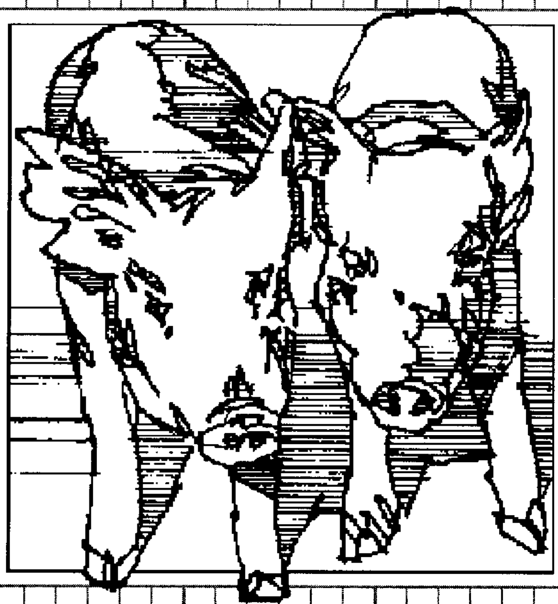

K-STATE
Kansas State University

SWINE DAY 1997

REPORT OF PROGRESS 795, KANSAS STATE UNIVERSITY AGRICULTURAL EXPERIMENT STATION AND COOPERATIVE EXTENSION SERVICE

FOREWORD

It is with great pleasure that we present to you the 1997 Swine Industry Day Report of Progress. This report contains updates and summaries of applied and basic research conducted at Kansas State University during the past year. We hope that the information will be of benefit, as we attempt to meet the needs of the Kansas swine industry.

Editors, 1997 Swine Day Report of Progress,

Bob Goodband   Mike Tokach   Steve Dritz

ABBREVIATIONS USED IN THIS REPORT

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

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BIOLOGICAL VARIABILITY AND CHANCES OF ERROR

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

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

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

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

Swine Day 1997

LAGOON SEEPAGE THROUGH SOIL LINERS

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

Summary

Most compacted soils can be used for lagoon liners to achieve seepage guidelines established by the Kansas Department of Health and Environment.

(Key Words: Lagoon Seepage, Permeability, Soil Lagoon Liner.)

Introduction

This article is a condensed draft of the new Natural Resources Conservation Service's (NRCS) Technical Note 716. Information contained in this draft should not be considered as final NRCS data until the draft is formally approved and distributed.

The protection of surface and groundwater and the utilization or disposal of animal waste are the primary functions of waste storage ponds and treatment lagoons. Seepage from these structures creates risks of pollution of surface water and underground aquifers. The permeability of the soil in the boundaries of a constructed waste treatment lagoon or waste storage pond strongly affects the potential for downward or lateral seepage of the stored wastes.

Research has shown that many natural soils on the boundaries of waste treatment lagoons and waste storage ponds will seal at least partially as a result of physical, chemical, and biological processes. Suspended solids settle out of suspension and physically clog the pores of the soil mass. Anaerobic bacteria produce byproducts that accumulate at the soil-water interface and reinforce the seal. As organic material is metabolized, the soil structure also can be altered. Chemicals in animal waste, such as salts, can disperse soil, which may be beneficial in reducing seepage. Under these conditions, researchers have reported that the permeability of the soil can be decreased several orders of magnitude in a few weeks following contact with an animal waste storage pond or treatment lagoon.

The physical clogging of the soil is considered to be a function of the type of waste, the percent total solids in the waste, and the permeability and the size and geometry of soil pores. Until recently, research has focused on total solids of the waste as the most important factor in the physical sealing process. Research published in the late 1980's convincingly showed that a soil's equivalent pore size computed as a function of particle size distribution and porosity is probably the more important parameter in the physical sealing mechanism. Research has shown that manure sealing will cause a reduction in permeability of 1 to 3 orders of magnitude for all soils. However, for soils with a very high initial permeability, this reduction alone will probably not provide enough protection against excessive seepage and groundwater contamination. Other research has demonstrated that for soils with a clay content exceeding 5 percent for ruminant or 15 percent for monogastric animal manure, a final permeability of 10^{-6} to 10^{-7} cm/sec usually results from manure sealing.

[1]Department of Biological and Agricultural Engineering.

Clay content is defined as the percent by dry weight of a soil that is smaller than 2 microns (0.002 mm).

Site Investigation

A site investigation for a waste storage structure is important to ascertain the potential risk posed by the stored animal waste. Evaluating soils, bedrock, groundwater, climatic conditions, and local water uses provides insight into the potential impact of the site on groundwater resources. Prior to an onsite investigation, you should consult available geology or groundwater maps, published county soil surveys, previous designs in the same physiographic area, and any other information that aids your assessment of the site. Data should include the presence of any water wells or any other water supply sources, depth to the seasonal high water table, general groundwater gradient, general geology of the site, and depth to bedrock, if applicable. Features such as sole source aquifers or important aquifers underlying the proposed site must be noted, because they create a special concern over the impact a site could have.

An onsite investigation always should be conducted at a proposed lagoon or storage pond location. Determining the intensity of any detailed site investigation is the joint responsibility of the designer and the person who has authority to approve the engineering job. The intensity of investigation required depends on the experience in a given area, the types of soils and variability of the soil deposits, the size of the structure, the environmental sensitivity, and an assessment of the associated risks involved. State and local laws should be followed in all cases.

The subsurface investigation can employ auger holes, dozer pits, or backhoe pits. The investigation should extend to at least 2 feet. below the planned bottom of the excavation. A site investigation can include field permeability testing or taking samples for laboratory testings, or it can be limited to field classification of the soils. Records from site investigations are important, and the information should be documented and included in the design documentation. When logging soils from auger holes, always consider that the augering can obscure the presence of cleaner sand or gravel lenses by mixing soil layers. Pits and trenches expose more of the foundation, which is helpful in detecting small, but important, lenses of permeable soil. Always use safety rules around trenches.

Soil Properties

The NRCS soil mechanics laboratories have a database of permeability tests performed on over 1,100 compacted soil samples. Experienced NRCS engineers have analyzed these data and correlated permeability rates with soil index properties and degree of compaction of the samples. Based on this analysis, Table 1 has been developed to provide general guidance on the probable permeability characteristics of soils. The grouping of soils is based on the percent fines (percent by dry weight finer than the #200 sieve), Atterberg limits, and degree of compaction of the soils.

Table 2 summarizes a total of 1,161 tests. Where tests are shown at 85 to 90 percent of maximum density, the vast majority of the tests were at 90 percent. Where 95 percent is shown, data includes both 95 and 100 percent degree of compaction tests, with the majority of the tests performed at 95 percent of maximum density. The following general statements then can be made for the four soil groups.

Table 1. Grouping of Foundation Soils According to Their Estimated Permeability

Group	Description
I	Soils that have less than 20% passing a no. 200 sieve and have a plasticity index (PI) less than 5.
II	Soils that have 20 to 100% passing a no. 200 sieve and have a plasticity index (PI) less than or equal to 15. Also included in this group are soils with less than 20% passing the no. 200 sieve with fines having a plasticity index (PI) of 5 or greater.
III	Soils that have 20 to 100% passing a no. 200 sieve and have a plasticity index (PI) of 16 to 30.
IV	Soils that have 20 to 100% passing a No. 200 Sieve and have a Plasticity Index (PI) of more than 30.

Note: Table 1 is revised from the table shown in NRCS Technical Note 716. Additional permeability test data provided the basis for the revised grouping of soils. A plasticity index (PI) of 16 or higher is required for Group III in the new table, compared to a value of 11 in the original table. Soils with PI's from 11 to 16 that were in Group III are now in Group II.

Table 2. Summary of Permeability Test Data from Soil Mechanics Laboratories

Soil Group	Percent of ASTM D698 Dry Density	Number of Observations	Permeability Median K		
			cm/sec	inch/day	inch/year
I	85-90	27	7.2×10^{-4}	24	8760
I	95	16	3.5×10^{-4}	12	4380
II	85-90	376	4.8×10^{-6}	.17	62
II	95	244	1.5×10^{-6}	.048	18
III	85-90	226	8.8×10^{-7}	.030	11
III	95	177	2.1×10^{-7}	.0072	2.6
IV	85-90	41	4.9×10^{-7}	.0168	6.1
IV	95	54	3.5×10^{-8}	.0012	.44

Group I - Generally, these soils have the highest permeability and, in their natural state, could allow excessive seepage losses. Because the soils have a low clay content, the final permeability value will exceed 10^{-6} to 10^{-7} cm/sec.

Group II - These soils generally are less permeable than the Group I soils but lack sufficient clay to be included in Group III.

Group III - These soils generally have a very low permeability, good structural feainitial seepage be less than .25 inches per day. The inch/day permeability column in Table 2 shows that most all soils in groups II, III, and IV can be sealed adequately. Remember that the permeability values represented are median values, so some soils in all the groups may have excessive seepage. Testing of existing soils is recommended to assess local conditions. Of the 1,160 soil tests in this table, only the median permeabilities in Group I (43 soil tests) did not meet KDHE regulations. The second column of Table 2 indicates the degree of compaction of the soil (the higher the percent dry density, the greater the compaction of the soil). The four different soil types have been tested at two different compaction rates. The data indicate that additional compaction of the same soil reduces the permeability by a factor of 2 to 13.

Liners are relatively impervious barriers used to reduce seepage losses to an acceptable level. A liner for a waste storage pond can be constructed in several ways. When soil is used as a liner, it often is called a "clay blanket" or "impervious blanket." One method of providing a liner for a waste storage structure is to improve the soils at the excavated grade by discing, watering, and compacting them to a suitable thickness. Soils with suitable properties make excellent materials for liners, but the liners must be designed and installed correctly. Soil has an added benefit in that it provides an attenuation medium for the pollutants.

Those onsite soils in Groups I considered to be unsuitable usually can be treated with bentonite to produce a satisfactory soil liner. Additives such as bentonite or soil dispersants should be added and mixed well into a soil prior to compaction.

Using high quality sodium bentonite with good swell properties is important for this application. The highest quality bentonite is mined in Wyoming and Montana. NRCS soil mechanics laboratories have noted the importance of using the same type and quality of bentonite in the mixtures for lab tests that will be used at the lagoon construction site. Both the quality of the bentonite and how finely ground the product is prior to mixing with the soil affect the final permeability rate of the mixture. You should work closely with bentonite suppliers and your soil testing facility to ensure understanding of these factors.

A soil liner can be constructed by compacting imported clay from a nearby source onto the bottom and sides of the storage pond. This is often the most economical method of constructing a clay liner if suitable soils are available nearby. Liners also can be made from concrete or synthetic materials such as geosynthetic clay and geomembranes. In all cases, liners should provide a reduction in seepage from the storage/treatment pond and diminish the potential for contamination of groundwater.

HISTORICAL ECONOMIC RETURNS TO ALTERNATIVE SWINE ENTERPRISES IN KANSAS

R. Jones and M. R. Langemeier[1]

Summary

This study examines historical net returns to average Kansas swine producers over the past 16 years. Swine production has been a profitable enterprise. As expected, average returns per head have been higher for farrow-to-finish producers than for feeder pig finishers, and farrow-to-finish producers have nearly always been able to at least cover variable costs of production.

(Key Words: Net Returns, Variable Costs, Total Costs.)

Introduction

An investigation of the historical economic returns and other measures affecting the profitability of alternative agricultural enterprises is informative for both long- and short-run planning. For example, expansion or contraction decisions should be based on long-term expected profitability. Long-term historical means and distributions of important economic factors provide at least some indication of future results. Using this information, producers are able to compare alternative enterprises and make effective strategic plans.

Procedures

Data regarding average market hog prices, sow prices, feeder pig prices, feed costs, and other variable costs were obtained for 64 calendar quarters from January 1981 through December of 1996. Measures of fixed costs for swine enterprises were calculated for the same time period. Cash prices for market hogs, sows, milo, soybean meal, and other feed ingredients were obtained from various publications of the Kansas Agricultural Statistics Service and the United States Department of Agriculture, Agricultural Marketing Service (AMS). Feeder pig prices for 45 lb feeder pigs also were collected from AMS. Feeder pig prices from southern Missouri were used early in the sample period, and prices from St. Joseph, Missouri were used later in the sample period. Other variable costs were obtained from representative average Kansas farrow-to-finish and feeder pig finishing budgets developed by Extension Agricultural Economists at Kansas State University for the respective time periods. Variable costs include milo, soybean meal, vitamins and minerals, pig starter, feed processing, labor, veterinary and supply costs, marketing, utilities, repairs, miscellaneous costs, and interest on operating expenses. The labor cost includes an opportunity charge for operator labor. Data from actual Kansas swine enterprises in the Kansas Farm Management Associations were used to obtain cost estimates. These costs vary with the level of production. An additional variable cost incurred by feeder pig finishers is the cost of the feeder pig itself. The fixed costs of swine production include annual charges needed to recover the investment in buildings, equipment, and breeding stock, and the insurance and taxes on buildings and equipment. These costs were calculated based on estimated investments and were converted to per pig measures. The fixed costs are incurred even if no hogs are produced.

[1]Department of Agricultural Economics.

