to those fed .54 to .64% digestible lysine. Carcass lipid gain is limited when adequate digestible lysine is fed.

During the finishing period (160 to 300 lb), ADG and carcass protein gain decreased as body weight increased (Figure 2). This reduction suggests that carcass protein gain was beyond the inflection point for maximum gain. These responses are similar to those from Purdue University indicating that carcass protein gain per day decreased as body weight increased from 130 to 280 lb. The magnitude of response to digestible lysine was not as great as the responses from 80 to 160 lb. The total lysine intake in the finisher gilts is 5 g/d greater to support carcass pro-

tein gains that are 20 to 30 g/d less than those of grower gilts. This is apparent in reduced feed efficiencies as body weight increases. The poorer efficiencies for lysine use also can be attributed to increased lipid deposition that resulted from greater feed intake and excess nutrient intake.

Thus, performance and carcass composition are poorer as a result of increased body weight. Our data suggest increased carcass protein gain and decreased lipid gain as a result of greater digestible lysine intake. However, the efficiency of lysine utilization is reduced for gilts fed from 80 to 160 lb. This reduction is evident by the decreased slope of carcass protein gain on lysine intake. However, the increased carcass protein gain was proportionally greater for nonlean tissue gain (i.e., lipid gain), which is evident in our data. Although carcass protein gain is greater with increased digestible lysine, the cost of achieving maximum carcass protein gain is not economically feasible. It becomes a question of economics to determine the level of lysine that can be fed for maximum profit.

In conclusion, the growth and composition models described in this experiment indicate the importance of regression models to accurately describe nutrient requirements in growing-finishing pigs. In the growing period (80 to 160 lb), the models more accurately estimated digestible lysine for maximum carcass protein gain as body weight increased. Although digestible lysine gave less of a response in the finishing period (160 to 300 lb), the models characterized the diminishing response to digestible lysine as body weight increased. Thus, maximal profit will dictate the level of digestible lysine that can be fed in the finishing period rather than maximal carcass protein gain.

Table 1. Live Weight Growth Parameters for High-Lean Growth Gilts Fed from 80 to 160 lb and 160 to 300 lb where Live Weight Gain on Test = $b_o + b_1(days) + b_2(days)^2$[a]

	80 to 160 lb			160 to 300 lb		
Digestible lysine, %	b_o	b_1	b_2	b_o	b_1	b_2
.54	75.610	1.306 (.082)***[a]	.002 (.002)***	162.439	1.984 (.070)***	-.002 (.001)
.64	74.440	1.637 (.088)***	-.003 (.002)***	159.940	2.110 (.070)***	-.004 (.001)**
.74	75.610	1.393 (.088)***	.003 (.002)***	158.331	2.061 (.071)***	-.002 (.001)
.84	75.668	1.566 (.102)***	.005 (.003)***	157.390	2.190 (.069)***	-.005 (.001)***
.94	74.557	1.875 (.103)***	-.002 (.003)***	159.001	2.123 (.068)***	-.004 (.001)***
1.04	75.610	2.194 (.094)***	-.014 (.002)***	--	--	--

[a]Where liveweight gain on test = $b_o + b_1(days) + b_2(days)^2$
[b]Probability levels of deviations of coefficients from 1.00, ** P<.01, *** P<.0001.

Table 2. Growth of Carcass CP and Lipid Components using the Relationship of $Y = aX^b$, where Y Is the Component and X Is the Live Weight (lb), for High-Lean Growth Gilts fed from 80 to 160 lb

	Carcass lean gain			Carcass lipid		
Digestible lysine, %	a	b	R^2	a	b	R^2
.54	.2064***[a]	2.314 (.086)***	.98	.0108***	1.742 (.178)***	.87
.64	.1804***	2.396 (.090)***	.98	.0229***	1.526 (.156)***	.87
.74	.1188***	2.660 (.130)***	.96	.0401***	1.364 (.129)***	.87
.84	.1320***	2.592 (.092)***	.98	.0630***	1.240 (.154)***	.79
.94	.1342***	2.589 (.101)***	.97	.0591***	1.263 (.138)***	.83
1.04	.1415***	2.545 (.123)***	.96	.00606**	1.240 (.140)***	.82

[a]Probability levels of deviations of coefficients from 1.00, *** P<.0001.

Table 3. Growth of Carcass CP and Lipid Components using the Relationship of $Y = aX^b$, where Y Is the Component and X Is the Live Weight (lb), for High-Lean Growth Gilts fed from 160 to 300 lb

	Carcass lean gain			Carcass lipid gain		
Digestible lysine, %	a	b	R^2	a	b	R^2
.54	.9702***[a]	1.580 (.128)***	.91	.0046***	1.876 (.178)***	.87
.64	.7080***	1.734 (.141)***	.90	.0022***	2.030 (.152)***	.91
.74	.7896***	1.679 (.103)***	.94	.0053***	1.843 (.198)***	.85
.84	.6222***	1.797 (.200)***	.85	.0134***	1.622 (.179)***	.84
.94	.5232***	1.885 (.110)***	.95	.0059***	1.836 (.179)***	.87

[a]Probability levels of deviations of coefficients from 1.00, *** P<.0001.

Figure 1. The Influence of Digestible Lysine (.54 to 1.04%) in High-Lean Growth Gilts Fed from 80 to 160 lb on End-Point ADG (Panel A), the Change in Live Weight Gain over Time (Panel B), End-Point Lean Gain (Panel C), the Change in Lean Gain over Time (Panel D), End-Point Carcass Lipid Accretion (Panel E), and the Change in Carcass Lipid Accretion over Time (Panel F)

Figure 2. **The Influence of Digestible Lysine (.54 to .94%) in High-Lean Growth Gilts Fed from 160 to 300 lb on End-Point ADG (Panel A), the Change in Live Weight Gain over Time (Panel B), End-Point Lean Gain (Panel C), the Change in Lean Gain over Time (Panel D), End-Point Carcass Lipid Accretion (Panel E), and the Change in Carcass Lipid Accretion over Time (Panel F)**

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CALCULATING FEED COSTS WITH ALTERNATIVE LYSINE DIETS FOR HIGH-LEAN GROWTH GILTS

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Summary

Data from two experiments were used to determine the feed cost per lb of lean gain for high-lean growth gilts fed various digestible lysine levels (.54 to 1.04%). The cost for producing 1 lb of lean increased as live weight increased from 75 to 160 lb (Exp 1) and from 160 to 300 lb (Exp 2). However, in Exp 1, the cost per lb of lean gain was minimized for gilts fed 1.04 and .94% digestible lysine (1.25 and 1.15% total lysine, respectively) from 75 to 90 lb and from 90 to 160 lb, respectively. These data are similar to the data for maximum rates of lean gain for grower gilts (75 to 160 lb), indicating that maximum gain is the most cost-effective gain during the grower period. During the finishing period (160 to 300 lb), maximal lean gain was attained for gilts fed .94% digestible lysine. However, cost of attaining this rate of lean gain was also the most expensive. The least feed cost per lb of lean gain was achieved when gilts were fed .84 and .54% digestible lysine (1.0 and .65% total lysine, respectively) from 160 to 180 lb and from 180 to 300 lb, respectively. In conclusion, these data indicate that feeding for maximum lean gain during the growing period (75 to 160 lb) results in least cost production. However, during the finishing period, economics will dictate the level of digestible lysine fed rather than maximum rate of lean gain.

(Key Words: Modeling, Requirements, Economics.)

Introduction

Many pork producers are already adopting phase-feeding programs that increase feed efficiency and improve profitability. Phase feeding refers to a series of diets that are the most profitable at different stages of growth. Key ingredients in feed efficiency are the levels of lysine and other essential amino acids present in the diet. Hogs with genetic capacity for increased lean growth have higher amino acid requirements than hogs with average genetic capacity for lean growth. Also, these requirements change as the pig matures. The percent protein in the diets declines as the pigs increase in weight, and lean efficiency decreases.

Successful implementation of phase-feeding programs is dependent upon the costs associated with them. When evaluating the optimal number of diets to use in a phase-feeding program, producers require information on feed costs, which account for over 60% of total production costs. The focus of this paper is the costs of feeding alternative lysine diets for high-lean growth gilts.

Procedures

Bioeconomic Model. The data from two experiments conducted at Kansas State University were used in this study and included 216 gilts (PIC Line 326 gilts). The objectives of the experiments were to determine dietary lysine requirements for optimal growth performance and measure carcass

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characteristics from 80 to 160 and 160 to 300 lb. Additional details of the experiment were presented in Friesen et al. (p. 134).

Both experiments were designed as a randomized complete blocks (three pigs/pen, six pens/treatment) with six dietary treatments varying from .54 to 1.04% digestible lysine (total dietary lysine ranged from .68 to 1.25% in increments of .1%) for the first experiment (initial weight was 76 lb). Digestible lysine ranged from .54 to .94% (.52 to 1.11% total lysine) for the second experiment (initial weight was 160 lb). Diets were formulated to assure that lysine was the first limiting amino acid. Dietary lysine was increased by adjusting the corn-soybean meal ratio. L-lysine-HCl addition was held constant at .05% of the complete diet.

Nonlinear live weight growth and protein (lean) accretion growths were developed according to previously published procedures. Live weight gain on a test was fit to a linear and quadratic function of days on test. Allometric equations ($Y=aX^b$) were used to develop coefficients for carcass lean where *Y* is carcass lean, *a* is an intercept term, *X* is live weight, and *b* is an exponential growth coefficient. These functions were used to establish the body component growth curves. Daily feed costs were determined using January 1994 average ingredient prices for each diet, which included corn, soybean meal, soy oil, lysine, methionine, monocal, limestone, salt, trace mineral, and vitamins. Once the cost of feeding the single diet over the entire weight range was determined (80 to 160 and 160 to 230 lb), diets were evaluated at 20-lb weight increments to determine recommendations for producers. The cost per lb of lean gain was determined by multiplying the lean efficiency (lb feed per lb lean gain) by the cost per lb of complete feed. The equation for fitting this feed cost per lb of lean gain is:

Cost per lb of lean gain = lean efficiency × cost per lb complete diet

Results

The cost, based on January 1994 prices of each diet, is reported in Table 1. As the amount of dietary lysine in the diet increased, a higher feed cost was incurred. Figure 1 presents the feed costs assuming a constant level of digestible lysine in each diet for 80 to 160 and 160 to 230 lb weight ranges. The lowest total feed costs were found using the .54% diet ($11.97), whereas the highest feed costs were found with the 1.04% diet ($18.18). The biggest increase in cost was between the .94% and 1.04% diet, with an associated cost increase of $4.18 per hog. Similar results were found for the 160 to 230 lb weight range. The .54% diet had the lowest feed costs ($17.44), whereas the .94% diet had the highest costs ($22.70).

Table 1. Feed Costs for Six Different Diets Based On Alternative Lysine Levels

Percent digestible lysine	Diet cost per lb
.54	.0664
.64	.0682
.74	.0704
.84	.0728
.94	.0752
1.04	.0776

Table 2 presents the ratios for average daily gain, average daily feed intake, feed efficiency, average daily lean gain, and lean efficiency for 80 to 160 lb and 160 to 230 lb for each diet. The .84% diet had the most improved lean efficiency (4.89) from 80 to 160 lb while the .74% had best lean efficiency from 160 to 230 lb (8.38). Lean efficiency was highest for the .64% diet for both weight ranges (6.09 and 9.19, respectively). The differences in lean efficiency were not significant from 160 to 230 lb. This suggests that producers should focus on promoting

profitable lean growth from 80 to 160 lb. From 80 to 160 lb, pigs fed a .94% diet grew the fastest (46 days), whereas pigs fed a .54% diet grew the slowest (55 days). However, from 160 to 230 lb, the number of days was approximately the same (38).

The costs per lb of lean gain associated with each diet in the grower period are given in Figure 1. From 80 to 110 or 120 lb, a 1.04% digestible lysine diet had the lowest cost per lb of lean gain. Then the .94% digestible lysine diet had lowest costs from 110 or 120 lb until 160. A similar analysis of the 160 to 230 lb weight range revealed that the .54% digestible lysine diet had the lowest costs per lb of lean gain. These digestible lysine levels also resulted in maximum lean gain for the respective weight periods. The cost per lb of lean gain increased as liveweight increased from 160 to 300 lb. However, the feed cost per lb of lean gain was minimized for gilts fed .84 and .54% digestible lysine from 160 to 180 lb and from 180 to 300 lb, respectively.

Discussion

These analyses indicate that feeding for maximal carcass lean gain from 75 to 180 lb also results in the most economical production for high-lean growth gilts. From 180 to 230 lb or greater, economics has to be the underlying consideration. The cost of production increases by $.08 to .32 per lb of lean gain when feeding for maximal lean gain instead of cost-effective lean gain from 180 to 300 lb. These economic analyses reflect the changes in the efficiency of lysine use for lean tissue accretion. This suggests the importance of phase feeding throughout the growing and early finishing periods for cost-effective lean gain.

Specific recommendations for the hogs in this study would be to feed three different dietary lysine diets at different weight ranges in order to achieve increased feed efficiency and a faster marketing time. For the 80 to 100 or 120 lb weight range, a 1.04% digestible lysine diet is recommended. From 100 or 120 lb to 160 lb, a .94% diet is suggested, whereas from 160 to 230 lb, the .84% diet is preferred. Using these recommendations results in a 9-day savings in marketing time to offset this increased feed cost.

Using different digestible lysine diets for these pigs makes sense, because they have the genetic capacity for increased growth. However, for your operation, feeding different diets may not be economically feasible because of facility constraints or your feeding system. These results are derived from pigs grown in a controlled experiment under ideal conditions. Consequently, growing hogs in commercial conditions might change the feed costs depending upon your management, feeding system, and crowding. Many different feed programs are available that can be customized for your grower or finishing unit and the pigs' genetics. Analyzing differences in feed costs with respect to alternative lysine levels is one way to improve the bottom line.

Table 2. The Influence of Dietary Lysine on Selected Growth Performance Variables

	Digestible lysine, %					
Variable and live weight range	.54	.64	.74	.84	.94	1.04
Average daily gain, lb						
80 to 160 lb	1.51	1.65	1.63	1.82	1.87	1.82
160 to 230 lb	1.93	1.95	1.97	2.03	2.05	
Average daily feed intake, lb						
80 to 160 lb	4.31	4.23	3.79	4.03	4.14	4.03
160 to 230 lb	6.24	6.45	6.43	6.67	6.49	
Feed efficiency, lb						
80 to 160 lb	2.88	2.56	2.32	2.20	2.16	2.23
160 to 230 lb	3.25	3.32	3.28	3.29	3.17	
Lysine intake, g/day						
80 to 160 lb	14.86	15.35	16.86	19.39	22.18	24.02
160 to 230 lb	18.97	23.13	26.55	31.18	33.87	
Average daily lean gain, lb						
80 to 160 lb	.73	.84	.94	1.02	1.01	.95
160 to 230 lb	.76	.70	.81	.75	.74	
Lean efficiency						
80 to 160 lb	7.16	6.61	5.26	4.89	5.44	5.47
160 to 230 lb	8.83	9.19	8.38	8.54	8.77	
Days to market						
80 to 160 lb	54.8	51.3	51.3	47.8	45.5	46.7
160 to 230 lb	37.3	37.3	38.5	37.3	37.3	

Figure 1. Feed Cost per Lb of Lean Gain for High-Lean Growth Gilts Fed .54 to 1.04% Digestible Lysine from 75 to 160 Lb

Figure 2. Feed Cost per Lb of Lean Gain for High-Lean Growth Gilts Fed .54 to .94% Digestible Lysine from 160 to 300 Lb

Swine Day 1994

INFLUENCE OF DIETARY METHIONINE ON BODY WEIGHT GAIN AND COMPOSITION IN HIGH-LEAN GROWTH GILTS FED FROM 100 TO 240 Lb[1]

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Summary

One hundred-fourteen high-lean growth gilts (initial wt of 100 lb) were used to determine the level of digestible methionine required to optimize growth performance and carcass characteristics from 100 to 240 lb. The experiment was designed as a randomized complete block with blocks based on initial BW. Three pigs per pen and six pens per treatment were used. Gilts were fed a corn and soybean meal-based diet containing .21, .24, .27, .30, .33, or .36% digestible methionine (.25 to .425% total methionine) in both the grower and finisher periods. The grower diet (fed from 100 to 165 lb) was formulated to contain 1.17% total lysine (.94% digestible) and .52% cystine, whereas the finisher diet contained 1.01% total lysine (.83% digestible) and .49% cystine. Cornstarch was replaced by DL-methionine to provide the experimental methionine concentrations. Average daily gain, ADFI, and feed efficiency (F/G) were not influenced by increasing digestible methionine from 100 to 165 lb, 165 to 240 lb, or 100 to 240 lb. Neither average backfat thickness nor longissimus muscle area was influenced by increasing digestible methionine at 240 lb. From 100 to 240 lb, carcass protein and lipid accretion were not influenced by digestible methionine. The data from this experiment suggest that the methionine requirement for high-lean growth gilts is not greater than .25% total methionine (.21% digestible methionine; 6 g/d total methionine intake) from 100 to 240 lb. Thus, the required methionine:lysine ratios do not exceed 22 and 25% for high-lean growth gilts fed diets containing adequate cystine from 100 to 165 and 165 to 240 lb, respectively.

(Key Words: Pigs, Methionine, Sulfur Amino Acids, Genotype, Carcass Composition.)

Introduction

Efforts to develop ideal dietary amino acid patterns for swine have resulted in inconsistencies amongst the proposed patterns. One of the largest differences is in the estimate of methionine plus cystine:lysine ratio. Previous research at Kansas State University (Swine Day 1993) suggested that the ratio of methionine plus cystine:lysine increased as live weight increased. These results are consistent with research from the University of Illinois. However, feeding diets formulated on an ideal amino acid ratio did not indicate improved growth performance compared to pigs fed a corn-soybean meal-based diet. When the first four limiting amino acids (lysine, tryptophan, threonine, and methionine) were added to the diet, growth performance was similar to that of the corn-soybean meal-fed pigs, whereas backfat thickness was increased and longissimus muscle area was decreased. Considering the greater dietary lysine requirement for high-lean growth pigs, the objective of this experiment was to determine the dietary methionine requirement for maximum growth

[1]We would like to acknowledge Rhone Poulenc Animal Nutrition, Atlanta, GA, for partial financial support for this project.

performance and carcass protein accretion rate in high-lean growth gilts.