Net returns per head for farrow-to-finish and feeder pig finishing are estimated for each quarter by subtracting costs from gross returns obtained through market hog and cull sow sales. Two measures of net returns are calculated; returns above variable costs and returns above total costs. As long as returns are above variable costs, producers can remain viable in the short run. In the long run, all costs (variable and fixed) need to be covered. Charges for management and risk are not included in either measure, so the estimated return distributions represent the returns to management and risk associated with hog production.

The return distributions calculated here represent traditional swine production systems in Kansas. Historical data for relatively new technologies such as SEW swine production are not yet available. Preliminary cost and return estimates for 1997 suggest that net returns per head are slightly higher for SEW swine producers as a result of improved feed efficiency, especially during periods of high feed costs.

Results and Discussion

The estimated distribution of returns over variable costs for average traditional Kansas farrow-to-finish swine producers from 1981 through 1996 is presented in Table 1. Returns averaged $26.27 per head produced and ranged from a low of $-13.61 per head in the fourth quarter of 1994 to a high of $69.48 per head in the third quarter of 1987. Revenues failed to cover variable costs only about 3% of the time. The estimated distribution of returns over total costs for average traditional Kansas farrow-to-finish swine producers also is presented. Even after accounting for fixed costs, producers still averaged a return of $7.56 per head. Average Kansas farrow-to-finish swine producers have been able to cover all costs over two thirds of the time in recent years. A comparison of the first half of the data set with the last half reveals that returns per head were on average slightly higher in the early period than in more recent times, as illustrated in Figure 1. This suggests that some increase in enterprise size may be needed over time to maintain a constant level of overall enterprise profits.

The estimated distribution of returns over variable costs for traditional feeder pig finishers in Kansas is presented in Table 1 as well. Producers have averaged $11.79 per head over variable costs, ranging from a minimum of $-12.52 in the fourth quarter of 1994 to a maximum of $42.76 per head in the fourth quarter of 1986. Returns failed to cover variable costs about 16% of the time. The estimated distribution of returns over total costs for traditional feeder pig finishers in Kansas reveals that even after accounting for fixed costs, an average net return per head of $3.33 has been realized. Returns per head were below the breakeven needed to cover total costs about 37.5% of the time. A comparison of the first half of the data set with the last half reveals no difference in average returns over variable costs between the two periods, as illustrated in Figure 2.

These results suggest that Kansas swine production has been profitable for average producers in recent years. As expected, potential returns per head are higher for farrow-to-finish producers than for feeder pig finishers. However, farrow-to-finish production is more capital intensive and requires a different set of management skills. Preliminary estimates suggest that the same relative relationships between farrow-to-finish and feeder pig finishing continue to hold for SEW swine production, though the absolute returns to each enterprise may be slightly higher.

Table 1.
Estimated Distribution of Quarterly Hog Production Returns in Kansas from 1981-1996

Item	Farrow-to-Finish Production		Feeder Pig Finishing	
	Returns over Variable Costs	Returns over Total Costs	Returns over Variable Costs	Returns over Total Costs
Average, $/head	$26.27	7.56	11.79	3.33
Maximum, $/head	69.48	51.36	42.76	34.25
Minimum, $/head	-13.61	-29.83	-12.52	-20.14
Quarters less than 0	2 (3%)	20 (31%)	10 (16%)	24 (38%)

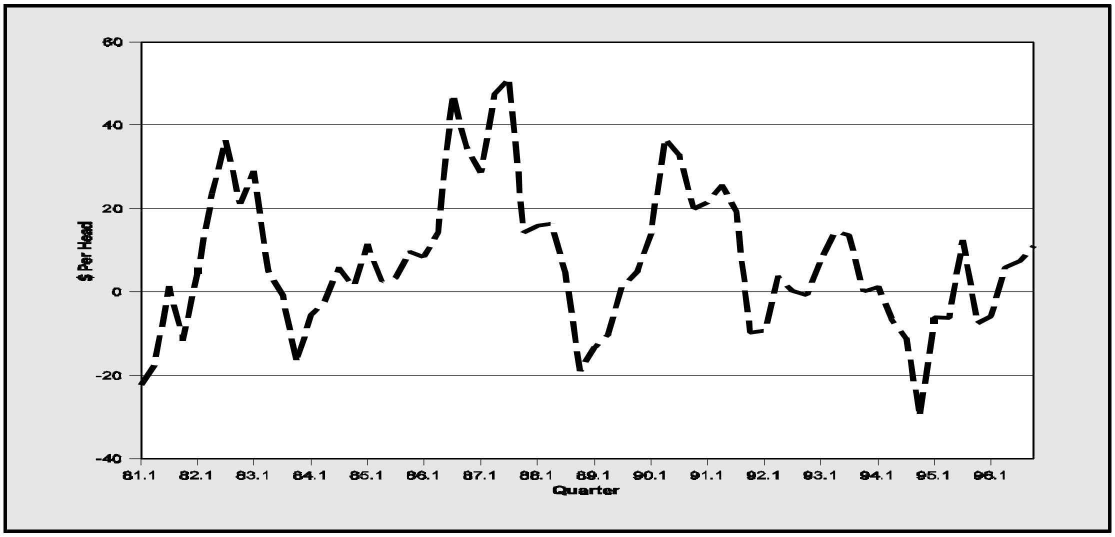

Figure 1.
Estimated Quarterly per Head Returns over Total Cost for Farrow-to-Finish Hog Production in Kansas.

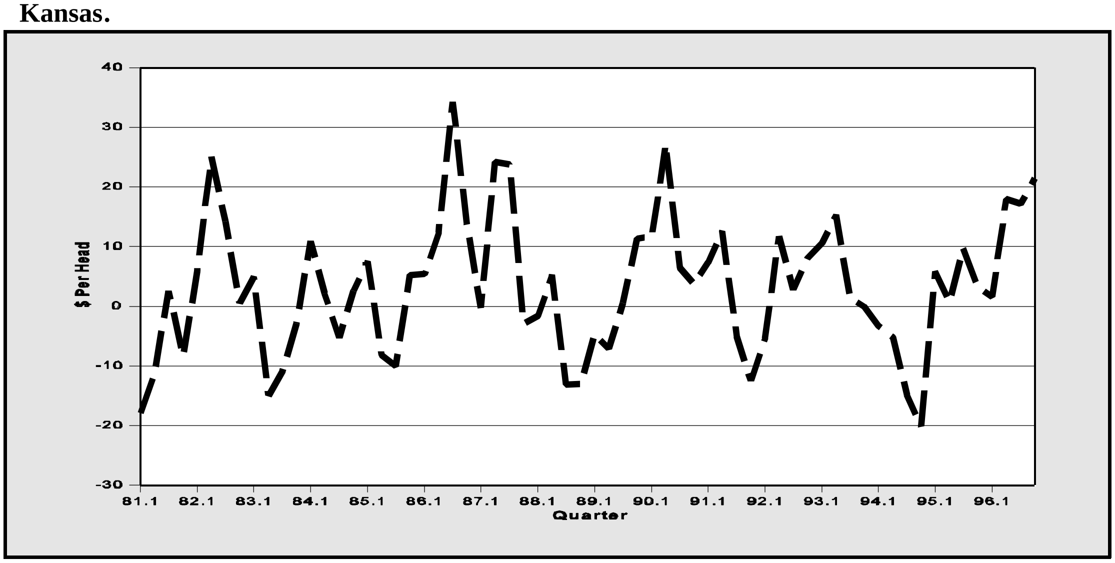

Figure 2.
Estimated Quarterly per Head Returns over Total Cost for Feeder Pig Finishing Hog Production in Kansas. .

TRENDS IN THE SWINE INDUSTRY: OPERATIONS AND MARKETINGS

***J. L. Parcell*[1] *and K. C. Dhuyvetter*[1]**

Summary

Trends in the size of swine operations in Kansas and the U.S. are toward fewer and larger operations. The number of operations in Kansas and the U.S. continues to decline; however, the number of hogs marketed has increased because of an increase in operation size. Kansas producers have increased operation size at a slower rate compared to U.S. producers. Kansas ranks *tenth* nationally in hogs marketed. A migration of swine production from eastern, central, and northern Kansas to southwest Kansas has occurred in the past 5 years.

(Key Words: Swine Operations, Hog Marketings, Trends.)

Introduction

The Kansas and the U.S. swine industries have undergone numerous structural changes in the past 15 years. Structural change is motivated by profitability. Swine operations, large or small, locate in areas where they can receive the highest rate of return and where the rate of return to swine production is larger than that of alternative enterprises.

Producers in Kansas need to be aware of where they rate relative to U.S. production and marketing trends. Determining if Kansas swine production is expanding, contracting, or stable and in what locations of the state changes are occurring is important for production, marketing, and policy decisions. The focus of this report is on trends in the number and size of swine operations and hog marketings for Kansas and the U.S.

Procedures

Number of swine operations, hogs marketed annually, annual marketings per operation, and inventory by size of operation for Kansas and the U.S. were obtained from various issues of the United States Department of Agriculture (USDA) Hogs and Pigs report. Hog marketings by state were obtained from various issues of the USDA's Meat Animals Production, Disposition, and Income report. Kansas pig crop data were obtained from Kansas *Farm Facts* (Kansas Department of Agriculture).

Number and Size of Operations

The number of swine operations has declined substantially over the last 15 years for Kansas and the U.S. (Table 1 and Figure 1). From 1980 to the present, Kansas has experienced a 71% decline in the number of operations, and the number of U.S. hog operations has declined by 77%. These are annual declines of 7.4% and 8.7% for Kansas and the U.S., respectively. The annual decline in swine operations has decreased for Kansas and increased for the U.S., and over the past 6 years, the number of operations has declined at annual rates of 6.2% in Kansas and 8.9% in the U.S. However, the number of hogs marketed per operation during this time has increased dramatically to ultimately increase the total number of hogs marketed annually (Table 1 and Figure 2). This increase has been larger for the U.S. than Kan-

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2 Northeast Area Extension Office.

sas during the past 5 years; however, these values converged in 1996. Thus, Kansas producers are becoming larger at a slower rate compared to other producers in the U.S. However, Kansas producers have historically been larger, which decreases their potential rate of expansion.

Table 2 indicates how operation size has grown in Kansas and for selected states in the U.S. The general trend has been toward operations larger than 1000 head. In Kansas, not much change has occurred in the distribution of operations, but a major change has occurred in inventories. This increase in operation size is related directly to the economies of scale (i.e., decreasing average cost by becoming larger) and marketing advantages of large-scale swine production. This has forced medium and small producers to become larger to compete in the marketplace to take advantage of genetics, health risks, and marketing methods.

States not having laws to deter corporate hog farming are increasing the percent of inventory for large operations at a staggering rate. For instance, larger operations in Oklahoma account for 95% of the inventory within the state. This structural change coincided with the opening of the Seaboard hog processing plant in Guyman, Oklahoma. These changes in operation size have influenced the level and location of swine production in the U.S.

Hog Marketings

Table 3 shows the rankings of the 10 largest hog-producing states and their shares of the U.S. market for 1996. Also shown is each state's rank and share in 1991. This indicates in which states hog production has increased and decreased because of expansion, relocation, entries, and exits. Kansas has maintained the rank of *tenth*. The small loss of market share is due to the increase in the number of hogs marketed in the U.S. over the previous 5 years and not to a decline in the number of hogs marketed in Kansas. Two states stand out as growing rapidly, North Carolina and Oklahoma. Although North Carolina has experienced substantial growth during the past 10 years, Oklahoma is only beginning to experience growth.

Table 4 shows the market share of U.S. hog marketings for selected states from 1980 through 1996. Similarly, Figures 3 and 4, respectively, plot the market share of hogs marketed for Kansas compared to neighboring states to the south and west and neighboring states to the north and east (Iowa was not included because of the large market share).

Oklahoma and Colorado have each experienced increased market share with the opening of the Seaboard hog processing plant in Guyman, Oklahoma. How much these states will continue to increase market share is uncertain. Clearly, the Kansas swine industry has not experienced the same growth pattern as these states.

Missouri and Nebraska have experienced large fluctuations in market share. Recently, Missouri has overtaken Nebraska, primarily because of expansions in Premium Standard Farms, Murphy Family Farms, and Continental Grain. The 5-year trend in Nebraska is a declining market share. Missouri has experienced much more market share variability during the past 5 years.

Figures 5 and 6 summarize the geographic distribution of the Kansas pig crops for 1991 and 1996, respectively. Pig production has shifted from eastern, central, and northern Kansas to southwest Kansas. Since 1991, the market share of the Kansas pig crop in the southwest has increased from 11% to 36% or from 255,000 to 927,000 (a 263% increase). This increase coincides with the opening of the Seaboard plant in Guyman, Oklahoma.

Table 1. Numbers of Swine Operations and Marketings in Kansas and U.S.

	Number of		Hogs Marketed		Marketings per	
Year	Kansas	U.S.	Kansas	U.S.	Kansas	U.S.
1980	14,000	674,800	3,300	100,651	236	149
1985	8,300	391,000	2,636	86,731	318	222
1990	6,000	275,440	2,476	89,373	413	324
1995	4,300	181,750	2,203	102,684	512	565
1996	4,100	157,450	2,553	101,809	623	647

Source: USDA Hogs and Pigs.

Table 2. Percent of Operations and Inventory by Inventory Size*

		1-99 Head		100-499 Head		500-999 Head		1000 + Head	
State	Year	Oper	Inv	Oper	Inv	Oper	Inv	Oper	Inv
KS	1985	60.9	8.9	30.7	37.7	6.8	53.4	–	–
	1990	51.0	7.5	40.0	36.5	5.7	16.0	3.5	40.0
	1995	53.5	5.0	35.0	22.0	6.3	15.0	5.2	58.0
	1996	58.5	4.5	29.0	18.0	7.6	15.0	4.9	62.5
NC	1985	88.3	10.4	7.8	12.5	3.9	77.1	–	–
	1990	83.0	4.2	8.0	5.3	3.0	5.6	6.0	87.0
	1995	67.7	1.0	7.1	1.5	4.0	2.5	21.2	95.0
	1996	66.7	0.5	5.2	1.0	3.2	1.5	25.0	97.0
NE	1985	44.3	6.3	42.9	37.1	12.8	56.5	–	–
	1990	36.0	4.0	47.0	33.0	11.4	23.0	5.6	40.0
	1995	32.0	3.0	47.0	27.0	13.0	21.5	8.0	48.5
	1996	32.5	3.0	43.8	23.0	13.8	20.0	10.0	54.0
IA	1985	30.7	3.9	49.8	39.4	21.0	56.7	–	–
	1990	26.0	2.5	47.0	31.0	18.5	32.5	8.5	34.0
	1995	20.4	1.5	44.0	22.0	22.8	28.0	12.8	48.5
	1996	21.9	1.0	41.9	18.0	21.9	25.0	14.3	56.0
MO	1985	65.9	14.8	28.3	44.7	5.8	40.5	–	–
	1990	62.0	10.0	29.5	39.0	6.0	23.5	2.5	27.5
	1995	51.7	3.5	31.7	16.5	10.0	16.0	6.5	64.0
	1996	51.4	2.0	32.9	12.0	10.0	12.0	5.7	74.0
OK	1985	–	–	–	–	–	–	–	–
	1990	–	–	–	–	–	–	–	–
	1995	94.1	2.5	2.9	3.0	0.6	2.0	2.4	92.5
	1996	94.1	2.0	2.4	2.0	0.6	1.0	2.9	95.0
U.S.	1985	73.8	10.3	19.5	34.2	6.7	55.5	–	–
	1990	64.7	6.5	25.0	28.0	6.5	23.5	3.8	42.0
	1995	59.4	3.5	25.0	18.0	8.6	17.5	6.9	61.0
	1996	61.0	3.0	23.0	15.0	8.5	15.0	7.6	67.0

*In 1990 a larger size class of producers with inventory of 1000 plus was added.
Source: USDA Hogs and Pigs.

Table 3. Hog Marketings of Leading States

1996 Rank	1991 Rank	State	1996 Hogs Marketed (1000 Head)	1996 Share of U.S. (%)	1991 Share of U.S. (%)
1	1	Iowa	22,190	21.80	24.71
2	6	N. Carolina	14,234	13.98	6.19
3	3	Minnesota	9,097	8.94	8.50
4	2	Illinois	8,315	8.17	10.21
5	7	Missouri	6,718	6.60	5.18
6	4	Indiana	6,634	6.52	7.93
7	5	Nebraska	6,453	6.34	7.92
8	8	Ohio	3,117	3.06	3.66
9	22	Oklahoma	2,836	2.79	0.45
10	10	Kansas	2,553	2.51	2.68

Source: USDA Meat Animals Production, Disposition, and Income.

Table 4. Share of Annual Hog Marketings, Selected States (1980-1996)

Year	KS	NC	NE	IA	OK	CO	MO
1980	3.28	3.85	6.56	23.26	0.54	0.72	7.23
1981	3.20	3.79	6.40	24.30	0.54	0.48	6.85
1982	3.17	3.53	6.92	26.85	0.35	0.61	6.01
1983	3.09	3.96	6.76	25.40	0.29	0.56	6.89
1984	2.99	4.15	6.76	25.52	0.38	0.52	6.71
1985	3.04	4.32	6.49	26.30	0.34	0.36	6.55
1986	2.98	4.57	7.33	25.76	0.34	0.41	5.91
1987	2.72	4.93	7.53	24.87	0.37	0.36	5.73
1988	2.76	5.01	7.36	24.87	0.38	0.38	5.64
1989	2.81	5.62	7.62	24.35	0.46	0.42	5.17
1990	2.77	5.64	7.74	24.61	0.48	0.47	5.02
1991	2.68	6.19	7.92	24.71	0.45	0.61	5.22
1992	2.54	7.08	7.72	25.67	0.44	0.72	4.91
1993	2.52	8.27	7.65	24.64	0.60	0.84	5.20
1994	2.33	9.78	7.29	24.66	1.01	1.08	5.81
1995	2.15	11.97	6.98	22.86	1.57	0.99	6.84
1996	2.51	13.98	6.34	21.80	2.79	1.35	6.60

Source: USDA Meat Animals Production, Disposition, and Income.

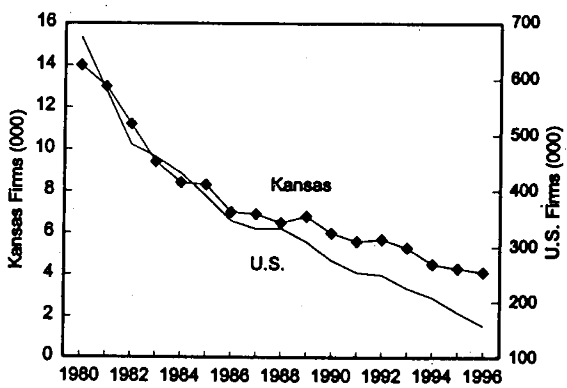

Figure 1. **Number of Swine Operations, Kansas and U.S.**

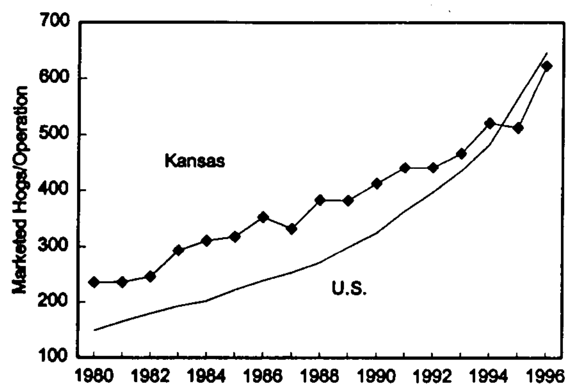

Figure 2. **Numbers of Hogs Marketed per Operation, Kansas and U.S.**

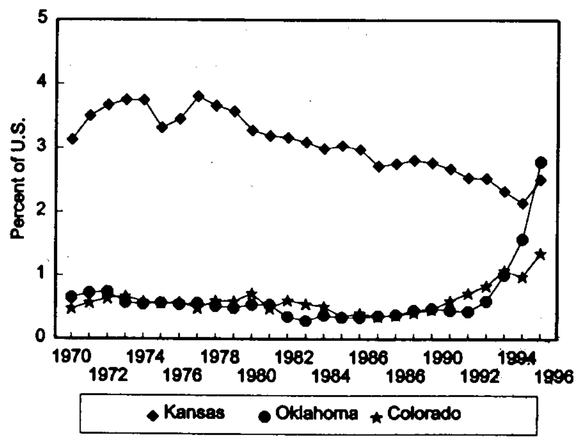

Figure 3. **Shares of Marketings for Colorado, Kansas, and Oklahoma.**

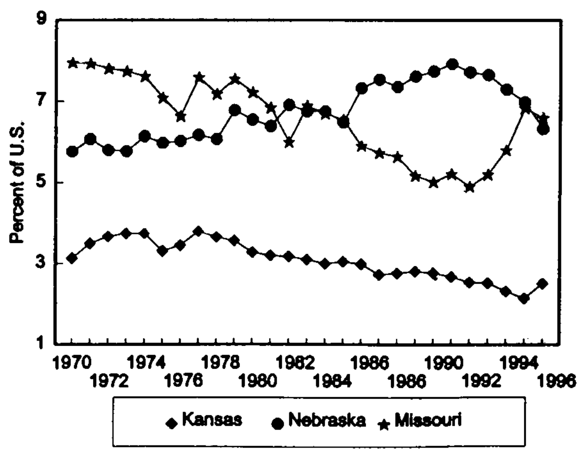

Figure 4. **Shares of Marketings for Kansas, Missouri, and Nebraska.**

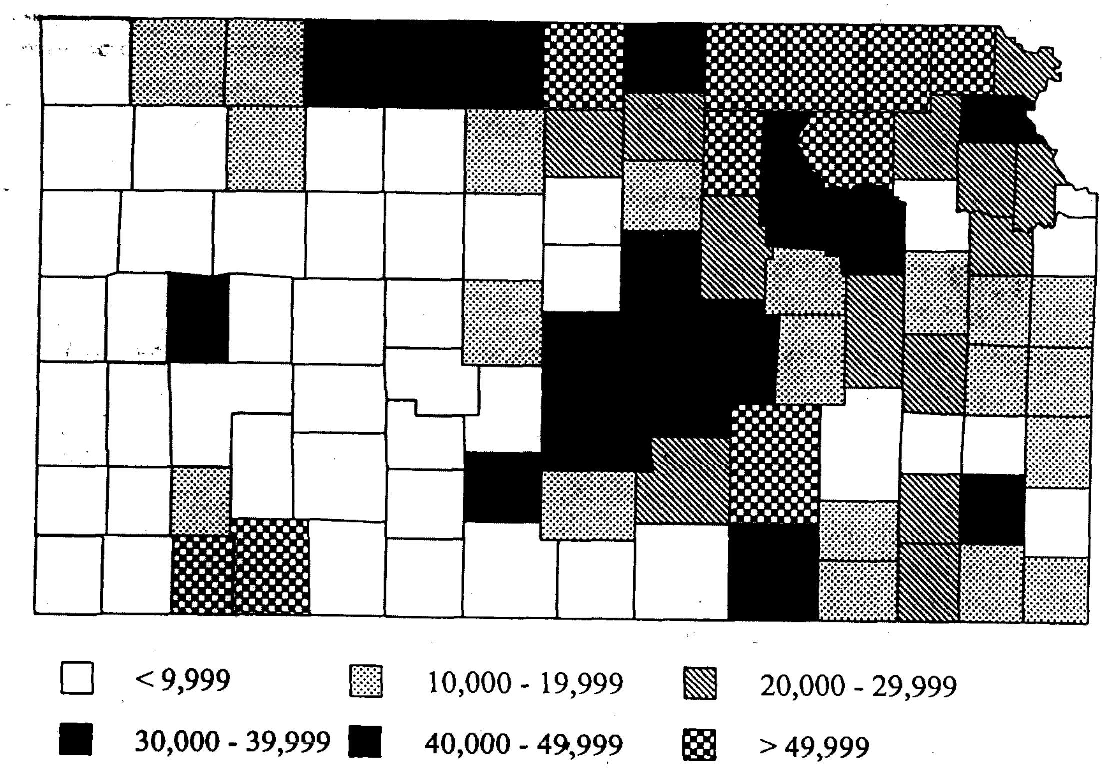

Figure 5. Geographic Distribution of Pig Crop in Kansas, 1991. (Total = 2.3 million head)

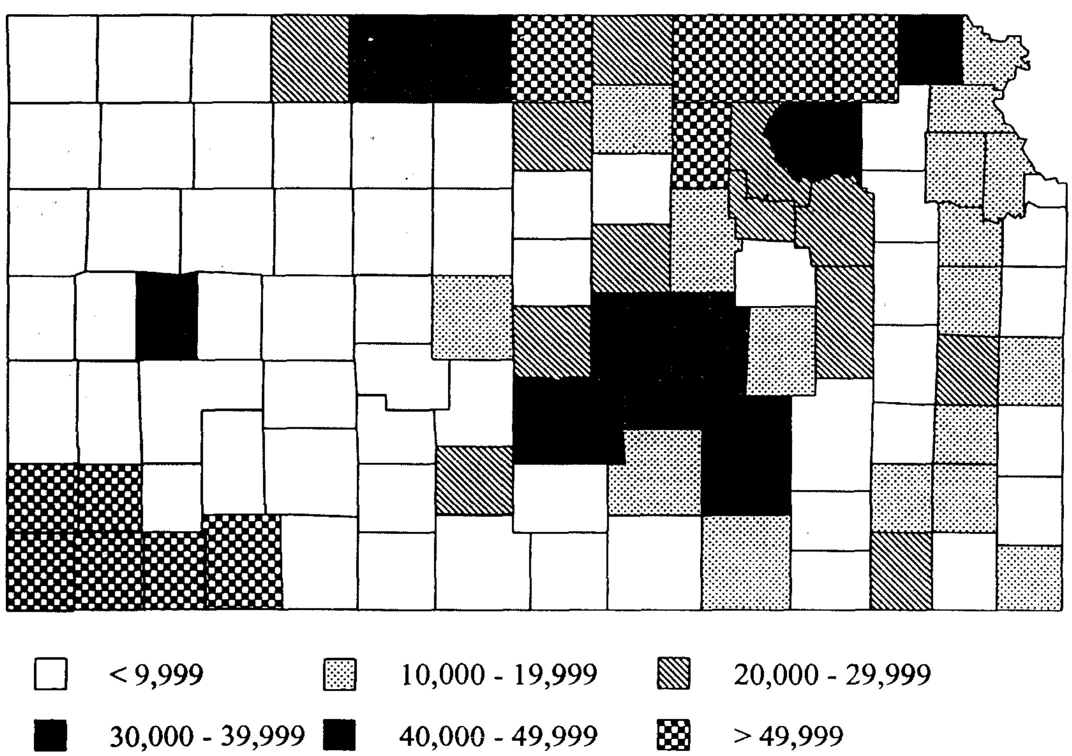

Figure 6. Geographic Distribution of Pig Crop in Kansas, 1996. (Total = 2.6 million head)

TRENDS IN THE SWINE INDUSTRY: PRODUCTIVITY MEASURES

K. C. Dhuyvetter[1] and J. L. Parcell[2]

Summary

Productivity has been trending up in the swine industry over the last 15 years. Much of the increased productivity is due to increased pigs/litter and increased market weights. The efficiency of the breeding herd (litters/sow/year) has been trending up in the U.S. but has remained relatively constant in Kansas.