Procedures

Animals. A growth assay was conducted using 114 high-lean growth gilts (Pig Improvement Co., L326, Franklin, KY; initial wt of 100 lb) fed one of six dietary methionine levels. The gilts (55 lb) were delivered to the Kansas State University Swine Teaching and Research Center and were fed a corn-soybean meal diet containing 1.15% total lysine (.97% digestible lysine) until they weighed 100 lb. Three pigs were housed per pen (4.6 m × 1.2 m pens) with solid flooring in an open-fronted building, with six replicate pens per treatment. The trial was conducted from August to November, 1993. When temperatures exceeded 80°F, drip coolers were activated to wet the pigs for 3 of every 15 min. Each pen contained a single-hole self-feeder and a nipple waterer to allow ad libitum access to feed and water. Pig weights and feed consumption were measured weekly to determine ADG, ADFI, and feed:gain ratio (F/G). Methionine, methionine + cystine, and lysine intakes were calculated based on analyzed dietary values.

Diet Formulation. Control diets fed from 100 to 165 lb (grower) and 165 to 240 lb (finisher) were formulated to contain 1.10 and 1.00% total lysine, respectively (.95 and .83% digestible lysine, respectively). These lysine levels were selected based on the results of Friesen et al. (Swine Day, 1993). DL-methionine replaced cornstarch to provide the five additional experimental treatments ranging from .21 to .36% digestible methionine (.25 to .425% total methionine; Table 1). Total cystine was .52 and .49% for the grower and finisher diets, respectively. Choline chloride was added at .05% (176 mg/lb added choline) to all diets. The essential amino acid concentrations were set using an ideal amino acid ratio in an attempt to make methionine the first limiting amino acid. The dietary ME was increased in all diets to 1,550 kcal/lb by the addition of soybean oil, so that the lysine:ME ratios equaled 3.4 and 2.9 g/Mcal for the grower and finisher diets, respectively. All other nutrients either met or exceeded NRC (1988) estimates for the 40- to 110-lb pig.

Carcass Characteristics. Carcasses were weighed immediately following slaughter and reweighed 24 h postmortem to record hot and chilled carcass weights, respectively. Dressing percentage was determined from live weight and hot carcass weight. The heart, liver, kidneys, and kidney fat were removed and weighed. Backfat thickness was measured at the first rib, last rib, and last lumbar vertebrae from both the right and left sides of the carcass. All six measurements were used to calculate the average backfat thickness. Tenth-rib fat depth was measured at 3/4 the length from the midline of the longissimus muscle. Longissimus muscle area at the 10th rib was traced, and the area calculated using a planimeter. Carcass color, firmness, and marbling were scored using a five-point scale developed by NPPC (1991). Muscling scores were based on a three-point NPPC (1991) scale.

Carcass Composition. Six gilts were selected randomly for slaughter at 100 lb, and the right side of each carcass was ground to determine initial empty body composition (percentage of moisture, CP, lipid, and ash). The ground carcass tissue was analyzed. When the mean weight of pigs in a pen reached approximately 240 lb, one pig from each pen (six pigs per treatment) was selected randomly and slaughtered for carcass analysis. The head, leaf fat, and viscera were removed at slaughter and were not included in determination of carcass tissue accretion rates. At 24 h postmortem, the right side of each carcass was ground once through a .40-mm plate and once through a .25-mm plate, then homogenized for 3 min in a ribbon-paddle mixer. From the chemical analysis, amounts of CP, lipid, ash, and DM were determined for each carcass based upon chilled carcass weight. Chemical components (DM, CP, lipid, and ash) from the initial six gilts were averaged and expressed as percentages of carcass weight. Tissue accretion rates were calculated as the difference between final (240 lb) and initial (100 lb) carcass content divided by the days on test.

Results

Growth Performance. Average daily gain, ADFI, and F/G were not influenced (P>.10) by dietary methionine throughout the entire experiment (Table 2). Increased digestible methionine resulted in greater (linear, P<.01) methionine and methionine + cysteine intakes from 100 to 165 lb, 165 to 240 lb, and 100 to 240 lb. From 100 to 240 lb, lysine intake tended to increase (quadratic, P<.08) as digestible methionine increased from .21 to .36%. However, dietary methionine did not influence (P>.10) lysine intake from 165 to 240 lb and from 100 to 240 lb.

Carcass Characteristics. High-lean growth gilts slaughtered at 240 lb had similar (P>.10) live weight at slaughter and hot and chilled carcass weights regardless of digestible methionine level (Table 3). However, dressing percentage tended to decrease and then increase (quadratic, P<.09) as digestible methionine increased. Average backfat thickness and 10th rib fat depth were not influenced (P>.10) by digestible methionine. Longissimus muscle area was not significantly influenced (P>.10) by dietary methionine. Carcass length and kidney fat content at different levels of digestible methionine were similar (P>.10). Carcass moisture, CP, and lipid contents were not influenced (P>.10) as digestible methionine increased. Carcass ash content decreased (quadratic, P<.10) as digestible methionine increased. Carcass muscle score and longissimus marbling and color scores were similar (P>.10) across digestible methionine levels. However, carcass firmness scores tended to decrease (linear, P<.09) as digestible methionine increased.

Tissue Accretion Rates. For the entire experiment from 100 to 240 lb, moisture accretion increased (quadratic, P<.08) as digestible methionine increased. Crude protein, lipid, and ash accretion rates were not influenced by digestible methionine (P>.10).

Discussion

The results of this experiment do not support the concept that high-lean growth gilts require greater dietary methionine to attain maximum carcass protein deposition. Research investigating the "ideal protein" concept has speculated that the requirement for methionine plus cystine relative to lysine increases with body weight. However, these two amino acids are used preferentially in higher proportions for body maintenance rather than lean tissue synthesis. Research evaluating amino acid requirements suggests that body maintenance does not account for a large portion of the total amino acid needed in growing-finishing pigs.

In this experiment, dietary cystine was fed in excess of the pigs' requirement. Thus, this excess may have masked the potential response to dietary methionine in high-lean growth gilts. Further research is necessary to determine the methionine requirement when cystine is neither deficient nor in excess.

These data demonstrate that the methionine requirement for high-lean growth gilts is not greater than .25% total methionine (.21% digestible methionine; 6.4 g/d total methionine) for maximum carcass protein gain from 100 to 240 lb. Thus, the methionine:lysine ratios do not exceed 22 and 25% for high-lean growth gilts fed diets containing adequate cystine from 100 to 165 lb and 165 to 240 lb, respectively. However, further research is necessary to establish the cystine and total sulfur amino acid requirements for maximum protein deposition in high-lean growth gilts.

Table 1. Basal Diet Composition (as Fed Basis)[a]

Item, %	100 to 165 lb	165 to 240 lb
Corn	76.03	76.57
Soybean meal (48% CP)	14.34	14.21
Porcine plasma, spray-dried	2.50	2.50
L-lysine-HCl	.40	.25
L-cystine	.15	.145
L-threonine	.20	.11
L-tryptophan	.05	.03
L-valine	.08	--
L-isoleucine	.06	--
Soybean oil	3.00	3.00
Monocalcium phosphate (21% P)	1.38	1.38
Limestone	.91	.91
Salt	.30	.30
Choline chloride (60%)	.05	.05
Cornstarch	.15	.15
Trace mineral premix[b]	.15	.15
Vitamin premix[c]	.25	.25
Total	100.00	100.00

[a]DL-methionine replaced cornstarch at .7 lb increments in the complete diet to give the following total methionine concentrations: .25, .285, .32, .355, .39, and .425%.

Table 2. The Effect of Dietary Methionine on Growth Performance of High-Lean Gilts[a]

	Digestible methionine, %						Probability (P<)		
Item	.21	.24	.27	.30	.33	.36	Linear	Quadratic	CV
ADG, lb									
100 to 165 lb	1.96	1.89	1.96	1.89	1.91	1.91	.80	.83	10.35
165 to 240 lb	1.87	1.94	2.05	1.80	1.85	1.87	.49	.55	9.08
100 to 240 lb	1.91	1.91	1.98	1.89	1.89	1.91	.80	.80	8.06
ADFI, lb									
100 to 165 lb	4.91	4.42	5.06	4.58	4.73	5.04	.45	.21	8.50
165 to 240 lb	6.56	6.49	6.58	6.47	6.73	6.51	.90	.94	10.53
100 to 240 lb	5.68	5.39	5.79	5.50	5.68	5.72	.58	.63	7.37
F/G									
100 to 165 lb	2.51	2.34	2.51	2.42	2.48	2.51	.43	.92	11.34
165 to 240 lb	3.51	3.35	3.35	3.59	3.52	3.41	.49	.90	12.84
100 to 240 lb	2.97	2.78	2.97	2.97	3.01	2.99	.45	.88	8.27
Methionine intake, g									
100 to 165 lb	5.6	5.7	7.4	7.4	8.4	9.7	.01	.12	7.96
165 to 240 lb	7.4	8.5	9.6	10.5	12.0	12.6	.01	.84	9.58
100 to 240 lb	6.4	7.0	8.4	8.9	10.1	11.1	.01	.58	6.76
Met + Cys intake, g									
100 to 165 lb	16.3	15.4	18.4	17.4	18.7	20.7	.01	.17	8.23
165 to 240 lb	19.9	20.0	21.7	21.5	23.1	23.9	.01	.64	7.54
100 to 240 lb	18.0	17.6	20.0	19.4	20.8	22.2	.01	.33	6.79
Lysine intake, g									
100 to 165 lb	25.0	23.2	26.4	23.9	24.7	26.4	.78	.08	8.72
165 to 240 lb	28.4	29.7	30.0	29.4	30.7	29.6	.79	.44	11.56
100 to 240 lb	26.4	26.2	28.1	26.5	27.6	27.8	.90	.92	8.28

[a]A total of 108 pigs, three pigs per pen from 100 to 165 lb and two pigs per pen from 165 to 240 lb; six replicate pens per treatment.

Table 3. The Effect of Dietary Methionine on Carcass Characteristics, Composition, and Quality in High-Lean Growth Gilts Slaughtered at 240 lb[a]

	Digestible methionine, %						Probabilities (P<)		
Item	.21	.24	.27	.30	.33	.36	Linear	Quadratic	CV
Live wt, lb	240.2	242.8	244.0	244.4	245.4	245.2	.39	.65	3.2
Hot carcass wt, lb	177.5	176.0	179.1	180.4	176.9	181.8	.29	.82	3.8
Cold carcass wt, lb	174.5	172.5	175.8	176.9	173.4	178.6	.30	.72	3.7
Dressing percentage	73.9	72.5	73.4	73.8	72.1	74.2	.65	.09	2.9
Average backfat thickness, in	1.0	1.0	1.0	.9	.9	1.0	.97	.28	11.0
Tenth rib fat depth, in	1.0	1.0	1.1	.9	1.0	1.0	.70	.81	17.2
Longissimus muscle area, in^2	5.6	5.7	5.9	6.3	5.8	5.9	.36	.19	9.7
Carcass length, in	31.9	31.7	31.3	31.9	31.8	31.7	.88	.49	2.3
Kidney fat, lb	2.3	1.9	3.0	2.5	2.2	2.4	.77	.26	29.4
Carcass Composition, %									
Moisture	60.2	63.1	60.4	65.8	65.1	61.7	.19	.11	5.3
CP (N × 6.25)	17.9	17.3	17.3	17.0	17.0	17.1	.11	.34	5.7
Lipid	18.0	15.9	19.1	14.1	14.5	17.8	.48	.30	23.9
Ash	3.6	3.5	3.2	3.2	3.2	3.7	.81	.10	14.0
Quality									
Muscle score[b]	2.6	2.6	2.4	2.5	2.4	2.5	.48	.63	15.2
Marbling[c]	2.0	2.2	2.1	2.5	1.9	2.3	.65	.77	33.0
Color[c]	2.3	2.7	2.6	2.5	2.3	2.4	.65	.43	22.1
Firmness[c]	2.8	3.0	2.6	2.7	2.4	2.5	.09	.92	20.9
Tissue accretion, g/d									
Moisture	376	414	393	422	441	391	.24	.08	9
CP	120	114	117	104	110	111	.20	.37	12
Lipid	157	138	145	105	118	157	.59	.16	39
Ash	24	23	21	19	19	24	.66	.12	25

[a]Calculated from 36 pigs at a pen mean weight of 240 lb, one pig/pen, six pigs/treatment.
[b]Carcasses were evaluated on a three-point scale ranging from thin muscling (1) to extremely thick muscling (3).
[c]Loins were evaluated on a five-point scale according to NPPC (1991) procedures.

THE EFFECTS OF SUPPLEMENTAL DIETARY CARNITINE, BETAINE, AND CHROMIUM NICOTINATE ON GROWTH AND CARCASS CHARACTERISTICS IN GROWING-FINISHING SWINE[1]

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Summary

Sixty-four pigs (initially 75 lb) were used to determine the effects of dietary betaine, carnitine, and chromium nicotinate on growth performance and carcass composition. Pigs were blocked by sex, ancestry, and weight and allotted in a randomized complete block design to each of four dietary treatments. These treatments were a corn-soybean meal-based control diet and control diet plus 50 ppm carnitine, 1,000 ppm betaine, or 200 ppb chromium from chromium nicotinate. Grower diets (75 to 125 lb) were formulated to contain 1.0% lysine and finisher diets (125 to 225 lb) were formulated to contain .8% lysine. All diets were corn-soybean meal-based, were fed in meal form, and contained .15% L-lysine HCl and 2.5% soy oil. When mean weight of pigs in a pen reached 225 lb, one pig per pen was selected at random and slaughtered to obtain carcass measurements. During the grower phase, pigs fed carnitine had greater ADG and feed efficiency (F/G) than pigs fed the control diet. However, during the finishing phase and overall, no differences were observed for ADG, F/G, or ADFI. Pigs fed carnitine had larger longissimus muscle area and greater percentage muscle than pigs fed the control or betaine diets. Also, pigs fed carnitine had lower tenth rib backfat thickness compared to those fed the control diet. Average backfat thickness was lower in the pigs fed carnitine or chromium nicotinate than in pigs fed the control diet. These results indicate that additions of dietary carnitine and chromium nicotinate are viable means of increasing carcass leanness in growing-finishing pigs. Further study of the metabolism of carnitine, chromium nicotinate, and betaine is needed to examine possible modes of action in the growing-finishing pig.

(Key Words: Betaine, Carnitine, Chromium Nicotinate, Pigs, G/F.)

Introduction

The increased emphasis by consumers for lean, wholesome pork has led packers to demand leaner pigs from pork producers. To meet this demand, producers are using both genetics and nutrition to produce lean pork. One way to produce leaner market pigs is by supplementing the diets of growing-finishing swine with carcass modifiers.

Researchers have examined several compounds to determine their potential as carcass modifiers. Specifically, several research institutions have examined the effectiveness of using carnitine, chromium, and betaine to increase the leanness of finishing pigs.

Recent work at Kansas State University showed that feeding carnitine at 25 ppm increased longissimus muscle area but had no

[1]We would like to thank Lonza, Inc., Fair Lawn, NJ, for partial financial support and for providing the carnitine and Vita Plus, Corp., Madison, WI, for providing the betaine used in this trial.

[2]Vita Plus, Corp., Madison, WI.

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

effect upon growth of growing-finishing swine. Work at the University of the Wageningen in the Netherlands revealed that feeding carnitine at 40 ppm to growing-finishing swine increased average daily gain 10% and resulted in a 9% better efficiency. Also, these same pigs had 14% less backfat and 4% greater percentage muscle.

Three experiments at Louisiana State University with chromium picolinate showed positive results. In these experiments, researchers found that feeding 200 ppb chromium from chromium picolinate increased longissimus muscle area by 7 to 22% and decreased tenth rib backfat depth by 14 to 22%. However, chromium supplementation did not affect the growth performance of the pigs.

Research from Australia evaluated the efficacy of supplementing growing-finishing diets with betaine. In this experiment, the researchers found that adding 1 lb of betaine per ton of feed decreased backfat thickness by 11% in gilts and 7% in boars. However, no significant differences in growth or feed utilization were found.

Therefore, our objective was to test the effect that adding carnitine, chromium, and betaine to diets had on the growth and carcass characteristics of growing-finishing swine.

Procedures

The study used 64 pigs (32 barrows and 32 gilts) with initial weight of 75 lb. The pigs were blocked by sex, ancestry, and weight and allotted in a randomized complete block design to one of four dietary treatments. The four dietary treatments were a corn-soybean meal-based control diet and control diet plus 50 ppm carnitine, 1,000 ppm betaine, or 200 ppb chromium from chromium nicotinate. There were eight replicate pens per treatment (four replicates per sex), and the treatments were assigned randomly within each block.

Diets were formulated to 1.0 and .8% dietary lysine for the growing (75 to 125 lb) and finishing (125 to 225 lb) phases, respectively. The meal diets (Table 1.) were corn-soybean meal-based with .15% synthetic lysine and 2.5% soy oil.

The pigs were housed with two pigs per pens in an environmentally controlled finisher barn with totally slatted floors. Pigs and feeders were weighed every 14 d to calculate ADG, ADFI, and F/G. When the mean weight of pigs in a pen reached 225 lb, one pig per pen was selected at random and slaughtered. After a 24-hour chill period, standard carcass measurements were recorded.

Results and Discussion

During the growing period (75 to 125 lb; Table 2), pigs fed carnitine grew faster and more efficiently ($P<.05$) than pigs fed the control diet. Pigs fed the betaine and chromium diets had intermediate values for ADG and F/G. No differences occurred between treatments for ADFI. Also, no differences were detected between the diets for ADG, ADFI, or F/G in the finishing portion of this trial (125 to 225 lb) or for the entire experiment.

When pigs were slaughtered at 225 lb, differences in carcass traits were found between pigs fed the different carcass modifiers (Table 3). Pigs fed carnitine and chromium had lower last rib, last lumbar fat, and average backfat (average of midline first rib, last rib, and last lumbar fat depths) depths ($P<.05$) as compared with pigs fed the control diet. Pigs fed the carnitine diet also had lower tenth rib backfat thicknesses than pigs fed the control and betaine ($P<.05$) diets.

Pigs fed the carnitine diet had larger logissimus muscle area than pigs fed either the control or betaine diets ($P<.05$). Furthermore, the pigs fed the carnitine diet had higher values for percentage muscling and percentage lean than pigs fed the control and betaine diets ($P<.05$).

In conclusion, carnitine, betaine, and chromium from chromium nicotinate did not affect the overall growth performance in this

trial. However, carnitine decreased average backfat depth and increased longissimus muscle area, percent lean, and percent muscle. Chromium resulted in numerically higher percentage lean and percentage muscle. These results indicate that both carnitine and chromium are viable carcass modifiers for the growing-finishing pig. However, further study of the metabolism of carnitine, betaine, and chromium, is needed to further examine possible modes of action in the finishing pig.