(Key Words: Industry Trends, Productivity, Breeding Herd Efficiency.)

Introduction

The swine industry has undergone some major changes in the last 15 years with respect to productivity and the number and size of operations (see related article). Although we can argue that the increased concentration led to increased productivity, we also can argue that the potential for increases in productivity led to increased concentration. Regardless of what caused these changes, the result is that the swine industry has seen significant improvements in production efficiency.

This article highlights trends in the swine industry since 1980 of various productivity measures at the aggregate level for both Kansas and the U.S.

Procedures

Farrowings, pigs/litter, and breeding herd inventories data for Kansas and the U.S. were obtained from various issues of the United States Department of Agriculture (USDA) Hogs and Pigs report. Live weight, dressed weight, and pork production data for the U.S. were obtained from various issues of USDA's Livestock Slaughter report. All data collected were for the 1980 through 1996 time period.

Inventory data are based on values reported as of the first of the quarter. Quarters are defined as (1) Dec-Feb, (2) Mar-May, (3) Jun-Aug, and (4) Sep-Nov. In the first quarter, Dec refers to the previous year. Prior to 1988, U.S. inventory data were reported only for the first and third quarters, i.e., Dec and Jun.

Number of Sows Farrowing

The number of sows farrowing in the U.S. declined during the first half of the 1980s and then stabilized during the last half of the 1980s and early 1990s (Figure 1). Farrowings in Kansas declined at a fairly steady rate from 1980 through 1995. Kansas farrowings reached an all-time low in the third quarter of 1995 and then increased sharply through 1996. Farrowings were highest during the Mar-May quarter of the year (Table 1). However, seasonality in farrowings has been declining over the last 15 years.

Farrowings decreased 22.8% and 12% from 1981 to 1996 in Kansas and the U.S., respectively. However, Kansas farrowings increased in 1996 compared to 1995 (22.1%), while the U.S. farrowings declined (-5.6%). Even though Kansas farrowings were up significantly in 1996, they still represented only about 3% of the total U.S. farrowings.

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Pigs/Litter

The number of pigs weaned/litter is an important measure of sow productivity. Pigs/litter has been increasing at a constant rate since 1980 (Figure 2). Average pigs/litter increased 13.2% and 15.1% from 1981 to 1996 in Kansas and the U.S., respectively (Table 2). In the fourth quarter of 1996 and the first two quarters in 1997, average pigs/litter in Kansas reached and exceeded nine for the first time ever. This coincides with the startup of several large operations in Kansas.

Breeding Herd Efficiency

In addition to increasing the number of pigs/litter, producers also can increase their farrowing efficiency by weaning more pigs/sow/year. This is a function of both litter size and litters/sow/year. Data are not reported to allow pigs/sow/year to be calculated; however, using the number of total farrowings along with breeding herd inventories, an estimate of breeding herd efficiency can be calculated. This value will be lower than litters/sow/year, because the breeding herd inventory will include boars and replacement gilts. However, this value will reveal if the breeding herd is being used more efficiently over time.

Figure 3 shows the number of farrowings/animal in the breeding herd. This value gives an indication as to trends in litters/sow/year. Farrowings/breeding herd animal in the U.S. have been trending up since 1980, indicating that breeding herds are being utilized more efficiently. No discernable trend occurred in Kansas over this time period; however, the Kansas breeding herd efficiency value was above the U.S. value until 1994.

The size of the 1996 pig crop in Kansas was 12.4% less than the size 15 years earlier, but the size of the breeding herd was 21.1% less, indicating an improvement in production efficiency (Table 3). However, this improvement in efficiency was the result of more pigs/litter and utilizing the breeding herd more efficiently, i.e., litters/sow/year. In the U.S., increases in production efficiency have been due to increases in pigs/litter and litters/sow/year.

Live and Dressed Weights

Another way producers can increase productive efficiency is to increase the weight at which they market hogs. Live and carcass weights have been increasing at a steady rate since 1980 (Figure 4). Average live weight for all hogs slaughtered in 1996 was 254 lb compared to 243 lb in 1981 (4.6% increase). Similarly, average carcass weight in 1996 was 185 lb, which was an increase of 13 lb (7.8%) from 15 years earlier (Table 4).

Pork Production

The ultimate measure in productivity is the amount of pork produced. Figure 5 shows annual pork production and average breeding herd inventory in the U.S. The national breeding herd and total pork production declined during the first half of the 1980s. However, since then the breeding herd has been relatively constant at around 7 million head and production has been increasing.

Pork production per animal in the breeding herd has been increasing steadily since 1980 (Figure 6). Pork production in 1996 was 8.7% and 22% higher than 1981 and 1986 levels, respectively (Table 5). In 1996, the average breeding herd inventory was down 10.9% and 1% from levels 15 and 10 years earlier, respectively. This higher total production along with a smaller breeding herd result in 1996 values forpork production/breeding herd animal that were 22% and 23.3% higher than those 15 and 10 years earlier, respectively. This large increase in pork production efficiency/breeding herd animal is the result of increases in pigs/litter, pigs/sow/year, and market weights.

Table 1. Annual and Quarterly Number os Sows Farrowing in Kansas and U.S.

Area and Period	1981	1986	1991	1995	1996	Percent Change 96/95	96/91	96/86	96/81
Kansas									
Dec-Feb	82	76	74	61	62	1.6%	-16.2%	-18.4%	-24.4%
Mar-May	115	80	77	64	70	9.4%	-9.1%	-12.5%	-39.1%
Jun-Aug	95	72	74	62	81	30.6%	9.5%	12.5%	-14.7%
Sep-Nov	94	72	73	57	85	49.1%	16.4%	18.1%	-9.6%
Annual total	386	300	298	244	298	22.1%	0.0%	-0.7%	-22.8%
U.S.									
Dec-Feb	2,914	2,450	2,707	2,886	2,745	-4.9%	1.4%	12.1%	-5.8%
Mar-May	3,526	2,803	3,281	3,170	2,964	-6.5%	-9.7%	5.7%	-15.9%
Jun-Aug	3,197	2,743	3,104	2,976	2,761	-7.2%	-11.1%	0.7%	-13.6%
Sep-Nov	3,071	2,697	2,967	2,815	2,717	-3.5%	-8.4%	0.7%	-11.5%
Annual total	12,708	10,693	12,059	11,847	11,187	-5.6%	-7.2%	4.6%	-12.0%

Source: USDA Hogs and Pigs Report.

Table 2. Annual and Quarterly Numbers of Pigs/Litter in Kansas and U.S.

Area and Period	1981	1986	1991	1995	1996	Percent Change 96/95	96/91	96/86	96/81
Kansas									
Dec-Feb	7.42	7.50	7.90	8.10	8.20	1.2%	3.8%	9.3%	10.5%
Mar-May	7.82	7.90	7.90	7.95	8.40	5.7%	6.3%	6.3%	7.4%
Jun-Aug	7.55	7.55	7.85	8.20	8.80	7.3%	12.1%	16.6%	16.6%
Sep-Nov	7.60	7.75	7.81	8.30	9.00	8.4%	15.2%	16.1%	18.4%
Annual average	7.60	7.68	7.87	8.14	8.60	5.7%	9.3%	12.1%	13.2%
U.S.									
Dec-Feb	7.22	7.58	7.87	8.27	8.40	1.6%	6.7%	10.8%	16.3%
Mar-May	7.53	7.81	7.96	8.32	8.47	1.8%	6.4%	8.5%	12.5%
Jun-Aug	7.37	7.76	7.89	8.34	8.57	2.8%	8.6%	10.4%	16.3%
Sep-Nov	7.39	7.73	7.89	8.34	8.52	2.2%	8.0%	10.2%	15.3%
Annual average	7.38	7.72	7.90	8.32	8.49	2.1%	7.4%	10.0%	15.1%

Source: USDA Hogs and Pigs Report.

Table 3. Annual Pig Crop and Size and Efficiency of Breeding Herd in Kansas and U.S.

Variable and Area	1981	1986	1991	1995	1996	Percent Change			
						96/95	96/91	96/86	96/81
Annual Pig Crop (000)									
Kansas	2,938	2,304	2,344	1,984	2,574	29.7%	9.8%	11.7%	-12.4%
U.S.	93,853	82,571	95,315	98,516	94,972	-3.6%	-0.4%	15.0%	1.2%
Average Breeding Herd Inventory (000)*									
Kansas	227	190	176	149	179	20.2%	1.4%	-5.9%	-21.1%
U.S.	8,101	6,563	7,239	6,979	6,765	-3.1%	-6.5%	3.1%	-16.5%
Sows Farrowing/Average Breeding Herd Inventory									
Kansas	1.70	1.71	1.69	1.64	1.67	1.6%	-1.4%	-2.8%	-2.2%
U.S.	1.57	1.63	1.67	1.70	1.65	-2.6%	-0.7%	1.5%	5.4%
Annual Pig Crop/Average Breeding Herd Inventory									
Kansas	13.0	13.2	13.3	13.3	14.4	8.0%	8.3%	9.4%	11.0%
U.S.	11.6	12.6	13.2	14.1	14.0	-0.6%	6.6%	11.6%	21.2%

*Average is based on Jun and Dec inventories prior to 1988 and on Mar, Jun, Sep, and Dec inventories since 1988.

Source: USDA Hogs and Pigs Report.

Table 4. Commercial Hog Slaughter Live and Dressed Weights in the U.S.

Variable	1981	1986	1991	1995	1996	Percent Change			
						96/95	96/91	96/86	96/81
Live weight, lb	243	246	252	256	254	-0.8%	0.8%	3.2%	4.6%
Dressed weight, lb	172	176	181	185	185	-0.0%	2.3%	5.2%	7.8%
Dressed/live weight	70.7%	71.5%	71.8%	72.3%	72.9%	0.8%	1.4%	1.9%	3.0%

Source: USDA Livestock Slaughter.

Table 5. Pork Production and Size and Efficiency of Breeding Herd in U.S.

Variable	1981	1986	1991	1995	1996	Percent Change			
						96/95	96/91	96/86	96/81
Pork production, million lb									
	15,717	13,998	15,948	17,811	17,081	-4.1%	7.1%	22.0%	8.7%
Average breeding herd inventory, (000)*									
	7,629	6,865	7,287	6,843	6,794	-0.7%	-6.8%	-1.0%	- 10.9%
Pork production/average breeding herd inventory, lb									
	2,060	2,039	2,188	2,603	2,514	-3.4%	14.9%	23.3%	22.0%

*Average inventory is lagged 6 months (based on Jun and Dec inventories prior to 1988 and on Mar, Jun, Sep, and Dec inventories since 1988).
Source: USDA Hogs and Pigs Report and Livestock Slaughter.

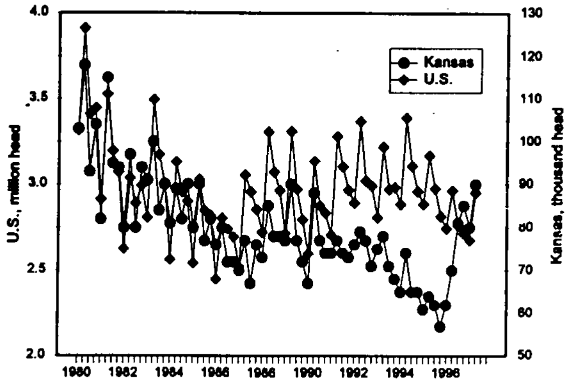


Figure 1. Quarterly Numbers of Sows Farrowing.

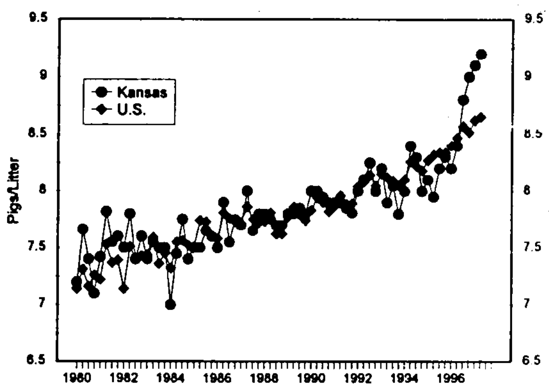
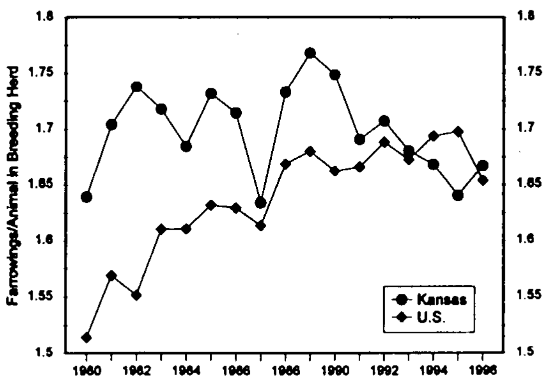


Figure 2. Quarterly Numbers of Pigs/ Litter.



* Prior to 1988 average is based on Jun and Dec inventories only

Figure 3. Annual Numbers of Sows Farrowing/Average Breeding Herd.

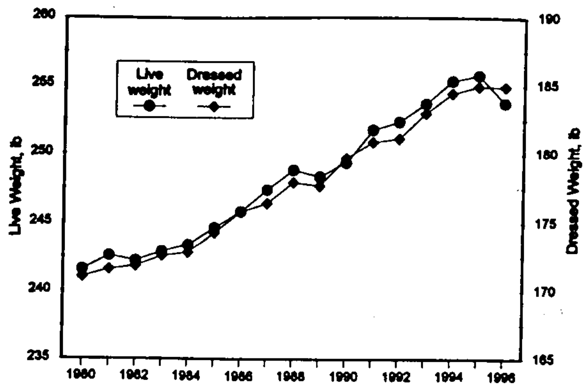
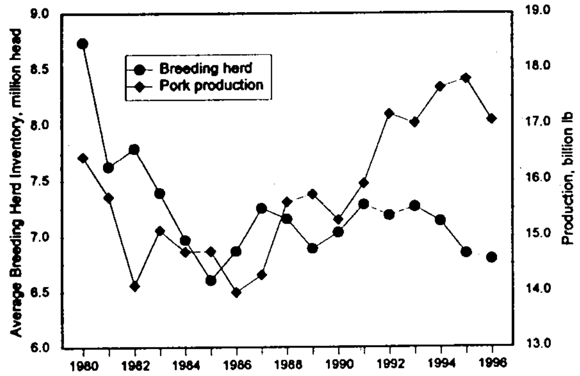
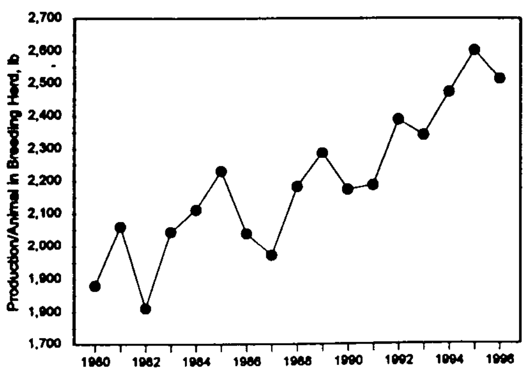


Figure 4. Hog Live and Carcass Weight in the U.S.



* Prior to 1988 average is based on Jun and Dec inventories only, inventory is lagged 6 months.

Figure 5. Annual Pork Production/ Average Breeding Herd.



* Breeding herd inventory is lagged six months.

Figure 6. U.S. Pork Production/ Average Breeding Herd.

SUMMARY OF KANSAS STATE UNIVERSITY SWINE ENTERPRISE RECORD [1]

R. D. Goodband, M. L. Langemeier [2], M. D. Tokach [3], and J. L. Nelssen

Summary

The Kansas Swine Enterprise Record Program evaluates biological and economic performance and is part of a cooperative record-keeping project with Extension personnel and swine producers in Kansas, Nebraska, and South Dakota. From January 1 to December 31, 1996, profit per cwt of pork produced by these producers (13 semi-annual and 18 annual data) averaged $10.62 for the last 6 months of 1996 and $8.08 for the entire year. Producers in the top one-third in terms of profitability had average profits of $15.11 per cwt, whereas producers in the bottom one-third had average profits of $.73 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., whether buying higher quality breeding stock will pay for itself).

Kansas State University joined the University of Nebraska and South Dakota State University in a cooperative record-keeping program in January 1991. This program compiles individual producer records of 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 this basis facilitates comparisons among producers of various sizes.

Regional Group Summary

Individual producers collect data on hog inventories, hog sales, hog purchases, feed inventories, feed purchases, operating expenses, labor, fixed expenses, and herd performance. These data from individual producer data were used by Extension personnel to compile the 1996 regional (KS, NE, and SD) group summaries for farrow-to-finish operations reported in Table 1. Records of 13 producers are summarized for the last 6 months of 1996, and records of 18 producers are summarized for the 12-month period January to December 1996. 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

[1][1]The authors thank Mike Brumm and Al Prosch, University of Nebraska, for their assistance with the program.

[2]Department of Agricultural Economics.

[3]Northeast Area Extension Office.

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 operations in the program.

Profit per cwt of pork produced averaged well above breakeven ($10.62 per cwt) over the last 6 months of 1996. However, profits varied substantially among producers. For the last 6 months of 1996, producers in the top one-third in terms of profitability had average profits per cwt of $18.93. Producers in the bottom one-third had average losses of $.47 per cwt. Profit differences remained similar between these two groups for the year ($15.11 vs $.73), but the average profit margin was lower for the whole year because of low market hog prices and high feed costs during the first 6 months of 1996.

Notice that returns over cash costs (Line 2) were positive for all three profit groups for the last 6 months and the whole year despite the negative profits of the low one-third profit group during the last 6 months. Typically, most producers can cover cash costs, even when prices are relatively low. All producers were able to cover unpaid labor and fixed costs for the entire year; thus, their return to management was positive (line 3) for the year. Although market conditions were excellent this past year, the range in profits among similar sized operations is dramatic. This indicates a need to develop some management options that will improve the profitability of the bottom one0third of producers in the future.

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 49.5%, which was substantially more than the average return on capital for all 18 producers for the entire year. Note that the return on capital for producers in the bottom one-third profitability group was 6.64% for the entire year.

Variable costs per cwt (Line 10) can be broken down into four categories: feed costs (Line 5), other operating expenses (Line 6), interest costs on operating capital (Line 9), and unpaid labor and management (Line 38). Total costs per cwt include these variable costs, plus interest charges on investments in buildings and equipment (Line 12) and economic life depreciation, taxes, and insurance costs (Line 13). Producers in the top one-third profit group had lower costs for each of the variable ($40.70) and total ($44.96) cost categories compared to the average producers' variable ($46.34) and total ($50.71) costs per cwt of pork produced. A $12.68 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 $4.86 or 38.3% of the difference in total costs for the two profit groups. The top one-third producers were able to purchase their feed for $.93/cwt less (line 52) for the year. A 5% improvement in feed efficiency occurred between producers in the top vs bottom one-third profit groups for the whole year.

Other operating expenses include utilities, hired labor, supplies, repairs, veterinarian costs, and professional dues. Other operating expenses (Line 6) and interest costs on capital (Line 9) accounted for 54% and 6% 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. However, unpaid labor and management were only $.26 per cwt higher for producers in the low-profit group than for producers in the high-profit group for the past year. This difference accounted for only 2% of the difference in total costs per cwt between the two groups.

Differences in fixed costs per cwt (Line 17 to Line 10) were very similar between producers in the high- and low-profit groups for the year ($4.26 vs $4.21, respectively).

As suggested by the similar fixed costs, producers in the top one-third group had the same litters per sow per year (line 25) compared with those in the bottom one-third (1.98). However, producers in the top one-third group weaned slightly more pigs per litter (line 28), and, therefore, produced more pigs per crate (line 30). Producers in the top one third had lower preweaning, finishing, and sow death losses (lines 32, 33, and 34). The high death loss of weaning to finishing pigs by producers in the bottom one-third (11.82 vs 3.71) is a major factor contributing to their low profitability.

Finally, swine enterprise records serve as a useful management tool for individual producers to monitor their individual herd's production and economic performance over the previous 6 months and for the year. As swine production becomes more competitive, the identification of good or problem areas of an operation becomes increasingly essential for producers to maintain profitability. By comparing an individual's records to the group summary, key economic criteria can be identified and management strategies implemented to improve profitability. The KSU Swine Enterprise Record program is an integral part of the swine extension service offered by Kansas State University.

Table 1. Regional Group Summary Averages for Farrow-to-Finish Operations (KS, NE, and SD)

	Farrow-to-Finish Operations					
	Semi-Annual Data (13 Farms)			Annual Data (18 Farms)		
Item	Average	High 1/3	Low 1/3	Average	High 1/3	Low 1/3
1. Net pork produced, lb	379,335	456,416	282,515	746,655	648,244	861,561
2. Income over feed, oper. exp., oper. int., & hired labor	71,320	111,363	18,764	112,562	152,350	72,647
3. Profit or return to management, ELD	48,400	88,787	1,399	65,075	112,566	23,856
4. Annual rate of return on capital, ELD	30.85	56.40	2.89	27.30	49.54	6.64
Variable expenses:						
5. Total feed expense/cwt pork produced	32.49	29.38	34.80	33.39	31.04	35.90
6. Other oper. expenses (total)/cwt pork produced	7.57	4.55	11.85	7.76	4.99	11.83
a. Utilities; fuel, electricity, phone/cwt pork produced	1.23	.65	2.29	1.28	1.05	1.86
b. Vet. expenses and medications/cwt pork produced	1.08	.73	1.69	1.07	.81	1.37
c. Remainder of other oper. expenses/cwt pork produced	5.25	3.17	7.87	5.32	2.84	8.60
7. Total cost of labor/cwt of pork produce	4.13	2.29	6.12	4.28	2.98	5.50
8. Total oper. capital inv./cwt of pork produced	25.73	22.41	29.60	22.85	20.07	26.45
9. Int. cost on oper. invest./cwt of pork produced	3.09	2.69	3.55	2.74	2.41	3.17
10. Total variable cost/cwt of pork produced	45.31	38.05	53.20	46.34	40.70	53.43
Fixed and total costs:						
11. Total fixed cap. inv. (ELD)/cwt of pork produced	17.15	14.19	16.57	17.97	16.96	16.48
12. Int. chg. on fixed inv. (ELD)/cwt of pork produced	1.72	1.42	1.66	1.80	1.70	1.65
13. E.L. deprec., taxes and ins. cost/cwt of pork produced	2.36	2.29	2.23	2.57	2.56	2.57
14. Tax deprec., taxes and ins. cost/cwt of pork produced	2.24	1.92	1.90	2.44	2.33	2.42
15. Fixed cost (ELD)/female/period	84.01	83.07	76.30	173.21	163.77	158.45
16. Fixed cost (ELD)/crate/period	405.97	421.13	302.77	825.56	790.07	684.91
17. Total cost (ELD)/cwt of pork produced	49.38	41.76	57.09	50.71	44.96	57.64
18. Total cost (ELD)/female/period	982.78	897.43	1055.31	1951.707	1714.04	2095.87
19. Total cost (ELD)/crate/period	4715.67	4571.40	4755.95	9352.22	8169.61	10223.60
Income and profit						
20. Profit based on econ. life deprec./cwt of pork produced	10.62	18.93	-.47	8.08	15.11	.73
21. Profit based on tax deprec./cwt of pork produced	10.94	19.52	.41	8.37	15.45	1.14
22. Profit based on econ. life deprec./female/period	222.77	411.48	-10.80	316.99	594.69	15.28
23. Profit based on econ. life deprec./crate/period	1109.32	2091.79	-46.33	1551.39	2802.15	227.21

(continued)

Table 1. Regional Group Summary Averages for Farrow-to-Finish Operations (KS, NE, and SD) (cont'd)

	Semi-Annual Data (13 Farms)			Annual Data (18 Farms)		
Item	Average	High 1/3	Low 1/3	Average	High 1/3	Low 1/3
Production summary:						
24. Average female inventory	189	207	163	194	166	246
25. Number of litters weaned/female/period	1.02	1.10	.96	1.99	1.98	1.98
26. Number of litters weaned/crate/period	4.93	5.65	4.31	9.60	9.37	9.75
27. Number of live pigs born/litter farrowed	10.15	10.30	10.21	10.10	10.23	10.03
28. Number of pigs weaned/litter farrowed	8.74	8.76	8.62	8.80	9.15	8.77
29. Number of pigs weaned/female/period	8.71	8.85	8.33	17.44	18.24	17.10
30. Number of pigs weaned/crate/period	41.71	44.57	37.62	83.76	86.36	84.11
31. Number of pigs sold/litter/period	8.30	8.40	7.99	7.71	7.69	7.38
Death loss:						
32. Birth to weaning (% of no. born)	13.70	14.96	12.30	13.52	10.47	15.71
33. Weaning to market (% of no. weaned)	6.23	4.54	10.13	6.60	3.71	11.82
34. Breeding stock (% of breeding herd maintained)	2.34	2.51	2.70	6.23	6.02	7.98
Labor:						
35. Labor hours/cwt of pork produced	.58	.43	.85	.61	.45	.80
36. Labor hours/female/period	11.48	9.47	15.83	23.41	17.48	29.59
37. Labor hours/litter weaned/period	11.33	8.51	16.37	11.78	8.83	14.82
38. Cost of unpaid labor & mgmt./cwt of pork produced	2.39	2.20	2.99	2.44	2.27	2.53
39. Total cost of labor (paid + unpaid)/cwt of pork produced	4.36	3.05	6.12	4.28	2.98	5.50
40. Total cost of labor (paid + unpaid)/female/period	86.45	66.86	113.20	166.42	115.39	202.24
41. Return/hour for all hours of labor and management	34.74	52.44	6.56	26.06	45.12	8.54
Marketing and purchases:						
42. Number of market hogs sold	1472	1730	1075	2825	2486	3359
43. Average weight/head for market hogs sold	246	255	240	244	247	239
44. Average price received for market hogs/cwt	57.40	57.46	55.44	55.91	56.04	55.78
45. Number of feeder pigs sold	68	42	39	97	192	49
46. Average weight/head of feeder pigs sold	65.60	53.70	60.30	55.80	51.80	86.30
47. Average price received/head for feeder pigs sold	46.05	25.74	38.00	41.43	37.43	53.83
48. Average price received/cwt for feeder pigs sold	61.62	47.94	67.41	71.92	72.35	69.37
Feed cost and consumption:						
49. Total lb of feed fed/cwt of pork produced	362	365	361	363	357	374
50. Total lb of grain fed/cwt of pork produced	282	287	282	284	280	291
51. Total lb of supplement fed/cwt of pork produced	80	78	79	79	76	83
52. Average costs of diets/cwt	9.03	8.05	9.72	9.20	8.69	9.62

Semi-annual data July 1 - December 31, 1996 and annual data January 1, 1996 - December 31, 1996.