Table 1. Basal Diet Composition[a]

Item, %	Growing (75 to 125 lb)	Finishing (125 to 225 lb)
Corn	71.43	78.81
Soybean meal, (48% CP)	22.54	15.53
Soy Oil	2.50	2.50
Monocalcium phosphate, (21% P)	1.46	1.09
Limestone	.91	.91
Salt	.35	.35
Vitamin premix	.20	.20
Trace mineral premix	.15	.15
L-lysine HCl	.15	.15
Antibiotic[b]	.20	.20
Cornstarch[c]	.11	.11
Total	100.00	100.00

[a]Growing (75 to 125 lb) diets were formulated to 1.0% lysine, .75% Ca, and .65% P. Finishing (125 to 225) diets were formulated to .8% lysine, .65% Ca, and .55% P.
[b]Provided 40 g/ton tylosin.
[c]Carnitine (.005%), betaine (.1%), and chromium nicotinate (1.3 g/ton) replaced cornstarch to provide the experimental diets.

Table 2. The Effect of Carnitine, Betaine, and Chromium on Growth of Growing-Finishing Swine[a]

Item	Control	Carnitine	Betaine	Chromium	CV
Growing					
ADG, lb	1.90[b]	2.09[c]	2.01[bc]	2.03[bc]	8.1
ADFI, lb	4.79	4.92	4.87	4.99	7.2
F/G	2.54[b]	2.36[c]	2.42[bc]	2.46[bc]	6.2
Finishing					
ADG, lb	2.10	2.07	2.17	2.09	7.7
ADFI, lb	6.97	6.71	6.92	6.87	6.0
F/G	3.32	3.25	3.19	3.28	5.8
Overall					
ADG, lb	2.03	2.07	2.12	2.07	6.7
ADFI, lb	6.23	6.11	6.24	6.25	5.4
F/G	3.07	2.95	2.95	3.02	5.2

[a]A total of 64 pigs, two pigs/pen, eight replicate pens/treatment, and four replicate pens/sex.
[bc]Means in row with different superscripts differ (P<.05).

Table 3. The Effects of Carnitine, Betaine, and Chromium on Carcass Characteristics[a]

Item	Control	Carnitine	Betaine	Chromium	CV
Fat depth, in					
Tenth rib	1.19[b]	.99[c]	1.15[bc]	1.06[bc]	14.9
Last rib	1.10[b]	.95[c]	1.02[bc]	1.00[c]	8.8
Last lumbar	1.06[b]	.91[c]	.99[bc]	.94[c]	10.2
Average[d]	1.25[b]	1.14[c]	1.21[bc]	1.14[c]	7.3
Loin muscle area, in^2	4.87[b]	5.42[c]	4.79[b]	5.03[bc]	9.7
Lean, %[e]	46.05[b]	49.49[c]	46.30[b]	47.94[bc]	5.5
Muscle, %[f]	51.56[b]	53.94[c]	51.81[b]	52.96[bc]	3.5

[a]Thirty two pigs, eight pigs/treatment; four pigs/sex were slaughtered at 225 lb to collect carcass measurements.
[bc]Means with different superscripts differ (P<.05).
[d]Average backfat was calculated as the average of first rib, last rib, and last lumbar fat depths.
[e]Lean, % was calculated from NPPC equation for percent lean with 5% fat.
[f]Musc, % was calculated from NPPC equation for percent muscle with 10% fat.

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THE EFFECTS OF SUPPLEMENTING GROWING-FINISHING SWINE DIETS WITH BETAINE AND (OR) CHOLINE ON GROWTH AND CARCASS CHARACTERISTICS[1]

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Summary

Eighty crossbred gilts (initially 134 lb) were used in a growth assay to evaluate the effects of supplementing finishing pig diets with betaine and (or) choline on growth performance and carcass characteristics. Betaine at 0 or 1000 ppm and choline at 0 or 100 ppm were used in a 2 × 2 factorial arrangement in eight randomized complete blocks. A fifth treatment, 1000 ppm betaine from a liquid, 16 carbon betaine (Lonzaine - 16, distributed by Lonza, Inc., Fair Lawn, NJ), was added to further evaluate the efficacy of another form of betaine. Pigs were blocked by weight and ancestry and allotted to one of the five dietary treatments. The corn-soybean meal based experimental diets were formulated to .75% lysine, .65% Ca, and .55% P. Pigs fed the diet supplemented with betaine had higher ADG than pigs fed the control diet. The pigs fed the diet with added choline had poorer feed efficiencies and lower growth rates than pigs fed the other diets. When pigs were slaughtered at 230 lb, the pigs fed the diet with added betaine tended to have larger loin muscle areas (LMA) than the pigs fed the control diet. In conclusion, further research into the mechanisms of betaine use is needed because of the different responses that betaine has elicited in various research trials. The cost of betaine must be low enough to reap the benefits of supplementing betaine in finishing swine diets.

(Key Words: Betaine, Choline, Pigs, Finishing.)

Introduction

Recently, researchers in Australia showed that feeding betaine to gilts from 132 to 230 lb decreased backfat depth ($P<.01$). In this study, feeding betaine did not affect growth rate, feed efficiency, or dressing percent. In another study, the Australian researchers fed four levels of betaine, 0, 2, 6, or 12 lb/ton, to boars and gilts from 120 to 200 lb. As in the previous study, feeding betaine at any level did not affect growth rate, feed efficiency, or dressing percent. However, adding betaine to the gilt diet resulted in a linear decrease in backfat thickness. Boars had decreased backfat thickness when fed betaine at 2 lb/ton. Feeding betaine at 2 lb/ton resulted in 11% and 7% decreases in backfat thickness for gilts and boars, respectively. Researchers in Finland tested the efficacy of replacing choline with betaine in livestock feeds. Their research indicated that livestock feeds required 2.31 times less betaine than choline. With these results in mind, our objective was to examine the effects of supplementing finishing pig diets with betaine and (or) choline on growth performance and carcass characteristics.

Procedures

Eighty crossbred gilts (initially 134 lb) were used in a growth assay. Betaine at 0 or

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

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

1000 ppm and choline at 0 or 100 ppm were used in a 2 × 2 factorial arrangement in eight randomized complete blocks. A fifth treatment, 1000 ppm betaine from a liquid, 16 carbon betaine (Lonzaine - 16, distributed by Lonza, Inc., Fair Lawn, NJ), was added to further evaluate the efficacy of another form of betaine. Pigs were blocked by weight and ancestry and allotted to one of the five dietary treatments. The corn-soybean meal-based experimental diets were formulated to .75% lysine, .65% Ca, and .55% P and contained .1% L-Lysine HCl.

Table 1. Basal Diet Composition[a]

Item	%
Corn	82.40
Soybean meal, 46.5%	14.92
Dicalcium phosphate	1.24
Limestone	.74
Salt	.35
Cornstarch[b]	.12
Trace mineral premix	.10
Vitamin premix	.08
Antibiotic[c]	.05
Total	100.00

[a]Diets were formulated to .75% lysine, .65% Ca, and .55% P.
[b]Betaine (.10%) and choline chloride (.02%) replaced cornstarch to form three experimental diets. Betaine - C16 (1.0%) replaced corn to form the other experimental diet.
[c]Provided 40 g/ton tylosin.

The pigs were housed at two pigs 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, average daily feed intake (ADFI), and F/G. When mean block weight reached 230 lb, all pigs within the block were slaughtered in a commercial slaughtering facility to collect standard carcass measurements.

The data from this trial were analyzed with the GLM procedure of SAS. The statistical model included the main and interactive effects of betaine and choline. Also, pigs fed the diet with the long-chain betaine product were compared to the pigs fed the control diet in a single degree of freedom contrast. One pen of pigs fed the control diet was removed from the trial because of health problems. Statistical analyses reflect this removal.

Results and Discussion

Adding betaine to the diet had a tendency to improve ($P<.07$) ADG compared to pigs fed the control diet. At the same time, a negative trend in ADG was detected ($P<.08$) when choline was added to the diet. The pigs fed the diets with supplemental choline had growth rates equal to or lower than those of the pigs fed the control diet. The pigs fed the diets with added choline had poorer feed utilization ($P<.04$) than the pigs fed the control diet.

When pigs were slaughtered at 230 lb, a trend for a betaine effect ($P<.08$) was detected for loin muscle area (LMA). No treatment differences were detected for any of the backfat measurements or percent lean or muscle.

When the pigs fed the long-chain betaine were compared the pigs fed the control diet, no differences were detected for any of the growth or carcass characteristics measured.

In conclusion, our research shows no benefit in carcass parameters from adding betaine, but the impact on growth must be further analyzed to determine the cost effectiveness of betaine. Further research is needed to explain the different responses in this trial compared to the research in Australia. Those studies never found an ADG response, and we have never found a backfat response in any of our research with betaine. The negative influence of choline on ADG and feed efficiency was surprising, since

previous research has shown no detrimental effects to supplemental choline. Because betaine and choline both act as methyl donors, further research into the level of sulfur-containing amino acids and possible interactions with betaine and choline levels in the diet is needed.

Table 2. The Effects of Betaine and (or) Choline on Finishing Pig Growth Performance[a]

Item	Control	Betaine	Choline	Bet + Chol	Betaine - C16	CV
ADG, lb[bc]	1.74	1.84	1.71	1.74	1.76	5.6
ADFI, lb	5.12	5.30	5.39	5.23	5.27	8.1
F/G[d]	2.94	2.87	3.15	3.00	2.98	7.3

[a]Means derived from 78 pigs housed at two per pen with seven or eight replicate pens per treatment.
[b]Betaine effect (P<.07).
[cd]Choline effect (P<.08, and .04, respectively).

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

Item	Control	Betaine	Choline	Bet + Chol	Betaine - C16	CV
Backfat						
Tenth rib, in	1.17	1.23	1.20	1.11	1.14	16.6
Last rib, in	1.13	1.11	1.10	1.07	1.15	14.4
Last lumbar, in	1.01	.96	.99	.91	.98	17.2
Average, in[c]	1.24	1.23	1.26	1.19	1.25	10.3
LMA, in^2[b]	4.36	4.80	4.39	4.50	4.75	13.4
Lean, %	45.02	45.40	44.81	45.90	46.18	6.7
Muscle, %	51.08	51.10	50.88	51.69	51.75	4.1

[a]Means derived from 78 pigs slaughtered at 230 lb with 15 or 16 pigs per treatment.
[b]Betaine effect (P<.08)
[c]AVGBF calculated as the average of first rib, last rib, and last lumbar fat depths.
[c]Lean percent was derived from NPPC equations for carcasses with 5% fat.
[d]Muscle percent was derived from NPPC equations for carcasses with 10% fat.

Swine Day 1994

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

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Summary

Ninety-six crossbred pigs (initially 75 lb BW) were used to investigate the effect of increasing dietary carnitine on growth performance and carcass characteristics in growing-finishing swine. Pigs (48 barrows and 48 gilts) were blocked by weight, ancestry, and sex in a randomized complete block design (two pigs per pen and eight pens per treatment). Dietary carnitine replaced cornstarch in the control diet to achieve added dietary carnitine levels of 25, 50, 75, 100, and 125 ppm. Grower (75 to 125 lb) and finisher (125 to 227 lb) diets were formulated to contain 1.0% lysine and .80%, respectively. All diets were corn-soybean meal-based, contained .15% L-lysine HCl and 2.5% soy oil, and were fed in meal form. When the mean weight for pigs in a pen reached 227 lb, one pig per pen was slaughtered to determine carcass characteristics. Dietary carnitine did not influence growth performance during the growing or finishing phases. However, for the overall trial, the mean of all pigs fed dietary carnitine had numerically improved average daily gain (ADG) and feed efficiency (F/G) when compared with pigs fed the control diet. Dietary carnitine reduced average backfat thickness and tenth rib backfat depth and increased longissimus muscle area, with 50 ppm providing the maximum response. These data suggest that 50 ppm L-carnitine fed during the growing- finishing phase had no effect on growth performance but resulted in increased muscle deposition and reduced fat accretion as measured by longissimus muscle area and average and tenth rib backfat depth.

(Key Words: Growing-Finishing, L-Carnitine, Performance.)

Introduction

Recent research at the University of Georgia has shown that supplementing finishing diets with L-carnitine results in a small reduction in backfat thickness. A similar response was observed at the Coastal Plains Research Center; however, these results were based on ultrasonic readings with no actual carcass measurements recorded. Recent research at KSU has shown that feeding L-carnitine during the growing-finishing phases resulted in a 16% improvement in longissimus muscle area, with small reductions in backfat thickness and daily lipid accretion rates. More recently, research conducted at the University of Wagenhagen (Netherlands) reports that pigs fed 40 ppm of L-carnitine had 10% higher ADG, 9% better F/G, 14% less average backfat thickness, and 4% more muscle. However, limited research has been conducted addressing the appropriate level of L-carnitine needed during the growing and finishing phases. Therefore, this research was conducted to determine the dietary carnitine level needed to elicit optimum response of growth performance and carcass composition characteristics in growing-finishing swine.

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[1]We would like to acknowledge Lonza, Inc., Fair Lawn, NJ, for partial financial support and for providing the L-carnitine used in this experiment.

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

Procedures

Ninety-six crossbred pigs (initially 75 lb BW) were used. Pigs (48 barrows and 48 gilts) were blocked by weight, ancestry, and sex in a randomized complete block design (two pigs per pen and eight pens per treatment). Two pigs were housed per pen (4 ft × 4 ft) in an environmentally controlled finishing barn with total slatted flooring. There were eight replicate pens per treatment (four replicate pens per sex). Each pen contained a single-hole self-feeder and a nipple waterer to provide ad libitum access to feed and water. Pig weights and feed disappearance were recorded every 14 d to determine ADG, ADFI, and F/G.

Basal diets were formulated for the grower and finisher phase (Table 1). Dietary carnitine replaced cornstarch in the basal diets to achieve added dietary carnitine levels of 25, 50, 75, 100, and 125 ppm. Grower diets (75 to 125 lb) were formulated to contain 1.0% lysine and finisher diets (125 to 227 lb) were formulated to .80% lysine. All diets were corn-soybean meal-based, contained .15% L-lysine HCl and 2.5% soy oil, and were fed in meal form. All other nutrients either met or exceeded NRC (1988) estimates for the 110 to 240 lb pig.

When the mean weight for pigs in a pen reached 227 lb, one pig per pen was slaughtered, and standard carcass measurements were recorded. Also, 25-gram samples of muscle, heart, and liver tissues were taken to analyze for tissue carnitine levels.

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

Results and Discussion

Dietary carnitine did not linearly or quadratically influence growth performance during the growing or finishing phases (P>.10) (Table 2). However, pigs fed 50 ppm of L-carnitine, had 10% (P = .04) higher ADG, and were 7% (P = .05) more efficient than pigs fed the control diet during the grower phase. This shows that carnitine might be influencing fatty acid metabolism by providing more energy to the pig, allowing for more rapid and efficient growth. For the overall trial, the mean of all pigs fed dietary carnitine was numerically higher for ADG (P = .16) and F/G (P = .12) when compared to pigs fed the control diet.

Dietary carnitine reduced average backfat and tenth rib backfat depth (quadratic, P<.05) and increased longissimus muscle area (quadratic, P = .13) (Table 3). Dietary carnitine improved (quadratic, P<.05) percentage lean and muscle, with 50 ppm L-carnitine providing the optimum response. A sex effect occurred for tenth rib backfat depth (P<.01), longissimus muscle area (P<.01), percentage muscle (P<.01) and lean (P<.01) with gilts being leaner and having larger longissimus muscle areas. These data support earlier research at Kansas State University suggesting that dietary L-carnitine causes an increase in loin muscle area and a slight decrease in backfat parameters. Currently, plans are under way to address possible modes of action dealing with L-carnitine.

No effects on liver or kidney weights occurred at time of slaughter. However, heart and kidney fat weights were reduced (quadratic, P = .08 and P<.01, respectively) with increasing levels of dietary L-carnitine (Table 3). Tissue samples taken from the heart, liver, and muscle showed that the level of carnitine present in each tissue was increased (linear, P<.01) as the level of L-carnitine increased in the diet. This allows us to conclude that the biological activity of dietary carnitine was increased in each tissue. Thus, results noted in this trial were due to L-carnitine supplementation.

These data suggest that dietary carnitine fed during the growing-finishing phase had no effect on growth performance, but resulted in increased loin muscle area and decreased average backfat and tenth rib

backfat thickness. Fifty ppm of added L-carnitine appears to have the greatest effect on carcass traits in growing and finishing pigs.

Table 1. Composition of Growing and Finishing Basal Diets[a]

Item, %	Growing (75 to 125 lb)	Finishing (125 to 230 lb)
Corn	71.43	78.96
Soybean meal, (48% CP)	22.54	15.53
Soy oil	2.50	2.50
Monocalcium phosphate, (21% P)	1.46	1.09
Limestone	.91	.91
Salt	.35	.35
Vitamin premix	.20	.20
Trace mineral premix	.15	.15
L-lysine HCl	.15	.15
Antibiotic[b]	.20	.05
Cornstarch[c]	.11	.11
Total	100.00	100.00

[a]Growing and finishing diets were formulated to contain 1.0% and .80% lysine, respectively.
[b]Provided 40 g per ton tylosin
[c]L-carnitine replaced cornstarch in the basal diet to achieve dietary carnitine levels of 0, 25, 50, 75, 100, and 125 ppm.

Table 2. Growth Performance of Pigs Fed Increasing Dietary L-Carnitine[a]

	Dietary L-carnitine, ppm						
Phase	0	25	50	75	100	125	CV
Growing							
ADG,lb[b]	1.90	2.02	2.09	2.01	2.05	2.05	9.0
ADFI,lb	4.80	5.16	4.92	4.96	5.02	5.01	5.4
F/G[b]	2.54	2.57	2.36	2.47	2.46	2.45	7.2
Finishing							
ADG,lb	2.10	2.13	2.07	2.13	2.20	2.09	6.5
ADFI,lb	6.97	6.97	6.71	6.85	7.01	6.77	5.6
F/G	3.32	3.26	3.25	3.21	3.18	3.25	5.4
Overall							
ADG,lb	2.03	2.10	2.07	2.09	2.15	2.07	6.0
ADFI,lb	6.23	6.37	6.11	6.21	6.33	6.18	4.5
F/G	3.07	3.04	2.95	2.97	2.94	2.98	5.0

[a]A total of 96 pigs (48 barrows and 48 gilts), two pigs per pen, eight replicate pens per treatment. Average initial and final weights were 74.8 and 228 lb, respectively.
[b]Pigs fed 50 ppm L-carnitine vs control ($P<.05$).