Swine Day 1997

FETAL AND MATERNAL RESPONSES TO HIGH FEED INTAKE FROM DAY 29 TO 45 OF GESTATION [1]

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Summary

Parity-four sows were fed either 4.0 lb/d (control, n = 6) or 14.0 lb/d (high, n = 9) of feed from d 29 to 45 of gestation. On d 45 of gestation, sows were slaughtered and uteri collected for fetal and placental measurements. High-feed-intake sows gained more weight from d 29 to 45 compared to control sows. Providing feed in excess of established requirements to gestating sows from d 29 to 45 of gestation increased IGF-I concentrations in maternal plasma and decreased crown-rump length variation of the fetus. Increased feed intake resulted in a removal of the correlation between average fetal weight and number of fetuses per sow. We postulate that the increased maternal IGF-I or other maternal responses to high feed intake altered the maternal limit on fetal growth at this stage of gestation.

(Key Words: Feed Intake, Fetal Growth, Insulin-Like Growth Factor.)

Introduction

Embryonic diversity within a litter contributes to the variation in birth weights and subsequent variation in finishing age. The ability to decrease variation in birth weight can provide great economic savings in all-in, all-out production systems. Birth weight variation may result from variations in nutrient flow from the sow to the fetuses during gestation. For example, fetuses with smaller placentas are likely to be smaller at birth because they receive fewer nutrients and have less capacity to remove waste products.

Previous research indicates that fetuses with longer implantation lengths tend to be heavier in weight. Therefore, the objective of our study was to determine whether feeding sows 14 lb/d of diet from d 29 to 45 of gestation would affect fetal and placental development.

Procedures

Fifteen (PIC Line C-15) parity-four sows were allotted to receive either 4 or 14 lb/d of a gestation diet from d 29 to 45 after insemination. All sows were housed in gestation stalls in an environmentally controlled gestation barn. Sows were fed at 8:00 a.m. and ad libitum sows were fed again at 8:00 p.m.. All sows had ad libitum access to water throughout the experiment. Sows fed ad libitum were provided 6 lb feed in morning and 8 lb feed in evening. Sows were weighed at d 29 and 45 of gestation.

Blood samples were collected from sows 2 hours after each feeding (10:00 a.m. and 10:00 p.m.) on d 43 of gestation, and plasma was harvested and frozen for later analysis of insulin-like growth factor I (IGF-I) and insulin.

Reproductive tracts were collected as sows were processed at a commercial processing facility. Placental volume was estimated by collecting allantoic and amniotic fluids after

[1]The authors thank Robert Beckley for assistance in feed and animal care. We also thank Patrick O'Quinn, Mylissia Stukey, LeAnn Johnston, and Perry Sorell for assistance in data collection.

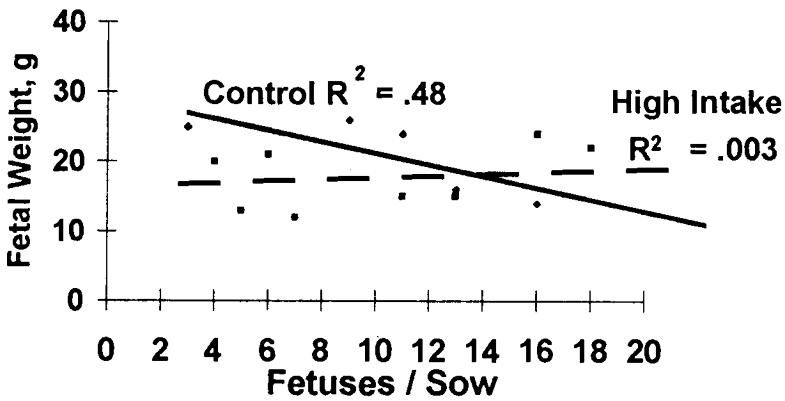
puncturing the membranes. Placental weight, fetal weight, and fetal crown-rump length were measured.

Data were analyzed using the GLM procedure of SAS. Variation about selected means was tested by calculating the residuals for each observation (e.g., absolute value of the difference between the observation and the mean weight of entire litter). Residuals were evaluated for treatment variation by analysis of variance. Smaller residual means would indicate that the litter had less variation in fetal weight.

Results and Discussion

High-feed-intake sows gained more weight from d 29 to 45 compared to controls. No differences were detected in number of fetuses, mummies, length of unoccupied uterus, implantation length, allantoic and amniotic fluid volumes, placental and fetal weight, and crown-rump length ($P > .10$). No differences were observed between the fetuses from sows fed control or a high level of feed intake in fetal weight or placental weight variation. However, crown-rump length variation was decreased in sows fed 14 lb of feed when compared to control sows. High-feed-intake sows had greater IGF-I concentrations in plasma than controls on d 43. As expected, a negative relationship between fetal number and fetal weight was observed for control sows (wt = -1.02 **x** fetal no + 32; R^2= .48). However, a similar relationship was not observed for fetuses from high-intake sows (R^2= .003). This suggests that the maternal limit on fetal growth had been altered (Figure 1).

In summary, providing 14 lb/d of feed from d 29 to 45 of gestation increased IGF-I concentrations in maternal plasma and decreased crown-rump length variation of the fetus. We believe that increasing the feed intake during early gestation altered the nutrient flow to the developing fetuses, possibly resulting in improved fetal growth. We postulate that the increased maternal IGF-I or other maternal responses to high feed intake altered the maternal limit on fetal growth at this stage of gestation.



Control (wt = -1.02 x fetal no. + 32.01)
High intake (wt = 0.08 x fetal no. + 18.03)

Figure 1. Effect of High Feed Intake from d 29 to 45 of Gestation on Fetal Pig Development.

Table 1. Effects of Increased Feed Intake from d 29 to 45 of Gestation on Sow and Fetal Performance

	Feed Intake, lb/d			
Item	4	14	CV	P <
No. sows/treatment	6	9		
Sow weight gain, lb	9.5	74.8	74.9	.01
No. fetuses	9.8	11.3	45.3	.57
No. mummies	3.3	2.7	74.1	.57
No. unoccupied space	4.2	3.9	69.9	.85
Implantation length, mm	57.4	40.5	49.4	.19
Allantoic fluid volume, ml	32.5	34.1	62.4	.88
Fetal weight, g	21.1	18.4	28.9	.38
Fetal weight variation, g	1.9	2.0	93.5	.81
Placental weight, g	64.0	61.4	31.7	.81
Placental weight variation, g	18.3	15.6	76.6	.21
Crown-rump length, mm	69.3	67.2	9.8	.57
Crown-rump length variation, mm	4.8	3.2	115.5	.03
IGF-I in peripheral sow blood,ng/ml[a]				
a.m.	27.2	64.2	19.8	.01
p.m.	32.4	77.1	19.8	.01
Insulin in peripheral sow blood,ng/ml				
a.m.	37.6	67.6	48.4	.01
p.m.	37.1	68.9	48.4	.01
Fetal IGF-I and insulin, d 45, ng/ml				
IGF-I	4.1	5.2	38.1	.24
Insulin	80.4	68.4	74.3	.72

[a]No a.m. vs p.m. effects or interactions were detected (P > .20).

EFFECTS OF INCREASED FEED INTAKE OR ADDITIONAL CORN FROM DAY 30 TO 50 OF GESTATION ON PERFORMANCE OF SOWS AND GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF OFFSPRING [1]

R. E. Musser, R. D. Goodband, D. L. Davis, S. S. Dritz [2], M. D. Tokach, J. L. Nelssen, J. S. Bauman [3], and M. Heintz [3]

Summary

A total of 321 PIC sows was used to determine the effects of either increased feed (8 lb/d of complete feed) or added corn (4 lb/d of complete feed plus 4 lb/d of ground corn) from d 30 to 50 of gestation on sow and offspring performance. Sows fed increased feed intake from d 30 to 50 of gestation had fewer pigs born live than control sows; however this decrease was not observed for sows fed ground corn. Increased complete diet feed intake from d 30 to 50 of gestation resulted in heavier offspring at slaughter, with offspring from sows fed additional corn being intermediate. Gilts from sows that were fed extra feed or corn had decreased 10th rib fat depth at market. Increased feed or addition of ground corn resulted in increased percentage lean and fat-free lean index for the sows' offspring. Although further research is needed to verify our results, they indicate that increased nutrient intake during critical periods in gestation can influence growth and carcass composition of the offspring.

(Key Words: Gestation, Offspring, Improved Lean.)

Introduction

The potential to alter growth potential of pigs by increasing nutrient levels fed to sows during early gestation is a relatively new area of research. The changes in growth potential may result from the ability to alter the number of muscle fibers in the developing fetus. The development of muscle at this stage involves the formation of primary and secondary muscle fibers. As the primary fibers develop, they are supported by the proliferation of secondary fibers. Research from Europe observed that increasing gestation feed intake from d 25 to 50 resulted in offspring that grew faster and more efficiently than controls. Therefore, the objective of this experiment was to determine if feeding sows either increased feed or carbohydrates from d 30 to 50 of gestation results in improved carcass characteristics of offspring.

Procedures

A total of 321 PIC sows was used. This experiment was conducted on a 3,000 sow farrow-to-wean operation in southwest Minnesota. On d 30 of gestation, sows were assigned randomly to one of three treatments in groups of five. Treatments consisted of sows being fed either: 4 lb/d of complete feed (control), 8 lb/d of complete feed (extra feed), or 4 lb/d of complete diet plus 4 lb/d of added corn (added corn). The control and extra feed treatments were fed via feed drop systems; for the added corn treatment, the complete feed was fed by feeder drops and the added corn via topdressing. Until being moved to the farrowing house, all sows were fed 4 lb/d of complete feed before d 30 and after d 50 of gestation.

[1]The authors thank Dave Logan, Jeff Enger, Curt Haug, Linda Flanagan, Virginia McIver, Todd Teal, Jay Schiebout, Richard Feucht, and Henry Peterson of Global Ventures I, Inc. for their assistance in animal care, data collection, and partial funding.

[2]Food Animal Health and Management Center.

[3]Global Ventures I, Inc., Pipestone, MN.

On d 95 of gestation, sows (15/trt) were bled, and plasma samples were frozen for later analysis for concentrations of insulin-like growth factor (IGF-I).

At farrowing, numbers of pigs born and born live, stillborns, and mummies per litter were recorded. In addition, a subsample of 20 litters per treatment was weighed to determine the effects of treatment on pig birth weight and the variation within litters. In 10 of these litters per treatment, the pig closest to the mean weight was bled for analysis of plasma for IGF-I concentrations.

Pigs were ear notched at birth according to the maternal treatment in gestation and were standardized across treatments. At weaning, pigs were mixed within sex and moved to offsite nurseries. Pigs were moved to finishing buildings at 10 weeks of age. As pigs reached market weight (260 lb), they were sorted and marketed by treatment and sex for a total of six different marketing groups (i.e. a load of barrows or gilts from each individual treatment). At the slaughter plant, experimental pigs were processed as the first pigs of the day to decrease potential variation in Fat-O-Meter measurements. Individual carcass measurements were obtained on 2,358 pigs.

Data was analyzed using the GLM procedure of SAS. Sow was used as the experimental unit for the analysis of farrowing data, and parity was used as a covariate. In the analysis of carcass data, pig was used as the experimental unit. Hot carcass weight was used as a covariate in the analysis of 10th rib fat depth, loin depth, percentage lean, and fat free lean index. Variation in birth weight was tested using Leaven's Test (the absolute difference between the mean birth weight and individual pig weight). Lower values from this test correspond to less variation within the litter.

Table 1. Gestation Diet Composition[a]

Ingredient,	%[b]
Corn	74.9
Soybean meal (46.5%)	15.6
Alfalfa meal	5.0
Other vitamin and trace mineral additions	4.5
Total	100.0

[a]Sows were fed either 4 lb/d (control), 8 lb/d (increased feed intake), or 4 lb/d of complete feed plus 4 lb/d ground corn.
[b]Formulated to contain .7% lysine, 1.0% Ca, and .90 % P.

Results and Discussion

Sows fed increased feed intake from d 30 to 50 of gestation had fewer pigs born live than control sows; however this decrease was not observed for sows fed ground corn. No differences were observed ($P > .10$) in number of pigs stillborn or mummified per litter (Table 2). No differences were observed ($P > .10$) in either pig birth weight or variation in birth weight within the litters ($P > .05$; Table 2).

No differences were observed in plasma IGF-I concentrations for either gestation sows on d 95 or newborn pigs ($P > .05$; Table 3).

The analysis of hot carcass weight revealed that offspring from sows fed increased diet from d 30 to 50 of gestation were the heaviest, with offspring from sows receiving additional corn being intermediate ($P < .05$; Table 4). Differences were not observed in barrows for 10th rib fat depth; however, gilts from sows fed added corn or increased feed had less 10th rib fat depth at slaughter. No differences were observed for loin depth in gilts from various maternal treatments;

however, barrows from sows fed added corn had greater loin depth than offspring from sows fed either the control diet or increased feed. Gilts from sows fed either increased corn or increased feed level were higher ($P < .01$) in percentage lean and fat free lean index than control gilts. No differences were observed ($P > .10$) in either percentage lean or fat free lean index of barrows.

The decrease in number born live with the increased feed intake, but not with added corn, is a concern. Research from Europe has shown no effect of high feed intake on number born live; but in that study, feed intake was increased then decreased over several days. Regardless, our experiment demonstrated the ability to alter the lean growth of offspring with adjustments in maternal nutrition. Additional research is needed to determine the mode of action. Our next step will be to determine the timing and amount of increased feed intake that will affect carcass characteristics of the offspring.

Table 2. Effects of Feed Intake from D 30 to 50 of Gestation on Sow and Litter Performance

	Feed Intake, lb/d				
Item	4 lb Feed	4 lb Feed + 4 lb Corn	8 lb Feed	P <	SEM
No. sows	111	108	102		
Average parity[1]	3.41	3.12	3.32	.54	6.0
Total born	11.01	10.67	9.80	.05	3.4
Born live	10.14	10.03	9.14	.06	3.3
Stillborn	.593	.423	.523	.41	17.5
Mummies	.277	.221	.144	.31	29.3
Lactation length, d	16.79	16.06	16.49	.22	1.9
Length of return to estrus, d	5.85	6.02	6.43	.56	6.2
Born live per litter weighed	10.94	11.72	10.82	.60	6.2
Litter birth weight, lb	34.79	34.77	32.96	.54	3.5
Pig birth weight, lb	3.13	3.23	2.95	.26	3.6
Variation in birth weight, lb[2]	.62	.54	.65	.29	8.6

[1]Used as a covariate in the analysis of farrowing performance.
[2]Approximately 20 litters per treatment were measured for weight and variation.

Table 3. Effect of Feed Intake from D 30 to 50 of Gestation on Blood Metabolites

	Feed Intake, lb/d				
Item	4 lb Feed	4 lb Feed + 4 lb Corn	8 lb Feed	P <	SEM
No. sows	14	14	14		
IGF-I, ng/ml					
Sow d 95 of gestation	20.64	29.06	20.08	.37	21.4
Newborn	13.55	13.35	10.13	.36	15.2

Table 4. Effects of Feed Intake from D 30 to 50 of Gestation on Offsprings' Carcass Characteristics

	Feed Intake, lb/d				
Item	4 lb Feed	4 lb Feed + 4 lb Corn	8 lb Feed	P <	SEM
No. of pigs					
Barrows	404	412	366		
Gilts	403	433	340		
Hot carcass weight, lb					
Barrows	207.8	209.3	211.3	.05	.58
Gilts	202.2	205.6	205.8	.03	.62
10th rib fat depth, mm[1]					
Barrows	20.27	20.23	20.44	.77	.13
Gilts	17.28	16.46	16.43	.01	.11
Loin depth, mm[1]					
Barrows	57.88	58.93	57.62	.01	.17
Gilts	58.97	59.72	59.23	.21	.18
NPPC percent lean, %[1]					
Barrows	53.47	53.59	53.31	.41	.07
Gilts	55.46	55.96	55.93	.01	.08
Fat-free lean index[1]					
Barrows	49.10	49.10	49.00	.77	.06
Gilts	50.36	50.75	50.76	.01	.06

[1]Used hot carcass weight as a covariate in the analysis.

EFFECTS OF L-CARNITINE ON PERFORMANCE OF GESTATING AND LACTATING SOWS [1]

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Summary

A total of 307 sows was used to determine the effects of adding 50 ppm of L-carnitine in gestation and lactation diets on sow and litter performance. Addition of 50 ppm L-carnitine in gestation increased both total litter (34.1 vs 32.1 lb) and pig (3.48 vs 3.27 lb) birth weight. Litter weaning weights increased (99.03 vs 90.71 lb) when sows were fed added L-carnitine during gestation. Sows fed added L-carnitine in gestation had increased IGF-I concentrations on d 60 and 90 (71.3 vs 38.0, and 33.0 vs 25.0 ng/ml, respectively). These results suggest that feeding 50 ppm of added L-carnitine during gestation increases litter birth and weaning weights.

(Key Words: L-Carnitine, Gestation, Birth Weight.)

Introduction

L-carnitine is involved in the transport of fatty acids across the mitochondrial membrane. Previous research at Kansas State University and the University of Georgia has demonstrated that the addition of L-carnitine to the diet decreases lipid accretion in weanling and growing-finishing pigs. L-carnitine also has been shown to affect several key enzymes involved in protein and lipid metabolism. Because of these effects on key metabolic enzymes, we speculated that L-carnitine may enhance productivity of the gestating and lactating sow. Therefore, the objective of this experiment was to determine if additional dietary L-carnitine during gestation and lactation would improve sow and litter performance during lactation.

Procedures

A total of 307 sows (PIC C15 × 326) and the experiment was conducted from June to December, 1996 on a 1,400-sow commercial swine farm in Northeast Kansas. At breeding, sows were weighed and ultrasonically scanned (Renco, Minneapolis, MN) for last rib fat depth, then allotted to one of two dietary treatments. The gestation diet was formulated to contain .65% total lysine, .95% Ca, and .85% P, with all other amino acids, vitamins, and minerals in excess of NRC (1988) requirement estimates (Table 1). Sows were fed 4 lb/d of the control diet (no added carnitine) in a single feeding (8:00 am). Sows fed added carnitine were fed 3.5 lb of this same gestation diet, and the added L-carnitine (50 ppm) was supplied in an extra .5 lb/d topdressing of the same diet at the time of feeding. Sows were weighed and last rib fat depth was recorded on d 110 of gestation, at

[1]The authors thank Rick Richards, Don Reeves, Michelle Walter, Angie Bruna, and Dale Keesecker of Keesecker Agribusiness, Washington, KS for use of animals, facilities, and data collection. We also thank Joe Loughmiller and Loree Burum for data collection and Lonza Inc., Fair Lawn, NJ for partial financial support.

[2]Northeast Area Extension Office.

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

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

which time sows were moved to an environmentally regulated farrowing facility.

At farrowing, sows were fed a diet formulated to contain 1.0% total lysine, .95% Ca, and .85% P, with or without 50 ppm of added L-carnitine. All other amino acids, vitamins, and minerals were in excess of NRC (1988) requirement estimates (Table 1). At farrowing, the numbers of pigs born live, stillborns, and mummies were recorded. Pigs were ear notched for identification and individual pig weight was recorded. All litters were equalized within dietary treatment by d 2 of lactation. Individual pig weight and number of pigs per litter were recordedat weaning (d 15), when sow weight and last rib fat depth were recorded. Sow feed intake was measured daily, then pooled to determine the average daily feed intake for 7-d intervals throughout lactation. After weaning, sows were monitored once daily with a boar for estrus. If a sow did not return to estrus within 35 d, she was culled. A standard culling program is used at this farm for age and genetic line. Subsequent farrowing rate, total number of pigs born, and number born alive also were determined.

Table 1. Diet Composition (As-Fed Basis)

Ingredient %	Gestation[a]	Lactation[b]
Milo	79.51	62.91
Soybean meal, (46.5% CP)	15.22	28.41
Soybean oil	—	4.00
Monocalcium phosphate	2.51	2.33
Limestone	1.11	1.12
Salt	.50	.50
Sow premix	.25	.25
Vitamin premix	.25	.25
Trace mineral premix	.15	.15
Medication[c]	.20	—
Vitamin E	—	.05
DL-Methionine	—	.02

[a]Gestation feeding levels of 4 lb/d, with or without a topdressing providing 50 ppm added L-carnitine.
[b]Sows were provided ad libitum access to feed and water during lactation.
[c]Provided 50 g of oxytetracyleen/ton of complete feed.

Sows were bled on d 10, 60, 90, and 110 of gestation and at weaning (d 15). Plasma samples were analyzed for concentrations of free and total carnitine, insulin, and unsulin-like growth factor-I (IGF-I). In addition, 15 pigs per treatment (no more than one pig per litter) were selected randomly and bled at weaning for analysis of plasma IGF-I and insulin.

Data were analyzed by analysis of variance using GLM procedure of SAS (1988). Treatments were arranged in a split-plot to determine the effects of additional L-carnitine in gestation diets on sow and litter weaning performance. The whole plot included the effects of feeding added L-carnitine during gestation and the subplot included the effects of feeding L-carnitine during lactation. Because of the randomized treatment structure, the split-plot analysis allowed for determination of effects of added dietary L-carnitine in gestation and/or lactation on sow and litter lactation performance. Sow weight and last rib fat depth at breeding were used as covariates to determine the effects of additional L-carnitine on sow weight and last rib fat depth change throughout gestation. Variation in pig birth weight within treatment was analyzed using Levene's test. Briefly, this calculated the residual for each observation (absolute value of the differences between the actual pig birth weight and the litter mean birth weight). A smaller residual mean would indicate less variation of pig birth weight within the litter.

Results

Gestation Performance. Sows fed 50 ppm of added L-carnitine had greater gains of weight ($P < .01$) and last rib fat depth ($P < .02$) gain during gestation (Table 2). At farrowing, feeding 50 ppm of added L-carnitine during gestation increased both pig ($P < .01$) and litter ($P < .05$) birth weight. However, no differences were observed in the variation of birth weights between litters from sows fed either treatment ($P > .10$).

No differences were observed in total numbers of pigs born, born live, or mummies; however, sows fed 50 ppm of added L-carnitine during gestation had a decreased number of stillborn pigs per litter (.49 vs .76 pigs/litter; $P < .02$). The differences in number of stillborn pigs did not affect the total number of pigs born alive.

Lactation Performance. Split-plot analysis of the effects of added L-carnitine during gestation on weaning performance indicated increased pig and litter weaning weight for sows fed L-carnitine compared with sows fed the control diet during gestation ($P < .03$ and $P = .08$; respectively, Table 3). Gains of both pig and litter weights throughout lactation tended ($P = .03$ and $P = .12$, respectively) to be increased by feeding L-carnitine during gestation.

Sows fed L-carnitine in gestation were heavier at weaning compared to control sows ($P < .01$; Table 4). No differences were observed in last rib fat depth at weaning ($P > .05$). The addition of 50 ppm of added L-carnitine to the gestation diet had no effect on the subsequent total number of pigs born, but increased the number of pigs born live ($P < .05$; Table 5). No differences were observed in subsequent days to estrus or farrowing rate ($P > .10$).

No differences ($P < .10$) were observed in either sow or litter performance as a result of feeding 50 ppm of added L-carnitine during lactation.

Plasma Analysis. Plasma insulin concentrations were increased on d 10 and 60 of gestation in sows fed L-carnitine compared with control sows ($P = .07$). Concentrations of IGF-I were increased on d 60 and 90 in sows fed added L-carnitine ($P < .05$). No differences were observed in plasma insulin or IGF-I in blood samples collected from pigs at weaning ($P > .10$).

Plasma free-carnitine concentrations were increased ($P < .05$) on d 60 and 90 of gestation, with sows fed L-carnitine having higher concentrations compared to control sows. Total plasma carnitine concentrations tended to be numerically increased after d 10 of gestation, with the greatest increase observed on d 90 ($P < .02$).

Discussion

These results suggest that the addition of L-carnitine to gestation diets may improve feed efficiency of the sow, as indicated by the increase in body tissue reserves. The increased pig weights may result from improved nutrient utilization, as suggested by the increased weight and backfat depth observed. The increase in sow weight and last rib fat depth gain in gestation could be influenced by the role of L-carnitine on beta-oxidation. Cooperative research between Kansas State University and Oklahoma State University reported that increasing dietary L-carnitine resulted in increased fatty-acid oxidation in finishing pigs. The increase in beta-oxidation may allow for enhanced lipid utilization, possibly sparing glucose.

Our results suggest that dietary L-carnitine fed during gestation increases both insulin and IGF-I in the sow. Other research has indicated that insulin and IGF-I may increase secondary muscle fibers in the fetal pig and that IGF-I may play a role in myogenic differentiation and proliferation. However, further research is necessary to confirm the mode of action by which dietary L-carnitine may increase pig and litter birth weights. Additional research is needed to determine the effects of various inclusion rates of L-carnitine to the gestating sow diet on fetal development. Further research also is needed to determine the mode of action and confirm the increase in subsequent litter size.