Table 3. Carcass Characteristics of Pigs Fed Increasing Dietary Carnitine[a]

	Dietary L-carnitine, ppm						
Item	0	25	50	75	100	125	CV
Average BF, in[b]	1.25	1.26	1.14	1.19	1.22	1.28	11.5
10th rib BF, in[c]	1.19	1.22	.99	1.10	1.17	1.23	15.7
Loin muscle, in[d]	4.86	4.55	5.47	4.87	4.80	4.89	9.3
Lean, %[c]	46.04	44.86	49.54	46.91	45.91	45.61	6.1
Muscle, %[c]	51.56	50.83	53.95	52.26	51.51	51.20	3.9
Liver wt, g	1,423	1,349	1,409	1,491	1,400	1,384	10.7
Heart wt, g[b]	356	348	377	373	343	344	9.0
Kidney wt, g	356	360	347	350	355	329	15.8
Kidney fat, g[e]	1,368	1,215	1,120	1,181	1,345	1,440	19.0

[a]A total of 48 pigs (24 barrows and 24 gilts), one pig per pen and 8 pigs per treatment.
[bcde]Quadratic effect of dietary L-carnitine (P = .10, P<.05, P = .13, P<.01, respectively).

Table 4. Total L-Carnitine in Muscle, Liver, and Heart Tissue[a]

	Dietary L-carnitine, ppm						
Item	0	25	50	75	100	125	CV
Whole tissue							
Muscle, nmole per g[b]	1,019	1,294	1,437	1,752	1,836	2,254	13.3
Liver, nmole per g[b]	101	127	119	154	163	195	33.5
Heart, nmole per g[b]	758	934	940	1,216	1,152	1,324	22.1
Non-collagen protein							
Muscle, nmole per mg[b]	2.58	3.75	4.14	4.8	5.16	6.04	15.7
Liver, nmole per mg[b]	.288	.375	.40	.50	.463	.625	36.4
Heart, nmole per mg[b]	2.36	3.17	3.32	3.92	4.14	5.33	32.1

[a]Total carnitine was analyzed on a tissue extract that was subjected to heat and alkaline pH in order to hydrolyze carnitine from acyl carnitine. Results include both per gram wet weight of tissue and per milligram noncollagen protein. A total of 48 pigs (24 barrows and 24 gilts), one pig per pen and 8 pigs per treatment.
[b]Linear effect of dietary L-carnitine (P<.01).

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EFFECT OF CHELATED MANGANESE ON GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF FINISHING PIGS[1]

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Summary

A total of 80 medium-lean growth cross-bred barrows (initially 77 lb) was used in a study to evaluate the effect of manganese level (24, 44, or 88 ppm) and source (inorganic vs chelated manganese) on growth performance and carcass characteristics of finishing pigs. Barrows were allotted by weight to pens containing two pigs per pen in a randomized complete block design. Pigs were assigned to one of four dietary treatments with 10 replications per treatment. Pigs were housed in pens (5 ft x 5 ft) in an environmentally regulated finishing barn and allowed ad libitum access to feed and water. Pigs were fed a corn-soybean meal-based diet formulated to contain .8% lysine and providing 24 ppm of inorganic Mn supplied from manganese oxide (control). Additional treatments included the control diet plus 20 ppm of a chelated form of Mn (a total of 44 ppm dietary Mn); control diet plus 20 ppm of inorganic Mn (manganese oxide; a total of 44 ppm dietary Mn); and the control diet plus 64 ppm of inorganic Mn (manganese oxide; a total of 88 ppm dietary Mn). Pigs were fed their respective experimental diet for the entire study. Pigs and feeders were weighed every 2 weeks to measure Average daily gain (ADG), average daily feed intake (ADFI), and feed conversion (F/G) until the mean weight of pigs in a pen averaged 225 lb. At this time, both pigs in the pens were slaughtered, and standard carcass measurements were recorded. For the overall trial, no differences occurred in growth performance among pigs fed any of the experimental treatments. Pigs had mean ADG, ADFI, and F/G of 2.10 lb, 6.88lb, and 3.24, respectively. No differences occurred in carcass traits, with all pigs having approximately 1.20 inches of backfat and between 4.50 and 5.0 square inches of longissimus muscle area. In conclusion, additional manganese above 24 ppm from an inorganic or chelated source had no effect on growth performance or carcass characteristics of medium-lean growth finishing pigs.

(Key Words: G/F, Pig, Manganese, Performance.)

Introduction

Research from Louisiana State University has found improvements in longissimus muscle area when the trace mineral, chromium picolinolate, was added to finishing pig diets. Chromium picolinate seems to have insulin-like properties that assist the pig's ability to deposit lean tissue. This is speculated to be the predominant mechanism for the increase in longissimus muscle area. Chelated manganese is similar in chemical structure to chromium picolinate. Therefore, the objective of this experiment was to evaluate effects of increasing dietary manganese from either a chelated manganese product or an inorganic form of manganese (manganese oxide) on growth performance and carcass characteristics of finishing pigs.

[1]The authors wish to thank Albion Laboratories, Inc. Atlantic, IA, for partial financial support and donating the chelated manganese used in this study.

Procedures

Eighty crossbred barrows (initially 77 lb) were allotted by weight to each of four experimental treatments. There were 2 pigs per pen and 10 pens per treatment. Pigs were housed in an environmentally regulated finishing barn and had ad libitum access to feed and water. Pigs were fed a corn-soybean meal-based diet that was supplemented with additional manganese from either inorganic manganese or from chelated manganese (Table 1). Diets were formulated to contain .8% lysine and were fed for the entire experimental period. The four experimental diets included a control diet containing 24 ppm of manganese from manganese oxide; control plus 20 ppm of chelated manganese (44 ppm dietary manganese); control plus 20 ppm of manganese from inorganic manganese oxide (44 ppm total dietary manganese); and the control diet plus 64 ppm manganese from manganese oxide (88 ppm total dietary manganese). Supplemental manganese was added to the diets in a corn-based premix (Table 1) with or without added soy protein isolate to ensure similar crude protein content of all diets. Pigs and feeders were weighed every 2 weeks to record ADG, ADFI, and F/G until the mean weight of pigs in a pen was 225 pounds. Then pigs were slaughtered, and standard carcass characteristics were recorded.

Table 1. Diet Composition[ab]

Item	Control
Corn	76.86
Soybean meal, (48% CP)	19.48
Monocalcium phosphate, (18% P)	1.47
Limestone	.94
Corn premix	.50
Salt	.35
Vitamin premix	.20
Trace mineral premix	.10
Antibiotic	.10
Total	100.00

[a]Diets were formulated to contain .8% lysine and were fed for the entire experiment. Analyzed composition of 6 samples of each diet were: CP 15.0, 14.8, 14.7, and 14.9 and Mn: 59.2, 76.8, 78.3, and 104.8 ppm for the control, 44 ppm chelated Mn, 44 ppm inorganic Mn, and 88 ppm Mn diets, respectively.

[b]Corn, Mn oxide, and soy protein isolate or corn and chelated Mn were used in the premix to provide the respective added Mn treatments.

Results and Discussion

During d 0 to 28 of the experiment, no differences occurred in ADG or ADFI of pigs fed additional manganese (Table 2). However, F/G was poorer for pigs fed 44 or 88 ppm inorganic manganese compared with those pigs fed either the control diet (24 ppm inorganic manganese) or the chelated manganese. However, for all other growth performance criteria for any phase of the experiment, no differences occurred in ADG, ADFI, or F/G.

No differences in carcass traits or organ weights were observed (Table 3). A trend ($P<.06$) occurred for pigs fed chelated manganese to have slightly greater last lumbar backfat depth; however, no differences were observed for average backfat thickness. Therefore, with the growth rate and lean tissue deposition of the pigs used in this study, additional manganese from either chelated or inorganic sources gave no improvements in growth performance or carcass characteristics.

Table 2. Growth Performance of Finishing Pigs Fed Added Manganese[a]

Item	Inorganic Mn, 24 ppm	Chelated Mn, 44 ppm	Inorganic Mn, 44 ppm	Inorganic Mn, 88 ppm	CV	P value
Day 0 to 28						
ADG, lb	2.15	2.13	2.05	2.13	8.1	.62
ADFI, lb	5.71	5.65	5.89	5.81	6.7	.52
F/G[b]	2.66	2.65	2.88	2.73	6.9	.04
Day 0 to 56						
ADG, lb	2.09	2.17	2.05	2.12	8.0	.44
ADFI, lb	6.41	6.55	6.54	6.59	6.8	.81
F/G	3.07	3.02	3.20	3.10	6.4	.23
Overall						
ADG, lb	2.12	2.17	2.08	2.13	7.4	.66
ADFI, lb	6.76	6.90	6.90	6.95	6.4	.78
F/G	3.19	3.18	3.32	3.27	6.3	.39
Days on test	71.4	70.0	73.5	72.1	7.6	.55

[a]A total of 80 barrows were used (initially 77 lb) with 2 pigs/pen and 10 pens/treatment.
[b]Mean of 24 ppm inorganic and 44 ppm chelated Mn vs 44 and 88 ppm inorganic Mn ($P<.04$).

Table 3. Carcass Characteristics and Organ Weights of Finishing Pigs Fed Added Manganese[a]

Item	Inorganic Mn, 24 ppm	Chelated Mn, 44 ppm	Inorganic Mn, 44 ppm	Inorganic Mn, 88 ppm	CV	P value
Final weight, lb[a]	223	220	220	225	4.4	.40
Hot carcass weight, lb	167.3	165.7	167.8	169.1	2.0	.15
Cold carcass weight, lb	164.7	163.1	165.1	166.2	2.0	.16
Dressing %	73.7	72.9	73.8	74.3	2.0	.17
First rib backfat, in.	1.45	1.63	1.59	1.54	13.0	.23
Last rib backfat, in.	.99	1.01	.94	.94	13.2	.39
Last lumbar backfat, in.	1.00	1.11	.97	.97	14.4	.06
Average backfat, in.	1.15	1.25	1.16	1.15	10.6	.16
Tenth rib backfat, in.	1.14	1.23	1.20	1.18	16.0	.76
Longissimus muscle area, $in.^2$	5.08	4.58	4.75	4.83	10.3	.15
Carcass length, in.	30.6	30.9	30.8	30.7	1.7	.45
Kidney fat, g	1,222	1,327	1,282	1,431	20.6	.39
Organ weights, g						
Heart	356	341	333	336	10.5	.66
Liver	1,521	1,518	1,522	1,456	9.4	.67
Kidney	350	341	333	336	10.3	.74

[a]A total of 80 barrows (initially 77 lb) with 2 pigs/pen and 10 pens/treatment. Final weight was used as a covariate for statistical analysis.

Swine Day 1994

EFFECT OF FEEDER DESIGN ON FINISHING PIG GROWTH PERFORMANCE[1]

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

Summary

A total of three hundred pigs (initial BW = 111.6 lb) was used in two identical 70-d growth trials to determine the effect of feeder design on finishing pig growth performance. Pigs were allotted by initial body weight and were assigned to pens with one of three different feeder designs. Five replications of each treatment were evaluated during the summer (July through September) and another five replications during winter months (November through January). All pigs were fed the same milo-soybean meal diet formulated to contain .65% lysine, .65% Ca, and .55% P and fed in meal form. Feeder design had no effect on average daily gain (ADG) or average daily feed intake (ADFI) of finishing pigs. Pigs fed from the wet/dry feeder had improved feed efficiency (F/G) compared to pigs fed from either of the dry feeders. Water disappearance was lower for the pigs eating from the wet/dry feeder. These results suggest that the use of a single-hole, wet/dry feeder for growing-finishing pigs improves F/G and reduces water wastage.

(Key Words: Pigs, Feeders, Growth.)

Introduction

Feed cost represents 60 to 70% of the total cost of production for a swine operation. The finishing phase will account for the major proportion of this cost. Therefore, reducing cost of feed per pound of gain would greatly affect the overall cost of production. Recent developments in feeder design and technology may affect feed intake, feed efficiency, water intake, water wastage, and feeding behavior. Therefore, the objective of this experiment was to compare three different feeder designs in terms of finishing pig growth performance and water disappearance.

Procedures

A total of 300 finishing pigs (initial BW 111.6 lb) was used in two identical 70-d growth trials. Pigs were allotted by initial body weight, gender, and ancestry and were assigned to pens with one of three different feeder designs. One hundred fifty pigs were used per trial in a randomized complete block design with 10 pigs per pen. Five replications were conducted during the summer months (July through September) and five replications were conducted during the winter months (November through January). The first feeder evaluated was a dry, two-hole feeder with a partition between the feeder holes to minimize pig interaction (Aco®). The second was a single-hole, wet/dry shelf feeder with a nipple waterer located at the base of the trough (Crystal Spring®). The third feeder was an eight-hole, round, dry feeder with a wheel agitator (Osborne®).Pigs were housed in a building with pens measuring 16 × 6 ft with 50% solid and 50% slatted flooring. Dry feeders contained one nipple waterer per pen, and the wet/dry feeder had one nipple waterer at the base of the feeder trough. This was the only access to water the

[1]Appreciation is expressed to Custom Ag Products Inc., Beloit, KS, and Grow Master Inc., Omaha, NE, for providing some of the feeders used in this research.

pigs received throughout the trial. During the summer months, the pigs were drip cooled. Three water meters were installed to record daily water disappearance for each treatment. Because only one observation was made per treatment, water usage was not statistically analyzed.

Results and Discussion

Average daily gain during the summer trial was not affected by the feeder design. However, pigs fed from the wet/dry feeder had a slight numerical advantage in ADG. No difference was observed for ADFI during the summer trial, with all pigs consuming about 6.6 lb of feed per day. Pigs fed from the wet/dry feeder had approximately 7.7% better F/G ($P<.05$) than pigs consuming feed from either of the dry feeders. A large numerical response occurred during the summer months, with the pigs eating from the wet/dry feeder using 42% less water than pigs using either of the dry feeders.

Similar to the results from the summer trial, no differences were observed in ADG or ADFI among pigs fed from the different feeders during the winter trial. Pigs fed during the winter months had greater ADFI ($P<.01$) and poorer F/G than pigs fed during the summer months. Similar to the summer trial, pigs fed from the wet/dry feeder had 7.7% better F/G ($P<.05$) than pigs fed from either of the dry feeders. The difference in water disappearance was not as great for pigs fed in the winter trial as compared to those in the summer trial. However, a slight numerical advantage occurred for pigs fed from the wet/dry feeder.

We were concerned at the start of the trial that the wet/dry feeder only having one feeder hole might result in restricted feeding or increased pig aggression. Competition for feed may decrease consumption and ADG. Therefore, pigs were weighed on d 14 of the trials to determine the acclimation period to the new feeders. The first 14 d of the summer trial showed no difference in pig performance. However, during the winter trial, pigs fed from the wet/dry feeder had decreased ADFI, resulting in decreased ADG. However, this resulted in an improvement in F/G (feeder design × season interaction $P<.05$). This suggests possible increased competition for feed and limited intakes. However, these initial differences did not affect pig performance for the overall trial.

In summary, feeder design had no effect on ADG or ADFI of finishing pigs. However, F/G was improved approximately 7 to 8% for pigs fed from the single-hole, wet/dry shelf feeder compared to pigs fed from either of the dry feeders. Water disappearance for pigs eating from the wet/dry feeder was lower, but this response was predominately observed during the summer trial. Therefore, use of a wet/dry shelf feeder for growing-finishing pigs improves F/G and reduces water wastage.

Table 1. Effect of Feeder Design on Finishing Pig Growth Performance[a]

	Summer			Winter			
Item	2-Hole dry	1-Hole wet/dry	8-Hole round	2-Hole dry	1-Hole wet/dry	8-Hole round	CV
Initial wt, lb[b]	109.35	109.35	109.35	113.98	113.98	113.98	1.1
ADG, lb	1.72	1.85	1.72	1.83	1.83	1.81	7.8
ADFI, lb[b]	6.55	6.70	6.70	7.76	7.08	7.50	4.4
F/G[bc]	3.85	3.57	3.85	4.17	3.85	4.17	6.8
Final wt, lb[d]	229.94	238.76	229.50	242.29	242.07	239.42	4.1
Water use, gal/d[e]	2.25	1.24	2.06	1.95	1.82	1.90	

[a]A total of 300 finishing pigs with 5 replications per treatment during the summer and winter trials.
[bc]Season effect (P<.01 and .05, respectively).
[d]1-hole wet/dry feeder vs 2-hole dry feeder or 8-hole round feeder (P<.05).
[e]Water disappearance (gallons/pig/d).

Table 2. Initial Growth Performance from d 0 to 14[a]

	Winter			Summer			
Item	2-Hole dry	1-Hole wet/dry	8-Hole round	2-Hole dry	1-Hole wet/dry	8-Hole round	CV
ADG, lb	1.76	1.61	1.83	1.61	1.79	1.68	15.0
ADFI, lb[b]	7.32	4.83	5.91	5.45	5.75	5.95	13.1
F/G[c]	4.17	2.94	4.35	3.45	3.23	3.57	11.3

[a]A total of 300 finishing pigs with 5 replications per treatment during the summer and winter trials.
[b]Feeder design × season interaction (P<.01).
[c]Winter trial feeder effect (P<.05).

Swine Day 1994

MIX TIME AFFECTS DIET UNIFORMITY AND GROWTH PERFORMANCE OF NURSERY AND FINISHING PIGS

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

Summary

Two experiments were conducted to determine the effects of mix time on diet uniformity and growth performance of nursery and finishing pigs. For Exp. 1, 120 weanling pigs (average initial body wt of 12.1 lb) were used in a 27-d growth assay. The same Phase I diet (pelleted) was fed to all pigs for 7 d postweaning, then the pigs were switched to Phase II diet treatments for d 7 to 27. Treatments were mixing times of 0, .5, 2, and 4 min per 1,000 lb batch of complete feed in a double-ribbon mixer. From d 7 to 27, ADG increased by 49% and F/G was improved by 19% as mixing was increased from 0 to 4 min, with most of this effect realized with mixing for only .5 min (i.e., a CV for diet uniformity of 28%). For Exp. 2, 128 finishing pigs (average initial body wt of 124 lb) were fed to an average slaughter wt of 259 lb. All pigs were fed the same corn-soybean meal-based diet not mixed (0 min) or mixed for .5, 2, or 4 min per 1,000 lb batch of complete feed in a double-ribbon mixer. Increasing mix time (i.e., reducing the CV for diet uniformity from 54% to <10%) did not significantly affect ADG, ADFI, or F/G. However, pigs fed the 0 min treatment had, numerically, the poorest rates and efficiencies of gain. Dressing percentage, backfat thickness, and bone strength were not affected by the dietary treatments. In conclusion, the difference in degree of response to diet uniformity for nursery vs finishing pigs probably was due to reduced palatability resulting from uneven distribution of specialty ingredients in poorly mixed nursery diets (e.g., whey, blood meal, and crystalline amino acids). Also, the lower daily food intake of nursery pigs (1.5 lb/d) vs finishing pigs (6.4 lb/d) would decrease the likelihood of weanling pigs meeting their needs for some of the nutrients in a poorly mixed diet.

(Key Words: Mixing, Diet Uniformity, Growth, Bones, Nursery, Finishing.)

Introduction

Mixing is considered one of the most essential and critical operations of feed manufacturing whether on-farm or in a commercial feed manufacturing facility. Lack of diet uniformity can lead to reduced animal performance and the need for overfortification of limiting (often expensive) nutrients to protect against the possibility of deficiencies. Surprisingly, we could find only one report, and that addressed the issue of diet non-uniformity, that was for broiler chicks (McCoy et al., 1994, J. Poultry Science). Controlled research projects have not been reported that demonstrate if, or how much, a poorly mixed diet affects growth performance in pigs. Yet, a CV of <10% has been adopted as the industry standard to represent a uniformly mixed feed. Therefore, the objective of this project was to determine the effects of mix time on diet uniformity and growth performance of nursery and finishing pigs.

[1]Department of Grain Science and Industry.

Procedures

Four batches of test feed were made to establish the mix times necessary to produce the desired levels of diet uniformity for treatments used in the subsequent pig growth assays. Each batch was 1,000 lb, representing the full-load capacity for the double-ribbon mixer (Sprout Waldron, Model B-37, 37 rpm) that was used. A computerized feed batching system was used to weigh ground corn into the main ingredient scale that discharged into the center of the mixer. Salt (3 lb) was added by hand to the corn. After mixing, the corn-salt blend was discharged into a screw conveyor (4 ft long) and lifted by a bucket elevator (65 ft high) before being dropped (49 ft) into a sack-off bin and packaged in paper bags. Thus, some mixing occurred in the handling of the diets. Samples (.5 lb each) were taken from every other bag (10 samples total) during the bagging operation for diet uniformity analyses. Ten grams of each sample were assayed for salt (Quantab® analysis for chloride ion) concentration to allow calculation of a coefficient of variation for each batch. We determined that no mixing and .5, 2, and 4 min mix times would give a suitable spread in CVs (note that the mixer manufacturer suggested a mix time of 3 to 4 min for swine and poultry diets).

For the pig experiments, major (corn and soybean meal) and minor (salt, vitamin premix, trace mineral premix, monocalcium phosphate, and limestone) ingredients were weighed using the computerized batching system. Remaining ingredients (e.g., dried whey, spray-dried blood meal, and synthetic amino acids in the nursery diets) were hand weighed and added via a hopper positioned near the center of the mixer. The major ingredients were discharged from the main batching scale, and the minor ingredients were discharged from the micro ingredient system while the mixer motor was stopped. The ingredients were not mixed (0 min) or mixed for .5, 2, and 4 min for the nursery and finishing experiments; the mixer was stopped; and the discharge gate was opened. The feed was bagged through the same system used for the mixer evaluation; however, the feed was discharged by starting and stopping the mixer to allow packaging in a sequential manner.

For Exp. 1, 120 weanling pigs (average initial body wt of 12.1 lb) were used in a 27-d growth assay. The pigs were blocked by weight and allocated to pens based on sex and ancestry. There were five pigs per pen (three barrows and two gilts or two barrows and three gilts) and six pens per treatment. The pigs were fed the same Phase I diet from d 0 to 7 postweaning and switched to the Phase II treatments for d 7 to 27 (Table 1). The Phase I diet was formulated to 1.5% lysine, .4% methionine, .9% Ca, and .8% P, and fed in pelleted form. Phase II diets were formulated to 1.25% lysine, .3% methionine, .9% Ca, and .8% P and were fed in meal form. The pigs were housed in 4 ft × 5 ft pens with wire-mesh flooring. Each pen had a self-feeder and nipple waterer to allow ad libitum consumption of feed and water. Pigs and feeders were weighed on d 7 and 27 to allow calculation of ADG, ADFI, and F/G. Because there were multiple sources of salt (e.g., spray-dried blood meal, dried whey, and salt) in the Phase II treatments, chromic oxide was added to allow calculation of CVs for diet uniformity. Data were analyzed as a randomized complete block design with pen as the experimental unit.

For Exp. 2, 128 finishing pigs (average initial body wt of 124 lb) were blocked by weight and allocated to pens based on sex and ancestry. There were eight pigs per pen (four barrows and four gilts) and four pens per treatment. The diets were corn-soybean meal-based and formulated to .65% lysine, .65% Ca, and .55% P. No crystalline amino acids were used in the diets for finishing pigs. 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 a weight block reached an average body wt of 260 lb, the entire block was removed from the growth assay. Two blocks reached the end weight on d 74 and two blocks on d 81 of the experiment. The barrows were slaughtered at a commercial slaughter facility and hot carcass weights were recorded for calculation of dressing percentage. Last rib backfat thickness was measured with a ruler on both sides of the split carcass at the midline. Metacarpals from the right front foot were collected from each of the barrows for determination of bone breaking strength. These data were collected to determine if poorly mixed diets could result in soft bones because of inadequate mineral consumption. Data were analyzed as a randomized complete block design with pen as the experimental unit.

Results and Discussion

For the nursery experiment, increasing mix time from 0 to .5 min decreased the CV for chromium concentration from 106.5 to 28.4%. Diet uniformity improved further as mix time was increased, with a CV of 12.3% for the diet mixed for 4 min. Rate of gain increased markedly as mix time was increased from 0 to .5 min and continued to increase at a lower rate as mix time was increased further (quadratic and cubic effects, $P<.02$). Likewise, ADFI increased as mix time was increased from 0 to 4 min (1.32 lb/d vs 1.59 lb/d, respectively), but most of the response occurred as mix time was increased from 0 to only .5 min (quadratic and cubic effects, $P<.08$). Efficiency of gain improved (quadratic and cubic effects, $P<.03$) by 16% as mix time was increased from 0 min to .5 min and by 19% overall (i.e., as mix time was increased for 0 to 4 min). These data indicate that, although most of the growth improvement was achieved with a diet CV of 28.4%, nursery pigs need a CV of <12.3% to maximize growth performance.

For the finishing experiment, mix time had no statistically significant effects on growth performance or bone strength ($P>.13$). However, rate and efficiency of gain had numerical increases of 4% and 5%, respectively, as mix time was increased from 0 to .5 min. Carcass backfat thickness decreased as mix time was increased from 0 to .5 min but plateaued and began to increase as mix time was further increased to 4 min (quadratic and cubic effects, $P<.04$).

In conclusion, increased mix time improved diet uniformity and performance of nursery pigs. Finishing pigs were less sensitive to diet nonuniformity, with growth performance affected only slightly as mix time was increased from 0 to 4 min. The finishing pigs were quite tolerant of CVs to a least 15% and even up to 54%. Thus, our data suggest that feedmill throughput could be increased by reducing mix time of diets for finishing pigs. However, we must emphasize that some mixing occurred as the feed was moved through our feed plant, and that a simpler system (e.g., a grinder-mixer) with 0 min mix time could yield a CV considerably greater than 54%. Thus, it is the CV of the diet, and not the mix time per se, that is likely to determine growth performance. Also, caution should be taken when using a medicated feed article. According to the Good Manufacturing Practices set forth by the FDA, all feed manufacturers (commercial, on-farm, and integrated operations) must demonstrate the ability to produce uniform diets with the intended potency of any regulated feed additive. Finally, Kansas feed regulations stipulate that any feed or feed article for sale is considered adulterated if a representative sample fails to conform to the label guarantees. Nonetheless, under these experimental conditions, our data demonstrate acceptable growth performance at considerably greater CVs for diet uniformity than once deemed necessary.

Table 1. Diet Composition for Nursery and Finishing Pig Experiments

	Nursery experiment		Finishing
Ingredient	Phase I[a]	Phase II[b]	experiment[c]
	%		
Corn	37.11	58.75	83.18
Soybean meal (48% CP)	15.95	25.00	14.17
Spray-dried blood meal	2.50	2.50	--
Spray-dried porcine plasma	7.50	--	--
Dried whey	20.00	10.00	--
Lactose	10.00	--	--
Soybean oil	3.00	--	--
Monocalcium phosphate (21% P)	2.01	1.87	1.08
Limestone	.74	.99	1.02
Salt	--	.20	.30
Lysine-HCl	.10	.06	--
DL-methionine	.11	--	--
Chromic oxide	--	.15	--
KSU vitamin premix	.25	.25	.15
KSU trace mineral premix	.15	.15	.10
Copper sulfate	.08	.08	--
Antibiotic[d]	.50	--	--

[a]The Phase I diet was formulated to 1.5% lysine, .4% methionine, .9% Ca, and .8% P.
[b]Phase II diets were formulated to 1.25% lysine, .32% methionine, .9% Ca, and .8% P.
[c]Finishing diets were formulated to .7% lysine, .65% Ca, and .55% P.
[d]Provided 100 g/ton chlortetracycline, 100 g/ton sulfathiazole, and 50 g/ton penicillin.

Table 2. Effects of Mix Time on Diet Uniformity and Growth Performance of Nursery Pigs[a]

	Mix time, min					Probability value, P<		
Item	0	.5	2	4	CV	Linear	Quad	Cubic
CV for Cr, %[b]	106.5	28.4	16.1	12.3	N/A[c]	N/A	N/A	N/A
ADG, lb	.59	.83	.84	.88	12.0	.01	.02	.01
ADFI, lb	1.32	1.57	1.55	1.59	7.9	.01	.08	.02
F/G	2.24	1.89	1.85	1.81	9.1	.01	.03	.02

[a]A total of 120 weanling pigs with an average initial body wt of 12.1 lb (five pigs/pen and six pens/treatment).
[b]Coefficient of variation for Cr was determined from ten samples for each 1,000 lb of feed.
[c]Not applicable for mix analyses.

Table 3. Effects of Mix Time on Diet Uniformity and Growth Performance of Finishing Pigs[a]

	Mix time, min					Probability value, P<		
Item	0	.5	2	4	CV	Linear	Quad	Cubic
CV for salt, %[b]	53.8	14.8	12.5	9.6	N/A[c]	N/A	N/A	N/A
ADG, lb	1.71	1.78	1.75	1.73	3.7	--[d]	--	--
ADFI, lb	6.49	6.40	6.36	6.35	3.7	--	--	--
F/G	3.80	3.60	3.63	3.67	3.5	--	--	.13
Dressing percentage	73.7	73.3	73.1	73.0	.6	.04	--	--
Last rib fat thickness, in	1.20	1.09	1.14	1.18	3.3	--	.04	.01
Bone breaking strength, kg of peak force	230	236	239	218	16.9	--	--	--

[a]A total of 128 pigs with an average initial body wt of 124 lb (eight pigs/pen and four pens/treatment).
[b]Coefficient of variation for salt was determined from ten samples for each 1,000 lb of feed.
[c]Not applicable for mix analyses.
[d]Dashes indicate P>.15.

Swine Day 1994

ROASTING AND EXTRUDING AFFECT ILEAL DIGESTIBILITY OF NUTRIENTS FROM SOYBEANS IN GROWING AND FINISHING PIGS

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

Summary

Eight crossbred barrows (initial body wt of 90 lb and 180 lb for four growing and four finishing pigs, respectively) were fitted with T-cannulas at the distal ileum and used in 36-d metabolism experiments (4 × 4 Latin squares) to determine the effects of roasting and extruding full-fat soybeans on nutrient utilization. Treatments were 1) soybean meal, 2) roasted soybeans, 3) extruded soybeans, and 4) soybeans extruded with an extrusion enhancer (sodium sulfite). The soybean meal and soybeans were mill-run. The control diet was cornstarch-based, with .9% lysine, .65% Ca, and .55% P for the growing pigs and .75% lysine, .55% Ca, and .45% P for the finishing pigs. For the growing pigs, apparent total tract digestibilities of DM and GE were greater for soybean meal than full-fat soy products. However, ileal digestibilities of DM, GE, N, and amino acids generally were greatest for extruded soybeans and lowest for roasted soybeans, with soybean meal intermediate. Differences at the terminal ileum were more pronounced than for the total tract, thus indicating that hindgut fermentation is likely to mask many of the true nutritional differences in feedstuffs. For finishing pigs, total tract digestibilities of DM and GE were greater for soybean meal than for the full-fat soy products because of the relatively low digestibility coefficients for roasted soybeans. Ileal digestibilities of DM, GE, and N were greater for the extruded soybeans and extruded soybeans with sodium sulfite than for the roasted soybeans. Availabilities of the indispensable amino acids measured at the terminal ileum were greatest for extruded soybeans, intermediate for soybean meal, and lowest for roasted soybeans. In conclusion, nutrient digestibilities and availabilities of indispensable amino acids tended to be greatest in extruded soybeans, intermediate in soybean meal, and lowest in roasted soybeans for growing and finishing pigs.

(Key Words: Pig, Soybean, Extrude, Roast, Sodium Sulfite, Ileum, Digestibility.)

Introduction

During the past 6 years, we have reported growth performance for pigs fed extruded soybeans that was equal to, or greater than, growth performance of pigs fed soybean meal. However, the performance of pigs fed roasted soybeans often has been less than that of pigs fed soybean meal and extruded soybeans. Thus, the objectives of the experiments reported herein were to determine if the greater nutritional value of extruded soybeans can be explained partially by greater nutrient availabilities (e.g., greater ileal digestibilities of amino acids). Also, we wished to evaluate differences in nutrient availability in pigs of different ages (i.e., growing vs finishing) and to generate nutrient availability values for the soybean preparations we have been using in growth assays.

Procedures

The soybean meal and full-fat soybeans used in these experiments were mill-run. For the roasting and extrusion treatments, processing conditions were those deemed usual for soybeans (i.e., a throughput of approximately 1,000 lb/h and an average exit temperature of 260°F in a Roast-A-Tron® roaster vs a throughput of approximately 1,500 lb/h

and an average barrel temperature of 290°F in an Insta-Pro® dry-extruder). Treatments were 1) soybean meal, 2) roasted soybeans, 3) extruded soybeans, and 4) soybeans extruded with an extrusion enhancer (sodium sulfite). Sodium sulfite is suggested to aid in the breaking of disulfide bonds that hold proteins in their biologically active configurations. Thus, it should ensure very low activities for trypsin inhibitors and other antinutritional factors that limit the utilization of soybean proteins. The soybean meal and full-fat soybeans preparations were incorporated into cornstarch-based diets formulated to .9% lysine, .65% Ca, and .55% P for the growing pigs and .75% lysine, .55% Ca, and .45% P for the finishing pigs (Table 1). Chromic oxide (.25%) was added to the diets as an indigestible marker.

Eight crossbred barrows (four growing and four finishing with average initial body wt of 90 and 180 lb, respectively) were surgically fitted with T-cannulas approximately 15 cm anterior to the ileo-cecal junction. The pigs were deprived of feed for 16 to 20 h prior to surgery and allowed a 14-d recuperation period before initiation of the experiments. The experimental designs were 4 × 4 Latin squares with pig and period as blocking criteria. Each period included 4 d of adjustment to diet, 3 d of total feces and urine collection, and 2 d (12 h/d) of ileal digesta collection. The pigs were limit-fed (.05 × body $wt^{.9}$) with two meals daily (7:00 a.m. and 7:00 p.m.). Feed was offered as a wetted mash. Water was available for ad libitum consumption between feedings. Feces and urine were collected twice daily during the 3 d of feces and urine collection. The urine was acidified during collection by 100 mL of 10% HCl in the collection vessel. Total urine volumes were recorded, and 5% was saved and frozen each day for later analyses. Ileal digesta were collected during the 12-h period between the morning and evening feeding for the last 2 d of each collection period. Feed, feces, and ileal digesta were analyzed for DM, N, and GE concentrations. Amino acid analyses were accomplished after hydrolysis for 24 h with 6N HCl. Chromium concentrations were determined by atomic absorption spectrometry. All data were analyzed using the orthogonal comparisons: 1) soybean meal vs other treatments; 2) roasted soybeans vs extruded soybeans; and 3) extruded soybeans vs soybeans extruded with sodium sulfite.

Results and Discussion

The chemical compositions of the soybean meal and full-fat soybean preparations are given in Table 2. Chemical analyses were similar to those anticipated and, as expected with their greater fat content, the full-fat soy products had greater GE. Crude protein and amino acid concentrations generally were greater for soybean meal than the full-fat soy products.

For the growing pigs, digestibilities of DM ($P<.05$) and GE ($P<.01$) for the total tract were greater for soybean meal vs the full-fat soy products (Table 3) because of the relatively low digestibilities for roasted soybeans. Digestibilities of DM, GE, and N at the terminal ileum were greater for pigs fed extruded soybeans than for pigs fed roasted soybeans ($P<.10$). For N digestibility, differences between small intestine and total tract averaged 13.3% for soybean meal, 22.0% for roasted soybeans, 12.2% for extruded soybeans, and 9.2% for soybeans extruded with sodium sulfite. Nutrients disappearing in the large intestine would be used largely for microbial activity and are of little benefit to the host animal. Apparent digestibilities of amino acid at the terminal ileum followed the same patterns as N digestibility (Table 4). Availabilities for nine indispensable amino acids measured at the terminal ileum averaged 80.3% for soybean meal, 62.6% for roasted soybeans, 81.7% for extruded soybeans, and 84.8% for soybeans extruded with sodium sulfite.

For the finishing pigs, digestibilities of DM ($P<.05$) and GE ($P<.001$) for the total tract were greater for soybean meal than for the full-fat soy products because of the relatively low digestibilities for roasted soybeans (Table 5). Ileal digestibilities for DM, GE, and N were greater ($P<.01$) for the extruded soybeans than for the roasted soybeans. Apparent amino acid digestibilities measured

at the terminal small intestine are given in Table 6. Availabilities for nine indispensable amino acids measured at the terminal ileum averaged 83.4% for soybean meal, 72.2% for roasted soybeans, 84.1% for extruded soybeans, and 87.8% for soybeans extruded with sodium sulfite. The availability of lysine was greatest in soybeans extruded with sodium sulfite (88.9%) and lowest in roasted soybeans (71.2%) with soybean meal intermediate (83.3%).

In conclusion, digestibilities of nutrients were lower at the terminal ileum than in the feces, and much of the treatment effect was lost with total tract determination. Thus, results based on the fecal analysis method may provide erroneous interpretations of the effects of heat treatment on full-fat soybeans. Ileal digestibilities of DM, GE, N, and various amino acids tended to be greatest for soybeans extruded with sodium sulfite and lowest for roasted soybeans. These trends were true for both growing and finishing pigs. Finally, our results demonstrate that future NRC values should indicate the type of processing used to generate full-fat soybean products to avoid overestimation of amino acid availabilities in roasted products and underestimation of amino acid availabilities for extruded products.

Table 1. Diet Composition, %

	Growing pigs[a]		Finishing pigs[b]	
Ingredient	Soybean meal	Soybeans	Soybean meal	Soybeans
Cornstarch	62.84	53.53	68.22	61.02
Soybean meal	29.08	--	24.11	--
Soybeans	--	40.43	--	33.33
Soybean oil	1.00	--	1.00	--
Cellulose fiber	4.00	3.00	4.00	3.00
Dicalcium phosphate	1.97	1.64	1.54	1.28
Limestone	.21	.50	.23	.47
Salt	.25	.25	.25	.25
KSU vitamin premix	.25	.25	.25	.25
KSU mineral premix	.15	.15	.15	.15
Chromic oxide[c]	.25	.25	.25	.25
Total	100.00	100.00	100.00	100.00

[a]All grower diets were formulated to .9% lysine, .65% Ca, and .55% P and to meet or exceed concentrations for all other nutrients as suggested by NRC (1988).
[b]All finisher diets were formulated to .75% lysine, .55% Ca, and .45% P and to meet or exceed concentrations for all other nutrients as suggested by NRC (1988).
[c]Used as an indigestible marker.

Table 2. Chemical Composition of Soybean Meal, Roasted Soybeans, Extruded Soybeans, and Soybeans Extruded with Sodium Sulfite[a]

		Soybeans		
Item	Soybean meal	Roasted	Extruded	Sodium sulfite
CP, %	43.5	34.0	35.1	33.6
Gross energy, kcal/lb	1,884	2,242	2,246	2,199
Indispensable amino acids, %				
Arginine	3.1	2.6	3.0	2.9
Histidine	1.1	1.0	1.0	1.0
Isoleucine	1.7	1.7	1.7	1.6
Leucine	3.0	2.9	2.9	2.8
Lysine	2.8	2.2	2.2	2.2
Methionine	.5	.5	.5	.5
Phenylalanine	1.8	1.7	1.8	1.7
Threonine	1.7	1.5	1.6	1.5
Valine	1.8	1.7	1.8	1.7
Dispensable amino acids, %				
Alanine	1.7	1.7	1.7	1.7
Aspartate	4.6	4.3	4.5	4.4
Glutamate	7.5	6.4	7.4	7.2
Glycine	2.0	1.7	1.9	1.8
Serine	2.3	2.1	2.3	2.2
Tyrosine	1.3	1.3	1.3	1.2

[a]Corrected to 90% DM.

Table 3. Apparent Nutrient Digestibilities in Growing Pigs

Item	Soybean meal	Soybeans			
		Roasted	Extruded	Sodium sulfite	CV
DM digestibility, %					
Small intestine[c]	75.7	71.5	75.6	80.1	7.9
Total tract[ae]	92.7	88.9	91.3	92.7	1.6
Difference	17.0	17.4	15.7	12.7	36.5
GE digestibility, %					
Small intestine[d]	76.5	70.1	78.1	81.2	7.9
Total tract[bf]	93.4	86.5	90.8	92.5	2.3
Difference	16.9	16.3	12.7	11.3	41.1
N digestibility, %					
Small intestine[f]	76.3	62.2	77.6	81.5	5.7
Total tract[f]	89.6	84.2	89.8	90.7	2.3
Difference[f]	13.3	22.0	12.2	9.2	27.1

[ab]SBM vs other treatments (P<.05 and .01, respectively).
[cdef]Roasted vs extruded (P<.10, .05, .01, and .001, respectively).

Table 4. Apparent Ileal Amino Acid Digestibilities in Growing Pigs, %

Item	Soybean meal	Soybeans			
		Roasted	Extruded	Sodium sulfite	CV
Indispensable amino acids					
Arginine[ac]	87.6	72.7	88.7	90.3	4.3
Histidine[bc]	82.7	63.3	83.6	87.6	5.1
Isoleucine[bc]	79.2	59.4	80.1	83.4	5.2
Leucine[c]	78.8	61.3	80.2	84.2	5.6
Lysine[c]	82.6	67.1	86.2	88.5	4.8
Methionine[bc]	80.9	63.9	82.7	84.1	4.5
Phenylalanine[c]	80.9	62.2	83.4	86.1	5.0
Threonine[c]	74.1	58.4	74.5	78.9	7.4
Valine[ac]	75.9	55.3	75.6	80.2	7.3
Total dispensable amino acids[c]	77.7	60.0	80.3	83.2	6.4

[ab]SBM vs other treatments (P<.10 and .05, respectively).
[c]Roasted vs extruded (P<.001).

Table 5. Apparent Nutrient Digestibilities in Finishing Pigs

Item	Soybean meal	Soybeans			CV
		Roasted	Extruded	Sodium sulfite	
DM digestibility, %					
Small intestine[e]	85.4	80.4	84.6	85.7	2.8
Total tract[bf]	92.6	87.9	92.7	93.0	1.2
Difference	7.2	7.6	8.1	7.4	33.4
GE digestibility, %					
Small intestine[af]	86.2	78.4	85.6	86.6	2.9
Total tract[cf]	93.2	84.9	92.7	93.0	1.3
Difference	6.9	6.5	7.1	6.4	40.4
N digestibility, %					
Small intestine[f]	80.7	69.2	83.9	85.6	7.3
Total tract[f]	87.6	79.6	89.7	89.0	3.9
Difference[d]	6.7	10.4	5.8	3.4	88.2

[abc]SBM vs other treatments (P<.10, .05, and .001, respectively).
[def]Roasted vs extruded (P<.10, .01, and .001, respectively).

Table 6. Apparent Ileal Amino Acid Digestibilities in Finishing Pigs, %

Item	Soybean meal	Soybeans			CV
		Roasted	Extruded	Sodium sulfite	
Indispensable amino acids					
Arginine[a]	88.2	76.7	88.5	91.6	5.6
Histidine[a]	84.3	72.7	85.3	88.7	6.3
Isoleucine[a]	84.9	71.9	84.4	87.1	5.9
Leucine[a]	84.4	71.7	84.4	87.3	6.6
Lysine[a]	83.3	71.2	84.7	88.9	6.6
Methionine[a]	83.9	75.5	85.2	89.4	5.6
Phenylalanine[a]	85.2	72.0	85.0	88.8	6.5
Threonine[a]	76.0	68.1	78.3	83.6	7.4
Valine[a]	80.8	69.6	80.8	84.7	6.9
Total dispensable amino acids[a]	78.6	69.0	79.9	85.7	7.6

[a]Roasted vs extruded (P<.001).

Swine Day 1994

INFLUENCE OF POSTMORTEM INJECTION OF CALCIUM CHLORIDE ON TENDERNESS OF PORK LONGISSIMUS MUSCLE

B. J. McFarlane and J. A. Unruh

Summary

Twenty-seven pork carcass sides were assigned randomly to either blast chilling for 1 h at -13°F followed by 23 h chill at 34°F or a standard chill at 34°F for 24 h. At 24 h postmortem, the longissimus muscle from the center loin region was removed and divided into anterior and posterior halves. Halves were assigned randomly to either calcium-chloride ($CaCl_2$) injection or non-injected controls. Those receiving $CaCl_2$ were injected with a .3 molar solution at 10% pump by weight. Muscles then were stored for 3 d at 34°F before 1-in chops were removed, cooked to an internal temperature of 160°F, and allowed to cool for 2 h before six .5 in cores were sheared. The Warner-Bratzler Shear (WBS) values were lower (more tender) for the $CaCl_2$-injected loins than controls. Blast chilling decreased the combined purge and cooking losses compared to standard chilling. A second trial was conducted to determine the influence of only a 10% water injection on WBS and cooking loss. Five loins were divided into anterior and posterior halves and assigned randomly to either water injection or noninjected controls. Water injection did not influence either WBS or cooking loss values. In conclusion, 24 h postmortem injection of $CaCl_2$ enhances the tenderness of pork longissimus muscle.

(Key Words: Pork, Calcium Chloride, Tenderness.)

Introduction

Tenderness is an important quality characteristic in pork. Postmortem storage (aging) at refrigerated temperatures gradually increases meat tenderness by proteolysis of myofibrillar proteins. Recent research has indicated that the calcium-dependent calpain system is involved in the tenderness observed during postmortem aging. Injecting carcasses or muscles with $CaCl_2$ has accelerated postmortem aging and improved meat tenderness in beef and lamb. In addition, the postmortem rate of temperature decline could influence the rate of glycolysis (pH decline) and proteolysis. Therefore, our objectives were to determine 1) the influence of injecting pork loin muscles with $CaCl_2$ on WBS values (tenderness) and 2) the influence of rapid chill on pork loin WBS values.

Procedures

Twenty-seven market hogs were slaughtered at the KSU Meats Laboratory. From these, 14 right sides were blast chilled for 1 h at -13°F, then chilled for the remainder of 24 h at 34°F. The other 13 right sides were chilled for the entire 24 h at 34°F. At 24 h postmortem, 27 center loin sections, measured from the 4th rib to the 2nd lumbar vertebrae, were boned out and closely trimmed. The loins then were divided equally into anterior and posterior halves at approximately the 10th rib. The treatment halves were injected with a .3 molar solution of $CaCl_2$ through the lateral sides with a 5-needle hand stitch pump injector at 50 p.s.i. until 110% of initial weight was reached (110%+/-.72% pump). The loins then were vacuum packaged and aged for an additional 3 d at 34°F, for a total of 4 d of aging. At 4 d postmortem, purge weights were taken and loins were cut into 1-in-thick chops. Chops from the 8th rib of the anterior and 12th rib of the posterior halves were used for analysis. Chops were weighed

and cooked to an internal temperature of 160°F in a Blodgett dual-air-flow oven. Temperature was monitored using thermocouples attached to a Doric Minitrend 205 temperature monitor. Chops were cooled at room temperature for 2 h, blotted, and reweighed before six .5-in cores were taken perpendicular to the chop surface and sheared using a Universal Instron.

On a follow-up study, loins from five right carcass sides were obtained at 24 h postmortem to determine if the water or injection procedure that was used in our initial study affects WBS values. The same procedures were used with the following exceptions: 1) only standard chill was used, and 2) the injection was 100% water.

Results and Discussion

Rapid chilling (blast chill for 1 h followed by chilling at 34°F) compared with standard chilling (34°F), decreased (P<.0001) longissimus muscle temperature at 2 h, but not (P>.10) at 45 min and 24 h postmortem (Table 1). Rapid chilling did not affect (P>.10) purge, had a tendency (P=.09) to increase cooking loss, and increased (P=.03) combined percentage of purge and cooking loss. Muscle pH measured at 45 min, 2 h, and 24 h and Warner-Bratzler shear values were similar (P>.10) for carcasses that were blast and standard chilled. By increasing chilling rate, combined percentage of purge and cooking loss was reduced without negatively affecting tenderness (WBS).

The injection of $CaCl_2$ into longissimus muscle resulted in minimal increases in the percentage of purge (P=.10), cooking loss (P=.08), or the combination of the two (P=.08) (Table 2). However, $CaCl_2$ injection reduced (P<.0001) WBS values of pork longissimus muscle compared with non-injected controls. The Ca^+ is theorized to increase the activity of the calcium dependent proteases (calpain) and increase muscle tenderness.

In the follow-up study, water injection had no effect (P=.64) on WBS values and only a minimal effect (P=.11) on cooking loss. Therefore, the enhanced tenderness of $CaCl_2$-injected loins was primarily due to $CaCl_2$ and not the addition of water or injection procedure. In conclusion, the incorporation of $CaCl_2$ into pork loins at 24 h postmortem increases tenderness as indicated by a reduction in WBS values.

Table 1. The Influence of Chill Method on Pork Longissimus Muscle Characteristics

Item	Blast chill	SE	Standard chill	SE
Number	14		13	
Temperature, °F				
45 min	102.18	.47	102.04	.56
2 h	75.11[b]	2.25	89.33[c]	2.66
24 h	33.84	1.28	34.09	1.51
ph				
45 min	6.07	.05	6.13	.05
2 h	5.73	.05	5.66	.06
24 h	5.54	.04	5.43	.05
Purge loss, %	5.65	1.29	6.43	1.66
Cooking loss, %	25	2.47	33.21	3.18
Combined loss, %[a]	29.22[b]	1.81	37.52[c]	2.33
WBS, lb	7.39	.28	7.34	.33

[a]Combined loss percentages = purge + cooking loss.
[bc]Means in the same row with different superscripts differ (P<.05).

Table 2. The Influence of $CaCl_2$ Injection on Pork Longissimus Muscle Characteristics

Item	$CaCl_2$ injection	SE	Control	SE
Number	27		27	
Purge loss, %	6.85	1.37	5.22	1.37
Cooking loss, %	32.58	3.00	25.63	3.00
Combined loss, %[a]	37.27	3.52	29.46	3.52
WBS, lb	6.59[b]	.06	8.11[c]	.06

[a]Combined loss percentages = purge + cooking loss.
[bc]Means in the same row with different superscripts differ (P<.05).

Table 3. The Influence of Water Injection on Pork Longissimus Muscle Characteristics

Item	Water injection	Control	SD
Number	5	5	
Cooking loss, %[a]	32.12	28.96	3.43
WBS, lb[a]	7.98	8.42	2.01

[a]No treatment difference (P>.10).

Swine Day 1994

FINANCIAL PERFORMANCE MEASURES FOR KANSAS SWINE FARMS, 1983-1992

M. R. Langemeier[1] *and B. M. Purdy*[1]

Summary

Financial performance measures assist managers in making strategic plans and in tracking progress in relationship to a firm's goals. Kansas Farm Management Association data were used to compute benchmark financial performance measures for swine farms from 1983 to 1992. Annual average net farm income during the study period was $36,370 and ranged from a loss of $6,808 in 1983 to a profit of $69,418 in 1990. Return on investment ranged from -9.36% to 12.09% and averaged 3.71% over the period. The average debt to asset ratio was above 40% in every year except 1989, 1990, and 1992. The average debt to asset ratio was lower in 1992 (29%) than in any other year of the study period.

(Key Words: Profitability, Liquidity, Solvency.)

Introduction

Financial performance measures can be used to assess the profitability, liquidity, solvency, and financial efficiency of a business. These measures provide information about the financial position and health of a business. Financial performance measures typically are used as warning signals and to track a firm's progress towards specific goals.

The objective of this study was to provide benchmark financial performance measures for swine farms in Kansas. This information can be used by swine farm managers and farm financial analysts for comparative purposes.

Procedures

Kansas Farm Management Association data from 1983 to 1992 were used in this study. Enterprise gross farm income was used to classify farms by type. For a farm to be classified as a swine farm, more than 50% of gross farm income had to come from swine sales.

Recommendations of the Farm Financial Standards Task Force were used to define profitability, liquidity, solvency, and financial efficiency measures. Specific definitions of the measures used in this analysis are available from the authors.

Profitability measures explain the efficiency with which a firm uses its resources to produce profits. Profitability measures used in this analysis included net farm income, return on investment, return on equity, and the profit margin ratio. Net farm income was calculated by subtracting cash operating expenses and depreciation from gross farm income. Return on investment represented the return to both debt and equity capital invested in the business. Return on equity measured the residual return to equity capital. The profit margin ratio expressed profit as a percent of total revenue. Rate of return measures were adjusted for capital gains and losses on land and for operator labor and management charges.

[1]Department of Agricultural Economics.

Liquidity measures were used as an indicator of a firm's ability to meet financial obligations as they come due without disrupting the normal operations of the business. Liquidity measures used in this analysis included the current ratio (current assets divided by current liabilities) and working capital (current assets minus current liabilities).

A firm's ability to cover all debt obligations can be depicted with solvency measures such as percent intermediate debt, percent long-term debt, debt to asset ratio, and net worth. The debt to asset ratio is the most commonly used solvency measure. This ratio is calculated by dividing total liabilities by total assets.

Financial efficiency measures show the intensity with which a business uses its assets to generate gross revenues and the effectiveness of production, purchasing, pricing, and financing decisions. The asset turnover ratio, the operating expense ratio, the depreciation expense ratio, the interest expense ratio, and the net farm income ratio were used to analyze financial efficiency. The asset turnover ratio was calculated by dividing gross farm income by total assets. This measure shows how efficiently capital is being used in the business. The expense and net farm income ratios were calculated by dividing the expense category or net farm income by gross farm income.

Results and Discussion

Table 1 presents annual profitability, liquidity, solvency, and financial efficiency measures for swine farms from 1983 to 1992. The average number of litters farrowed per farm was 228. Profits varied substantially from year to year. Net farm income over the period averaged $36,370 and ranged from a loss of $6,808 in 1983 to a profit of $69,418 in 1990. Return on investment for these farms was greater than 10% in 1987 and 1990, but averaged only 3.71% over the period. Because of capital losses on land and low net farm income, returns on investment were negative in 1983, 1984, and 1985.

On average, liquidity was not a problem on these farms. About 42% of the debt on these farms was long-term. Though not presented here, this percent was higher than the amount found on crop, beef, and dairy farms. The average debt to asset ratio over the period was about 41%. The debt to asset ratio peaked in 1986 and was lowest in 1992.

On average, about 70% of gross farm income was used for operating expenses. Another 19% was used for interest and depreciation. The remaining 11% represented net farm income or profit. About 29% of gross farm income was used for interest and depreciation expenses in 1983 and 1984. In contrast, in 1992, only 11% of gross farm income was used for depreciation and interest. The net farm income ratio was greater than 15% in 1986, 1987, 1988, 1990, and 1992.

To assess a farm's financial progress, financial performance measures should be computed and compared with the farm's goals and industry averages. If a farm's performance is below the industry average, corrective action may be needed.

Table 1. Annual Farm Financial Measures for Kansas Swine Farms, 1983-1992

Item	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Number of farms	109	109	84	95	72	71	88	90	101	73
Profitability measures:										
Gross farm income	$191,543	$226,488	$201,109	$249,492	$287,923	$286,252	$256,255	$299,476	$268,129	$327,290
Net farm income	($6,808)	$1,429	$15,371	$50,190	$58,714	$46,222	$31,238	$69,418	$40,077	$57,849
Return on investment	-1.02%	-9.36%	-4.74%	4.47%	12.09%	6.65%	6.47%	11.38%	4.90%	6.25%
Return on equity	-15.04%	-25.60%	-15.22%	1.33%	10.07%	13.29%	3.80%	8.82%	-0.11%	5.32%
Profit margin ratio	-7.30%	-6.99%	-1.27%	11.52%	8.63%	5.68%	3.25%	12.59%	5.57%	6.82%
Liquidity measures:										
Current ratio	1.06	1.18	1.46	1.64	2.33	2.09	2.52	2.71	1.55	2.01
Working capital	$29,135	$28,434	$70,905	$82,287	$109,592	$108,484	$113,983	$131,676	$103,668	$126,135
Solvency measures:										
Percent intermediate debt	20.15%	19.92%	34.62%	33.71%	22.19%	21.79%	28.65%	33.39%	23.26%	23.23%
Percent long-term debt	39.76%	38.24%	40.11%	51.69%	50.70%	50.53%	43.00%	39.47%	41.71%	23.92%
Debt to asset ratio	44.27%	45.60%	44.00%	48.20%	43.30%	41.57%	37.26%	35.93%	40.14%	28.74%
Total assets	$540,374	$569,027	$456,044	$427,299	$432,799	$449,210	$483,398	$504,605	$604,687	$646,944
Net worth	$312,549	$311,502	$284,719	$236,793	$260,534	$284,842	$335,875	$345,547	$419,747	$475,714
Financial efficiency measures:										
Asset turnover ratio	40.01%	44.91%	52.81%	61.22%	66.52%	65.23%	61.75%	69.74%	52.46%	55.22%
Operating expense ratio	77.79%	76.46%	71.86%	62.51%	65.34%	69.70%	72.40%	65.02%	71.14%	69.27%
Depreciation expense ratio	14.38%	15.09%	13.24%	10.47%	10.04%	9.23%	8.38%	7.46%	7.33%	6.34%
Interest expense ratio	14.61%	13.46%	11.16%	10.13%	6.66%	5.82%	6.45%	6.59%	7.22%	4.91%
Net farm income ratio	-6.79%	-5.02%	3.72%	16.87%	17.94%	15.22%	12.74%	20.91%	14.27%	17.81%

Source: Kansas Farm Management Associations.

Swine Day 1994

CASH OPERATING INCOME AND LIQUIDITY MANAGEMENT FOR SWINE FARMS

***B. D. Elliott*[1], *M. R. Langemeier*[1], *and A. M. Featherstone*[1]**

Summary

Net cash flow measures the amount of cash remaining after all cash expense obligations are satisfied. This cash is available for additional farm investment, off-farm investment, family living, and additional debt repayment. A 5-year average monthly cash flow statement was used to determine net cash flow for 13 swine farms. Results indicate that excess cash was used primarily to invest in machinery, vehicles, and nonfarm assets and to increase the allocation for family living. Investments in buildings increased moderately over the study period, but investment in land was minimal. Investment in additional swine facilities was small. Expansion of the breeding herd was not visible on these farms until 1992.

(Key Words: Cash Flow, Liquidity, Investment.)

Introduction

Liquidity and cash flow management tools are essential components used in the implementation of financial control. Liquidity refers to the ability of the farm business to meet financial obligations as they come due and typically is measured using a cash flow statement. Monthly cash flow statements provide information necessary to assess seasonal credit requirements. Long-term cash flow projections also can provide information pertaining to a firm's ability to repay intermediate and long-term loans.

The objective of this study was to determine how excess cash profits (if present) were used on several swine farms in Kansas. Monthly sources and uses of funds are presented and discussed.

Procedures

Data on cash transactions, inventories and production information for 13 swine farms was available from the Financial Plus program of the Kansas Farm Management Association. To be included in this analysis, a farm had to have data for 1988, 1989, 1990, 1991, and 1992.

A monthly cash flow statement was used to determine the amount of excess cash available for investment and debt repayment. A cash flow statement summarizes all cash transactions concerning the business or enterprise during a given period. The net cash flow measure included farm and nonfarm sources and uses of cash. Cash operating income, defined as the amount of cash income from the farm business, was used to measure both profitability and liquidity. This cash is used for discretionary purposes such as meeting scheduled principal payments, on and off farm investment, and family living. Net loans were calculated as loans received minus loans repaid and reflect the level of debt repayment. A negative value for net loans indicated that producers were paying down debt. Financial and production variables were analyzed to ascertain where excess cash was invested.

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Results and Discussion

Table 1 presents a 5-year average monthly cash flow statement for the 13 swine farms. The swine farms were profitable during the period, averaging $40,391 of net farm income (accrual basis) per year and $56,972 of cash operating income (cash basis) per year. Net cash flow averaged $217 per month or $2,604 per year. This cash was available for new or unplanned investments. Using Table 1, we can analyze the seasonality of the various revenue and expense items, as well as the summary variables (lower portion of the table). Cash operating income and net cash flow were, on average, negative in June, September, and December. The largest monthly net cash flows occurred in January and August. The largest monthly principal payment occurred in January. Swine producers took out the most loans in January, September, October, and December. June, July, September, and December were the months when net loans were positive. Net loans were negative in 1989, 1991, and 1992. This indicates that swine producers were paying off debt in those years. On average, these farms paid down loans by $6,672 per year during the study.

Net cash flow was positive from 1988 through 1991 and negative in 1992. Excess cash was used primarily to finance intermediate assets (Table 2). Table 2 is not a complete balance sheet but does list end-of-year balances for swine farm assets. Swine producers in this study increased vehicle and equipment inventories, nonfarm assets, and family living expenses. Family living expenses increased from $9,651 in 1988 to $34,647 in 1992. Most of the increases in family living occurred because of increases in taxes, medical expenses, and recreational expenses. Equipment inventory increased by $53,119 (83%) during the period. Nonfarm asset inventory increased from $7,912 in 1988 to $29,601 in 1992 or 274%. Investments in buildings grew by 44% over the period. The value of owned land increased by 5.8% during the period.

Fluctuations in the values of current livestock and crop inventories can be misleading and may not indicate a change of production. These fluctuations can be caused by changes in the individual commodity prices. Production numbers, such as average litters per year, suggest that swine production was very steady during the period. In 1992, breeding stock purchases increased. Before 1992, breeding stock purchases averaged five head per year. However, in 1992, an average of 22 head of breeding stock was purchased.

Cash flow management is an essential component of financial control. Anticipating cash needs alleviates last-minute decisions, which can be expensive. In addition, understanding the cyclical need of cash generation will allow producers to make better investment decisions.

Table 1. Monthly Cash Flow Statement for Swine Farms, 1988-1992

Item	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Sources													
Livestock	27,990	19,356	20,874	18,114	20,874	16,823	17,403	22,429	17,320	20,187	18,694	13,891	233,956
Breeding stock	1,020	1,058	1,305	1,494	1,646	982	1,142	1,633	1,113	1,642	1,723	1,171	15,928
Crops	11,771	4,520	5,981	5,981	2,911	2,081	6,941	3,403	3,219	10,934	8,415	10,576	76,732
Miscellaneous[a]	1,065	570	352	437	777	734	863	682	600	505	700	2,840	10,124
Vehicles	0	0	33	0	59	0	46	59	77	0	100	15	390
Equipment	52	51	22	91	22	34	18	1	0	0	11	226	527
Buildings	0	0	0	0	0	27	0	0	0	0	0	9	36
Land	0	0	0	369	0	0	0	0	0	0	0	0	369
Total farm sources	41,897	25,555	28,567	26,486	26,289	20,680	26,414	28,207	22,329	33,268	29,643	28,728	338,062
Nonfarm	1,103	1,567	1,041	4,003	2,061	1,319	1,726	1,128	825	2,527	2,062	4,928	24,290
Total sources	43,000	27,122	29,608	30,489	28,350	21,999	28,140	29,335	23,154	35,795	31,705	33,656	362,352
Uses													
Livestock purchases	614	178	1,358	924	356	160	214	674	739	1,703	2,226	1,214	10,360
Feed	7,493	7,486	8,055	8,703	8,202	8,905	8,749	8,871	10,673	13,407	10,306	14,847	115,698
Veterinary	430	501	463	546	608	472	426	482	484	485	454	661	6,011
Lvstck & crop mktg	260	100	378	226	306	352	372	207	198	369	229	184	3,181
Fert., seed & chem.	647	1,007	1,137	1,993	3,218	2,837	3,414	1,902	1,461	2,215	2,244	1,944	24,020
Machine hire & labor	1,780	1,526	1,830	1,907	1,674	2,099	2,197	2,075	1,787	2,102	1,764	2,399	23,140
Fuel and repairs	2,294	2,763	2,667	2,744	3,184	2,909	3,532	3,412	3,054	3,423	3,290	4,095	37,365
Grn pur. for resale	1,706	1,063	1,019	720	774	(24)	1,334	512	86	548	161	266	8,164
Farm utilities	813	909	875	937	759	688	754	727	799	827	742	764	9,594
Vehicles	841	798	361	571	595	247	734	743	994	3,028	246	(320)	8,838
Equipment	762	788	846	604	1,056	428	1,072	635	1,171	1,048	1,073	695	10,178
Buildings	326	271	289	1,917	132	302	321	338	392	128	220	328	4,963
Land	0	0	0	0	733	963	164	77	0	477	382	45	2,841
Prop tax & farm ins.	586	293	365	211	412	1,406	307	268	610	304	202	2,059	7,022
Interest paid	2,972	1,008	870	1,229	658	1,042	1,629	775	507	1,266	3,424	6,010	21,390
Cash rent	817	279	374	1,381	435	657	444	240	494	886	686	2,816	9,510
Miscellaneous	689	342	256	580	122	407	141	483	411	291	328	262	4,312
Total farm uses	23,029	19,313	21,143	25,193	23,224	23,849	25,804	22,422	23,861	32,505	27,976	38,269	306,588
Nonfarm	787	2,942	1,522	1,683	468	560	463	373	403	398	423	710	12,733
Family living	1,063	980	1,169	1,146	1,595	1,325	1,045	1,307	1,101	998	1,166	1,518	14,414
Nondeductible	1,124	1,827	1,767	1,039	675	421	529	471	497	1,288	818	3,194	13,650
Deductible	1,558	381	534	503	263	273	349	416	472	321	293	339	5,702
Total nonfarm uses	6,533	6,130	4,992	4,371	3,001	2,580	2,386	2,567	2,473	3,006	2,700	5,760	46,499
Total uses	29,563	25,443	26,135	29,564	26,225	26,429	28,189	24,989	26,334	35,511	30,676	44,029	353,087
Loans received	9,890	7,274	6,379	8,668	7,544	7,495	8,672	6,925	10,441	12,645	7,020	14,997	107,950
Loan payments	20,056	8,790	8,592	8,713	8,385	5,590	8,582	8,613	8,001	12,944	7,791	8,559	114,616
Net loans	(10,167)	(1,515)	(2,213)	(45)	(842)	1,904	90	(1,688)	2,440	(299)	(771)	6,439	(6,666)
Cash operating income	20745	8048	8865	3925	5500	-1290	2837	7518	948	5444	3477	-9043	56972
Net cash flow[b]	3,271	163	1,260	880	1,283	(2,526)	40	2,658	(740)	(15)	258	(3,934)	2,598
Debt service ratio (%)[c]	53.55	36.12	31.96	32.61	31.90	30.15	36.29	32.00	36.75	39.70	35.37	43.29	37.53

[a]Miscellaneous income includes custom hire income, acct rec, and other income.

[b]Total Sources - Total Expenses + Net Loans.

[c]Debt service ratio is principal and interest payment divided by total cash sources and then multiplied by 100.

Table 2. Swine Farm Assets, Liabilities, and Family Living Expenses, 1988 to 1992

Item	1988	1989	1990	1991	29
Current assets					
Cash and accounts receivable	39,548	39,217	43,338	32,945	6
Feeder hogs	60,767	60,415	70,160	62,191	4
Other feeder livestock	12,335	10,295	13,743	9,572	1
Stored grains	71,326	33,775	48,979	51,043	6
Supplies	2,579	785	1,455	1,372	
Intermediate assets					
Swine breeding stock	23,746	27,510	30,316	22,861	4
Other breeding stock	10,569	10,170	10,038	9,944	2
Vehicles and equipment	63,970	55,490	55,833	111,376	9
Longterm assets					
Land	233,294	241,833	250,314	246,853	3
Buildings	24,512	22,335	17,766	33,242	4
Liabilities					
Current loans	122,328	112,152	114,817	127,332	6
Intermediate loans	24,672	20,169	25,832	29,321	2
Longterm loans	105,456	110,706	102,952	98,072	7
Nonfarm					
Family living expense	9,651	11,719	13,499	21,908	7
Nonfarm assets	7,912	12,044	10,298	20,019	1
Nonfarm loans	3,923	3,654	3,385	1,885	

Swine Day 1994

ADVANTAGES AND DISADVANTAGES OF HOG MARKETING GROUPS[1]

J. Mintert[2], R. Tynon[2], M. Tokach, M. Langemeier[2], and T. Schroeder[2]

Summary

Ten hog marketing groups located in Kansas and Iowa were surveyed during 1993 to determine the success, operation, and management of hog marketing groups. Marketing group leaders were asked to identify principal advantages and disadvantages of marketing hogs in groups. Survey responses indicated that marketing hogs in groups led to producers receiving higher sale prices for their hogs and helped reduce their marketing costs. Commonly cited disadvantages of group marketing, included a loss in marketing flexibility, difficulties in coordinating loads among group members, and concerns about increased susceptibility to diseases from other herds.

(Key Words: Hog Marketing Groups.)

Introduction

Both the number of swine operations and the volume of hogs marketed in Kansas have declined dramatically in recent years. There were 13,000 swine operations with annual marketings of 3.069 million head in 1981. In 1993, there were 5,300 swine operations with annual marketings of 2.472 million head. This is a 60 percent reduction in the number of hog operations and a 20 percent reduction in hog marketings over a 12-year period in Kansas. The decline in the number of Kansas operations came solely from operations with inventories of less than 1000 head. The number of Kansas hog operations with 1000-2000 head inventories held steady, and operations with inventories greater than 2000 head increased by 10 operations from 80 to 90. Changes in the structure of Kansas' hog industry follow the national trend of fewer hog producers with a larger average size of operation.

The changing structure of the hog industry has encouraged many midwestern hog producers to form marketing groups. Group marketing entails individual pork producers marketing hogs collectively to increase the price received and/or reduce their marketing costs. One of the objectives of this study was to identify the advantages and disadvantages of group hog marketing.

Procedures

Hog marketing groups operating in Kansas and Iowa were identified through industry contacts. An in-depth survey was conducted through personal interviews with the leaders of the marketing groups.

Results and Discussion

Seven of the 10 hog marketing groups were located in Kansas. Six of these were still actively marketing hogs as groups in 1993. The groups surveyed were located primarily in the eastern half of Kansas.

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[1]Financial support for this study was provided by the Kansas State Board of Agriculture and the Kansas Agricultural Experiment Station. The cooperation of all producers completing surveys is greatly appreciated.

[2]Department of Agricultural Economics.

Group membership ranged from seven to 15 members. During 1993, 64 Kansas hog producers marketed hogs through the groups included in the survey. These six operational groups marketed approximately 100,000 hogs in 1993 based on average weekly marketings reported by group leaders. Annual hog marketings per group in Kansas ranged from 5,000 to 37,000 head. On an annual basis, hogs marketed by groups in the survey represented less than 5 percent of the hogs marketed by Kansas hog producers during 1993. The length of time the surveyed groups were in existence ranged from less than 1 year to 12 years. On average, marketing groups in the survey had been in existence approximately 5 years.

Hog marketing groups can be classified as a product differentiation group, a transaction cost group, or a transaction/marketing cost group, depending on the objective of the group. Groups oriented toward marketing a large volume of hogs with high quality carcasses and little variability among carcasses can be characterized as product differentiation groups. Transaction cost groups consist of independent pork producers banding together primarily to market hogs directly to packers in semitrailer loads. The third category, transaction/marketing cost groups, organize primarily to reduce group members' marketing costs, but also implement strategies designed to raise their members' sale prices.

Table 1 provides group leaders' responses to survey questions regarding marketing hogs in a group compared with marketing hogs as individual producers. Group leaders from all types of marketing groups felt that group marketing increased the prices received per cwt. for their members. However, product differentiation-group leaders were in stronger agreement that group marketing increased price received for their hogs than were leaders of transaction cost or transaction/marketing groups.

Ninety percent of all group leaders felt that the group marketing strategy reduced time spent marketing hogs by group members. Transaction cost- and transaction/marketing-group members were most likely to benefit from spending less time marketing their hogs. In several instances, producers in these groups were making round trips of considerable distance to market their hogs. Group marketing reduced the number of trips and the time for each trip.

Product differentiation-group leaders were more likely to report benefits associated with members reducing the worry over marketing their hogs as a result of group marketing. These groups used long-term marketing agreements. The negotiated base-bid formula found in these agreements provided many producers with the "peace of mind" that they were going to receive satisfactory base bids over an extended time period.

Group leaders were split on whether group marketing allowed members to significantly reduce sort loss discounts when selling hogs on a carcass merit basis. Some transaction cost-group leaders did not feel they marketed hogs often enough to significantly reduce sort loss discounts. Producers using the "all in-all out" management strategy to minimize health problems and gain production efficiency have trouble reducing sort loss discounts. Leaders that felt sort loss discounts declined when marketing with a group cited increased producer awareness of sort loss discounts and development of a more disciplined marketing schedule as reasons for the reductions.

Leaders of 80 percent of the groups felt that group marketing reduced marketing costs. Leaders of transaction cost groups unanimously agreed that transportation costs per cwt. declined when hogs were marketed in semitrailer loads rather than in small trucks. Marketing costs also fell because fewer marketing trips were made and/or producers travelled shorter distances to load hogs on the group's semitrailer versus marketing individually. Additionally, marketing costs declined because only one person solicited and accepted bids for the group versus each individual producer spending time and money soliciting and accepting packer bids.

Despite these apparent cost advantages for group marketing, two group leaders did not

feel marketing costs declined when producers were marketing hogs in a group. Transportation costs for some groups did not fall, because producer members were already marketing hogs directly to a packer in semi-trailer loads. In other groups, transportation costs did not decline because no significant difference occurred in the distance to the packing plant versus the group's central loading site. Groups that did not experience a reduction in transportation costs per cwt. felt that group marketing costs were higher for members, if marketing fees were charged.

The vast majority of group leaders (80 percent) felt producers gained valuable information on how to improve the genetic quality of their herds by marketing hogs in a group. These groups either formally or informally shared kill sheet data among group members and learned which genetic lines were performing well under packers' carcass merit programs. This sharing of information gives producer members more reliable data to make informed decisions and increase the profitability of their operations. Marketing groups that did not feel group marketing provided valuable information on how to improve genetic quality also did not put much emphasis on sharing and comparing data.

Table 2 provides a summary of survey results with regard to specific advantages, disadvantages, and desired changes in marketing group operations voiced by group leaders in the survey. This table was developed using the most often stated responses from the 10 marketing group leaders. The three main advantages of marketing hogs collectively in a group for independent swine producers are 1) increase price received per cwt., 2) reduced marketing costs, and 3) the ability to make more informed management decisions as a result of comparing and sharing information with other hog producers. If a member of a hog marketing group is realizing any one of these advantages, the group marketing strategy was at least partially successful.

The main disadvantages of group marketing were voiced by transaction cost- and transaction/marketing-group leaders. Product differentiation-group leaders were more satisfied with the group marketing strategy. The disadvantages of group marketing listed in Table 2 are problems that are inherent when many producers are needed to complete a group shipment. Ways to remedy these problems are to hire a market coordinator and to acquire a central loading site. Flexibility in marketing hogs will increase as the volume of hogs marketed by the group increases. Volume of hogs marketed and membership in the marketing group will grow as other area producers see current members benefitting from group marketing. Marketing groups that are well organized and increase prices received or reduce marketing costs will have no trouble gaining volume and increasing membership.

Table 1. Attitudes and Feelings Concerning Hogs Marketing Group

Factor	Strongly agree	Agree	Indifferent	Strongly disagree	Disagree
			(Percent of respondents)		
Group marketing members receive higher prices per cwt. versus marketing hogs as individual producers	40	40	10	10	0
Group marketing members spend less time and worry marketing hogs	70	20	0	10	0
Group marketing members market hogs more often and at more uniform weights, significantly reducing sort loss discounts	40	20	40	0	0
Group marketing lowers marketing costs (transportation, bid soliciting, etc.)	40	40	10	10	0
Group marketing provides members valuable information on how to improve herd genetic quality	40	40	20	0	0

Table 2. Survey Summaries: The Top Three Advantages/Disadvantages of Group Marketing and Desired Changes in Group Operations

ADVANTAGES	1. Increased price received per cwt. as a result of one or a combination of the following reasons: a. Increase in the base bid or live-weight bid from delivering hogs directly to the plant versus delivery to a buying station, b. Receiving premiums for quality by selling the hogs on carcass merit versus selling the hogs on a live-weight basis, c. Increase in base bid as a result of marketing a volume of consistent, high quality hogs, d. Increase in base bid from entering into long-term delivery contract with a packer, guaranteeing some minimum level of carcass quality. 2. Lower cost of marketing hogs as a result of one or a combination of the following reasons: a. Reducing the transportation costs per hundred-weight by shipping hogs in semitrailer loads versus small truck loads, b. Reducing the time spent marketing hogs by reducing the distance traveled and number of marketing trips. 3. Making more informed management decisions as a result of sharing and comparing data and information with other hog producers.
DISADVANTAGES	1. Lack of flexibility in marketing hogs as a result of marketing group shipments occurring only once a week or less. 2. Increased susceptibility to diseases from increased contact with other producers' hogs and equipment. 3. Difficulties in coordinating a group shipment when several producer-members' hogs are needed to fill a semitrailer shipment.
DESIRED CHANGES	1. Hire a market-coordinator. 2. Increase volume of hogs marketed by group. 3. Acquire central loading site. 4. Establish more procedures regarding coordination of a group load. 5. Require common genetics for group membership.

Swine Day 1994

SUCCESSFUL HOG MARKETING GROUPS[1]

J. Mintert[2], R. Tynon[2], M. Tokach, M. Langemeier[2], and T. Schroeder[2]

Summary

Ten hog marketing groups located in Kansas and Iowa were surveyed during 1993 to determine the success, operation, and management of hog marketing groups. Results offer insights into the structure and organization of cooperative hog marketing efforts. Several guidelines for organizing successful hog marketing groups are proposed. Producers interested in forming a marketing group should consider having a written agreement, hiring a marketing group coordinator, and marketing hogs on a carcass merit basis.

(Key Words: Hog Marketing Groups.)

Introduction

Independent pork producers are facing increased competition in the pork industry. Producers are trying new marketing strategies to increase the price received per hundredweight and to lower their marketing costs. Group marketing is a strategy that pork producers are using to help attain these goals. Group marketing entails individual pork producers marketing hogs collectively to increase price received and/or reduce marketing costs. One of the objectives of this survey was to identify the operation and management structure of successful marketing groups.

Procedures

Hog marketing groups operating in Kansas and Iowa were identified through industry contacts. The survey centered on personal interviews with marketing group leaders. Seven of the 10 hog marketing groups were located in Kansas. Six of these were still actively marketing hogs as groups in 1993. The groups surveyed were located primarily in the eastern half of Kansas. Group membership ranged from seven to 15 members. During 1993, 64 Kansas hog producers marketed hogs through the groups included in the survey. These six operational groups marketed approximately 100,000 hogs in 1993 based on average weekly marketings reported by group leaders. Annual hog marketings per group in Kansas ranged from 5,000 to 37,000 head. On an annual basis, hogs marketed by groups in the survey represented less than 5 percent of the hogs marketed by Kansas hog producers during 1993. The length of time the surveyed groups were in existence ranged from less than 1 year to 12 years. On average, marketing groups in the survey had been in existence approximately 5 years.

Results and Discussion

Hog marketing groups can be classified as a product differentiation group, a transaction cost group or as a transaction/marketing cost group, depending on the objective of the

[1]Financial support for this study was provided by the Kansas State Board of Agriculture and the Kansas Agricultural Experiment Station. The cooperation of all producers completing surveys is greatly appreciated.

[2]Department of Agricultural Economics.

group. All three types of groups were generally successful in meeting their goals, but groups that emphasize product differentiation appear to have the most potential to improve the net income of members.

Groups oriented toward marketing a large volume of hogs with high quality, homogeneous carcasses can be characterized as product differentiation groups. These groups seek to obtain higher prices for members' hogs by emphasizing carcass quality. By necessity, these groups have specific membership requirements designed to control or improve the quality of hogs marketed by the group. Marketing groups in this category tend to compensate the group leader and charge members fees to market hogs with the group. Group leaders often summarize carcass data for the group and make it easy for individual members to compare the performance of their hogs with those of other members of the group. Some groups in this category have entered into marketing arrangements with a particular packer lasting for several months.

Transaction cost groups consist of independent pork producers banding together primarily to market hogs directly to packers in semitrailer loads. Their primary objectives are to reduce transportation costs by capturing transportation economies of size and to increase their sale prices by gaining access to more markets. Marketing groups in this classification do not have specific membership requirements, pay their group leaders, or charge members to market with the group. Finally, these groups typically do not enter into long-term marketing agreements with a single packer.

The third category, transaction/marketing cost groups, organize primarily to reduce group members' marketing costs, but also implement strategies designed to help raise their members' sale prices. Unlike groups whose primary focus is to reduce transaction costs, these groups compensate their group leaders, charge members to market hogs with the group and enter into long-term marketing agreements with a single packer. These groups differ from groups that are attempting to market a differentiated product in that they do not have membership requirements to help control carcass quality. In turn, this sometimes leads these groups to negotiate marketing agreements with more than one base bid to help account for the carcass quality variation among members' hogs.

Table 1 provides insights into the organizational structure used by the various marketing groups. Hog marketing groups classified as transaction cost groups had relatively few formal rules regarding the structure of the marketing group. For example, they had no rules governing hiring or firing personnel or membership eligibility and charged no marketing fees. However, transaction cost groups did establish rules covering the various details needed to coordinate and complete a group shipment of hogs to a packer. These groups had no organizational structure to control the quality of the hogs marketed by the group. In general, groups oriented toward reducing marketing costs were loosely structured, had no membership requirements, and did not charge members a marketing fee to market hogs with the group.

Marketing groups organized to market consistent, high quality hogs had an organization structure in place to control the quality of the hogs marketed by the group. All three groups classified as product differentiation groups establish specific membership requirements to control the quality of hogs marketed by the group and charge members a fee to market hogs with the group. Three marketing groups indicated that they had the authority to establish rules requiring their producer-members to meet genetic and nutritional requirements, either through the market coordinator or the board of directors. However, only one of the product differentiation groups had established rules requiring members to have a certain line of genetics and to follow specific nutritional guidelines. Overall, a direct relationship existed between the organizational structure and the goals of a marketing group. Product differentiation groups require more rules designed to control the quality of the carcasses marketed by the group and, thus, require more organizational

structure than transaction cost-oriented groups.

The following guidelines for the operation of a hog marketing group are designed to help producers interested in starting a hog marketing group and to enhance current groups' operations. Seemingly small changes in group policy or operating procedures can spell the difference between success or failure of group marketing programs. Suggested guidelines for operating a successful marketing group are:

- Have a written agreement;
- Hire a marketing group coordinator;
- Market hogs on carcass merit rather than on a liveweight basis;
- Summarize and analyze kill sheet data;
- Distribute information to group members and make comparisons concerning carcass, growth, and reproductive traits; and
- Consider using new marketing strategies, such as long-term marketing agreements.

Table 1. Operational Details of Hog Marketing Groups

Decision	Market coordinator	Board of directors	No rules
		(percentage of groups)	
Hire and fire market coordinator and other personnel	10	30	60
Establish rules concerning member eligibility	10	20	70
Establish rules concerning shipping of hogs, allocating space on truck, and scheduling time intervals to load hogs	90	0	10
Establish rules concerning bid solicitation and acceptance	40	20	40
Establish marketing fees	40	20	40
Establish rules concerning optimal live-weights to market hogs	10	30	60
Establish rules concerning members meeting genetic, breeding, and nutritional guidelines to attain group objectives	10	20	70

Swine Day 1994

KANSAS STATE UNIVERSITY SWINE ENTERPRISE RECORD SUMMARY[1]

B. T. Richert, R. D. Goodband, M. L. Langemeier[2], M. D. Tokach, and J. L. Nelssen

Summary

Approximately 15 swine operations are enrolled in the 1993 to 1994 Kansas Swine Enterprise Record Program provided by Kansas State University. This 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. Records are summarized every 6 months, and the corresponding data are pooled to form state and regional averages. This summary includes the combined data for the 38 farrow-to-finish operations in the three-state region. The semi-annual data represent the first 6 months of 1994, whereas the annual data are for the 12-month period of July 1, 1993 to June 30, 1994. Profit per cwt of pork produced for these 38 producers averaged a loss of $0.85 for the first 6 months of 1994 and a loss of $2.92 for the past year. Profits varied substantially between producers. Producers in the top one-third in terms of profitability had average profits of $4.47 per cwt, whereas producers in the bottom one-third had average losses of $10.05 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.

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[2]Department of Agricultural Economics.

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 1993-94 regional (KS, NE, and SD) group summaries reported in Table 1. Profit per cwt of pork 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 for the 38 farrow-to-finish producers in the program averaged slightly below breakeven (-$.85 per cwt) over the first 6 months of 1994. However, profits varied substantially between producers. For the first 6 months of 1994, producers in the top one-third in terms of profitability had average profits per cwt of $7.25. Producers in the bottom one-third had average losses of $10.57 per cwt. Profit differences remained similar between these two groups for the year (+4.47 vs -10.05).

Notice that returns over cash costs (Line 2) were positive for all three profit groups for the last 6 months and the whole year. 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 last 6 months and the year. The average producer also could not cover these costs in the last 6 months of 1993; thus, their return to management was negative (line 3) for the year. 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 38 producers for the entire year. Note that the return on capital for producers in the bottom one-third profitability group was negative (-15.26) 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 per cwt for each of the variable (33.60) and total (38.17) cost categories compared to the average producers' variable (39.81) and total (44.83) costs per cwt of pork produced. A $13.75 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 $4.95 or 36% of the difference in total costs for the two profit groups. Cheaper diets did not correspond directly to lower feed costs. However, the top one-third producers were able to purchase their feed for $.90/cwt less (line 52) for the year. A 11.1% improvement in feed efficiency occurred between producers in the top vs bottom one-third profit groups for the first 6 months of 1994; however, for the whole year, the improvement in feed efficiency was 6.1%.

Other operating expenses include utilities, hired labor, supplies, repairs, veterinarian costs, and professional dues. Other operating expenses and interest costs on capital accounted for 26.5% and 7.8% 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 $2.37

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 17.2% of the difference in total costs per cwt between the two groups.

Differences in fixed costs per cwt accounted for the remaining 14.8% of the difference in total costs between producers in the high- and low-profit groups for the year.

Producers in the top and bottom one-third groups had similar litters per sow per year (line 25), 1.99 vs 1.95, respectively. Producers in the top one-third group weaned fewer pigs per litter (line 28), but weaned more litters per crate and, therefore, produced more pigs per crate (line 30). The number of pigs sold per litter farrowed (line 31) was higher in the top versus bottom one-third profit groups. This reflects the difference in death loss between these groups. 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 (18.11 vs 28.79). 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 last 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.

Item	Farrow to Finish Operations					
	Semi-Annual Data (38 farms)			Annual Data (22 Farms)		
	Average	High 1/3	Low 1/3	Average	High 1/3	Low 1/3
1. Net pork produced, lbs.	218,859	196,272	147,358	604-,431	617-,162	713-,259
2. Income over feed, oper. exp., oper. int., & hired labor	19,153	26,624	6,161	27,162	68,739	251
3. Profit or return to management, ELD	2,319	14,245	(11,098)	(16,186)	27,557	(57,321)
4. Annual rate of return on capital, ELD	7.40	27.41	-21.02	-.12	19.23	-15.26
Variable expenses:						
5. Total feed expense/cwt pork produced	27.23	24.56	29.08	26.49	23.55	28.50
6. Other oper. expenses (total)/cwt pork produced	6.33	4.30	8.28	7.57	5.82	9.46
a. Utilities; fuel, electricity, phone/cwt pork produced	1.31	0.98	1.63	1.39	1.23	1.45
b. Vet. expenses and medications/cwt pork produced	1.17	0.67	1.51	1.06	0.71	1.59
c. Remainder of other oper. expenses/cwt pork produced	3.85	2.64	5.14	5.11	3.88	6.43
7. Total cost of labor/cwt of pork produce	5.44	4.05	7.46	5.18	3.73	6.71
8. Total oper. capital inv./cwt of pork produced	20.99	17.62	23.70	18.93	15.43	21.39
9. Int. cost on oper. invest./cwt of pork produced	2.52	2.11	2.84	2.27	1.85	2.57
10. Total variable cost/cwt of pork produced	40.57	34.04	46.51	39.81	33.60	45.28
Fixed and total costs:						
11. Total fixed cap. inv. (ELD)/cwt of pork produced	20.30	15.60	31.41	21.09	18.11	28.79
12. Int. chg. on fixed inv. (ELD)/cwt of pork produced	2.03	1.56	3.14	2.11	1.81	2.88
13. E.L. deprec., taxes and ins. cost/cwt of pork produced	2.66	1.92	3.96	2.91	2.76	3.76
14. Tax deprec., taxes and ins. cost/cwt of pork produced	2.17	1.49	3.33	2.45	2.46	3.17
15. Fixed cost (ELD)/female/period	86.22	70.38	121.58	202.62	202.26	269.14
16. Fixed cost (ELD)/crate/period	368.37	296.80	520.62	1004.07	1116.54	1268-.28
17. Total cost (ELD)/cwt of pork produced	45.26	37.51	53.62	44.83	38.17	51.92
18. Total cost (ELD)/female/period	859.91	750.42	975.78	1754-.67	1584.12	2057.56
19. Total cost (ELD)/crate/period	3654.34	3046.32	4119.86	8446.37	8160.60	9723.02
Income and profit						
20. Profit based on econ. life deprec./-cwt of pork produced	-0.85	7.25	-10.57	-2.92	4.47	-10.05
21. Profit based on tax deprec./cwt of pork produced	-0.15	7.40	-9.08	-2.76	3.72	-9.67
22. Profit based on econ. life deprec./female/period	-2.78	145.69	-171.10	-112.03	177.85	-401.45

23. Profit based on econ. life deprec./crate/period	-0.98	585.97	-689.52	-513.89	-880.74 -1872.78

Semi-annual date January 1, 1994 - June 30, 1994 & annual date July 1, 1993 - June 30, 1994. Profit, 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) Aver-age	High 1/3	Low 1/3
Production summary:						
24. Average female inventory	117	100	85	157	145	187
25. Number of litters weaned/female/period	1.00	1.04	0.97	1.94	1.99	1.95
26. Number of litters weaned/crate/period	4.29	4.20	4.15	9.32	9.99	9.28
27. Number of live pigs born/litter farrowed	10.41	10.26	10.46	10.19	9.96	10.42
28. Number of pigs weaned/litter farrowed	8.94	9.04	8.75	8.73	8.58	8.87
29. Number of pigs weaned/female/period	8.88	9.21	8.41	16.88	16.81	17.48
30. Number of pigs weaned/crate/period	38.09	37.20	36.21	81.32	85.59	83.03
31. Number of pigs sold/litter/period	7.48	7.66	7.35	7.82	8.09	7.58
Death loss:						
32. Birth to weaning (% of no. born)	15.27	12.06	18.94	12.75	10.91	13.56
33. Weaning to market (% of no. weaned)	4.85	2.96	6.39	5.23	3.24	5.52
34. Breeding stock (% of breeding herd maintained)	2.37	2.75	1.53	3.67	3.03	3.45
Labor:						
35. Labor hours/cwt of pork produced	0.74	0.55	1.02	0.72	0.60	0.90
36. Labor hours/female/period	13.91	10.92	18.51	28.53	26.20	35.46
37. Labor hours/litter weaned/period	14.05	10.48	19.27	14.83	13.07	18.64
38. Cost of unpaid labor & mgmt./cwt of pork produced	4.49	3.07	6.32	3.49	2.38	4.75
39. Total cost of labor (paid + unpaid)/cwt of pork produced	5.44	4.05	7.46	5.18	3.73	6.71
40. Total cost of labor (paid + unpaid)/female/period	102.35	79.76	136.26	201.34	154.88	262.34
41. Return/hour for all hours of labor and management	9.65	21.56	-1.72	4.91	16.23	-3.87
Marketing and purchases:						
42. Number of market hogs sold	797	688	541	2212	2231	2638
43. Average weight/head for market hogs sold	245	246	245	245	247	246
44. Average price received for market hogs/cwt	45.29	45.06	45.61	45.96	46.22	46.19
45. Number of feeder pigs sold	36	66	4	101	25	74
46. Average weight/head of feeder pigs sold	44.1	46.1	81.2	46.4	54.2	33.5
47. Average price received/head for feeder pigs sold	47.40	48.03	58.74	44.70	44.00	46.07
48. Average price received/cwt for feeder pigs sold	92.11	101.28	67.15	75.90	86.31	79.78
Feed cost and consumption:						
49. Total lbs of feed fed/cwt of pork produced	362	337	379	376	356	379
50. Total lbs of grain fed/cwt of pork produced	284	266	299	298	290	295
51. Total lbs of supplement fed/cwt of pork produced	78	72	80	78	67	84
52. Average costs of diets/cwt	7.54	7.34	7.69	7.05	6.62	7.52

Semi-annual date January 1, - June 30, 1994 & annual date July 1, 1993 - June 30, 1994.

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