Table 2. Effects of L-Carnitine on Gestation Performance

Item	Control	Carnitine	SEM	P <
No. sows	155	153		
Total born per litter	11.28	11.11	.26	.62
Born live per litter	10.36	10.47	.24	.73
Stillborns per litter	.761	.490	.09	.02
Mummies per litter	.168	.144	.04	.64
Average sow parity	3.81	3.67	.13	.42
Litter birth weight, lb	32.07	34.13	.70	.04
Pig birth weight, lb	3.27	3.48	.05	.01
Residual birth weight per pig, lb	.64	.66	.01	.12
Sow weight, lb				
breeding	403	407.2	5.31	.58
d 110[a]	506.9	526.5	1.87	.01
change[a]	102.5	122.1	2.28	.01
Sow last rib fat depth, mm				
breeding	15.9	15.8	.29	.75
d 110[b]	17.5	18.4	.25	.02
change[b]	1.7	2.6	.25	.02

[a]Analyzed with sow weight at breeding as the covariate.
[b]Analyzed with sow last rib fat depth at breeding as the covariate.

Table 3. Effects of L-Carnitine on Lactation Performance

	Dietary Treatment					Probability (P <)		
Item — Gestation: / Lactation:	Control / Control	Control / Carnitine	Carnitine / Control	Carnitine / Carnitine	SEM	Gest	Lact	Gest. × Lact.
No. sows	75	75	86	58				
Parity	3.72	3.82	3.64	3.77	.13	.63	.43	.92
Lactation length, d	15.7	15.9	15.3	15.7	.16	.15	.30	.62
Pigs equalized by d 2	9.98	10.09	10.20	10.01	.32	.85	.91	.67
Litter birth weight, lb	31.50	32.73	34.46	34.49	.98	.03	.55	.57
Pig birth weight, lb	3.22	3.32	3.45	3.53	.06	.01	.17	.81
Pigs weaned per litter[a]	8.91	8.89	9.02	9.00	.31	.76	.96	.99
Survivability, %[a]	89.57	86.08	86.87	90.45	1.84	.69	.98	.10
Litter weight at weaning, lb	90.71	91.91	97.69	99.03	3.41	.07	.75	.99
Pig wean weight, lb	10.33	10.38	10.94	10.99	.18	.01	.79	.99
Litter weight gain, lb	58.69	58.59	62.83	64.25	2.71	.12	.84	.81
Pig weight gain, lb	7.08	7.11	7.52	7.45	.15	.03	.91	.76
Average daily feed intake, lb								
wk 1	11.70	11.55	11.52	11.88	.19	.73	.64	.28
wk 2	14.35	14.41	14.70	14.87	.21	.11	.64	.84
overall	13.22	13.01	13.16	13.58	.17	.20	.63	.12

[a]Analyzed with pigs per litter on d 2 as the covariate.

Table 4. Effects of L-Carnitine on Sow Body Condition during Lactation

		Dietary Treatment					Probability (P <)		
Item	Gestation: Lactation:	Control Control	Control Carnitine	Carnitine Control	Carnitine Carnitine	SEM	Gest	Lact	Gest. × Lact.
No. sows		75	75	86	58				
Sow weight, lb									
d 110		503.1	507.2	526.9	535.0	6.74	.01	.43	.79
weaning		493.0	488.2	511.0	524.9	7.36	.01	.61	.29
change during lactation		–6.05	–6.97	–12.44	–11.82	3.16	.14	.97	.85
Sow last rib fat depth, mm									
d 110		17.54	17.55	18.36	17.31	.48	.58	.32	.31
weaning		16.25	16.44	18.36	16.12	.51	.13	.09	.05
change during lactation		–1.34	–.72	.09	–1.24	.48	.42	.54	.09

Table 5. Effects of L-Carnitine on Subsequent Reproductive Performance

		Dietary Treatment					Probability (P <)		
Item	Gestation: Lactation	Control Control	Control Carnitine	Carnitine Control	Carnitine Carnitine	SEM	Gest	Lact	Gest × Lact
No. sows		47	44	55	37				
No. sows removed[a]		28	31	31	21				
Days to estrus		5.28	5.82	6.11	5.37	.38	.64	.80	.12
Farrowing rate, %		96.1	96.3	86.5	93.2	.05	.22	.51	.54
Number total born		11.24	12.26	11.97	12.85	.40	.21	.09	.90
Number born live		10.15	11.22	11.17	12.03	3.46	.04	.05	.83

[a]Sows were removed for injury, no estrus by d 35, or age.

Table 6. Effects of L-Carnitine on IGF-I and Insulin Concentrations[a]

Item	Control	L-Carnitine	SEM	P-Value
No. sows	14	14		
Sow IGF-I, ng/ml				
d 10	72.06	78.36	12.24	.82
d 60	37.95	71.25	8.17	.01
d 90	24.98	33.02	2.71	.04
Pig IGF-I at weaning[b]	108.17	119.00	18.92	.69
Sow insulin, ng/ml				
d 10	37.27	63.00	5.3	.07
d 60	51.38	81.67	11.0	.07
d 90	54.51	50.00	7.2	.66
Pig insulin at weaning[b]	26.38	22.27	3.1	.41

[a]Analysis of sows by gestation treatment.
[b]Analysis of plasma from 15 pigs at weaning from sows fed either control or additional L-carnitine throughout gestation and lactation.

Table 7. Effects of L-Carnitine on Total and Free Carnitine Concentrations in Plasma

Item,	Control	L-Carnitine	SEM	P-Value
No. sows	14	14		
Levels of free carnitine from sow plasma, nmol/ml				
d 10	23.70	23.12	1.15	.84
d 60	15.30	19.16	1.27	.01
d 90	22.74	27.12	1.02	.01
d 110	29.29	30.97	1.54	.42
Levels of total carnitine from sow plasma, nmol/ml				
d 10	27.60	26.32	1.38	.70
d 60	20.02	22.54	1.63	.11
d 90	26.63	31.29	1.24	.02
d 110	33.72	36.84	1.98	.25

EFFECTS OF ADDITIONAL L-CARNITINE DURING LACTATION ON SOW AND LITTER PERFORMANCE OF FIRST PARITY GILTS [1]

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Summary

A total of 107 first parity gilts was used to determine the effects of 50 ppm of added L-carnitine during lactation on sow and litter performance. At farrowing, gilts were fed a milo-soybean meal diet with or without 50 ppm of added L-carnitine. No differences were observed in litter weaning weight or weight gain or changes in sow weight and last rib fat depth during lactation. Although sows fed additional L-carnitine had lower average daily feed intake the first week of lactation, no differences were observed during the second week or in overall average daily feed intake. These results suggest that feeding 50 ppm of added L-carnitine during lactation to first parity gilts did not improve sow or litter performance.

(Key Words: Sow, L-Carnitine.)

Introduction

The role of carnitine is to transport fatty acids into the mitochondria for energy utilization. Previous research at Kansas State University has shown increased birth weight and sow weight gain during gestation and subsequent increases in pigs born live when 50 ppm L-carnitine was added to the gestation diet. That study observed no significant effect on sow and litter performance with the addition of 50 ppm L-carnitine to the lactation diet of sows (parity 2 or above). Although L-carnitine apparently influenced fetal growth during gestation, we wanted to determine if it might influence lactation performance of first litter gilts. Therefore, the objective of this experiment was to answer that question.

Procedures

At farrowing, 107 parity one sows (PIC C15 × 326) were fed a common milo-soybean meal diet with or without 50 ppm of added L-carnitine. This experiment was conducted from September to December, 1996 on a 1,400-sow commercial swine farm in Northeast Kansas. Sows were weighed and ultrasonically scanned (Renco, Minneapolis, MN) for last rib fat depth on d 110 of gestation when they were moved into the farrowing facility and at weaning (d 15). Once sows were moved into farrowing facility, they were allotted randomly to dietary treatment. The lactation diet was formulated to contain 1.0% lysine, .95% Ca, and .85% P, with or without 50 ppm of added L-carnitine. All other amino acids, vitamins, and minerals were in excess of NRC (1988) requirement estimates (Table 1). At farrowing, numbers of pigs born live, mummies, and stillborns were recorded. All litters were equalized by d 2 of lactation. Litter weights were recorded at equalization and weaning (d 15). At weaning, sows were

[1]The authors thank Rick Richards, Don Reeves, Michelle Walter, Angie Bruna, and Dale Keesecker of Keesecker Agribusiness, Washington, KS for use of animals, facilities, and data collection. We also thank Joe Loughmiller and Loree Burum for data collection and Lonza Inc., Fair Lawn, NJ for partial financial support.

[2]Northeast Area Extension Office.

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

monitored for estrus and subsequent farrowing. Sows culled because of failure to return to estrus within 35 d, injury or age were not used in the analysis.

Table 1. Lactation Diet[abc]

Ingredient	Control
Milo	62.91
Soybean meal (46.5% CP)	28.41
Soybean oil	4.00
Monocalcium phosphate	2.33
Limestone	1.12
Salt	.50
Sow premix	.25
Vitamin premix	.25
Trace mineral premix	.15
Vitamin E	.05
DL-Methionine	.02
L-Carnitine (97.8%)	—

[a]Sows were provided ad libitum access to feed and water during lactation.
[b]Lactation diets were formulated to contain 1.0% lysine, .95% Ca, and .85% P.
[c]L-carnitine (50 ppm) replaced corn to form

Sow feed intake was measured daily and averaged by week of lactation. At weaning, number of pigs weaned was recorded to determine pig survivability.

The analysis of the data utilized the GLM procedure of SAS (1982). No covariates were used in the analysis of numbers born live, stillborn, and mummies. All weaning and lactational changes were analyzed with length of lactation as a covariate, because sows fed added L-carnitine treatment lactated longer than control sows (16.13 vs 15.65 d; $P < .05$). The analysis of litter weaning weight and litter weight gain during lactation required litter weight at equalization to be a covariate, because litters on the added L-carnitine treatment had heavier litters after equalization on d 2. Sow weight and last rib fat depth during lactation used sow weight and last rib fat depth on d 110 as a covariate.

Results and Discussion

First parity one sows fed 50 ppm of added L-carnitine during lactation had performance similar to that of control sows (Table 2). No differences were observed ($P > .10$) in the number of pigs born live, stillborn, or mummified per litter with the additional of L-carnitine. No differences were observed ($P > .10$) in number of pigs weaned per litter or pig survival. Gilts fed added L-carnitine also had no improvement in ($P > .10$) litter weaning weight or litter weight gain during lactation. No differences were observed ($P > .10$) in sow weight and last rib fat depth change during lactation with the additional L-carnitine. Although sows that received the additional 50 ppm L-carnitine had lower (9.50 vs 10.23 lb/d; $P < .05$) average daily feed intake during week 1, no differences were observed ($P > .10$) during week 2 or in overall average daily feed intake.

In the analysis of subsequent farrowing performance, no differences were observed ($P > .10$) with regard to days to estrus, farrowing rate, or number born live per litter.

In conclusion, no benefits were observed with the addition of L-carnitine to the lactation diet for first parity sows. The results from this experiment agree with prior work done by KSU, which observed no benefit to the addition of L-carnitine to the lactation diet.

Table 2. Effects of Dietary L-Carnitine on Lactation Performance

Item	Control	L-Carnitine	SEM	P <
Number of sows	52	55	—	—
Lactation length, d	15.65	16.13	.17	.05
Total born per litter	11.25	11.09	.38	.76
Born live per litter	10.40	10.64	.37	.65
Stillborn per litter	.538	.291	.11	.11
Mummies per litter	.308	.164	.09	.26
Number of pigs per litter				
D 2	9.74	9.84	.15	.63
Weaned[a]	9.69	9.74	.10	.71
Survivability, %[a]	96.84	97.21	.98	.79
Litter weight, lb				
Birth	26.9	30.1	.87	.01
Weaning[a,b]	91.6	94.0	1.65	.31
Gain[a,b]	63.2	65.5	1.65	.31
Sow weight, lb				
D 110	397.9	407.3	7.21	.35
Weaning[c]	391.2	386.1	2.99	.23
Change[c]	-11.9	-17.0	2.99	.23
Sow last rib fat depth, mm				
D 110	17.2	16.9	.52	.66
Weaning[c]	14.9	14.8	.38	.87
Change[c]	-2.2	-2.3	.38	.87
Sow average daily feed intake, lb/d				
Week 1	10.23	9.50	.26	.05
Week 2	9.99	9.47	.30	.21
Overall	11.25	10.93	.26	.37
Return to estrus, d[a]	8.71	6.85	.92	.15
Subsequent farrowing performance				
Farrowing rate, %	91.67	92.00	3.99	.95
Born live	10.27	10.04	.41	.69
Stillborn	.55	.46	.13	.63
Mummified	.02	.09	.04	.27

[a]Utilized length of lactation as a covariate.
[b]Litter weaning weight used litter weight at equalization as a covariate.
[c]Sow weight an LRBF used measurements on d 110 as covariates.

PUBERTY INDUCTION IN YOUNG GILTS: OVARIAN, UTERINE, AND PREGNANCY RESPONSES

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Summary

The age of gilts when their first litter is produced affects reproductive efficiency and the applications of biotechnologies such as in vitro fertilization and genetic engineering. Therefore, we evaluated the effect of age on response to puberty induction in gilts. Gilts were injected with PG600® followed 96 h later with human chorionic gonadotropin to induce follicular growth and ovulation, respectively. In the first experiment, 84-, 104-, 124-, 144-, and 164-d-old gilts were used. For treated gilts, uterine weight, uterine length, number of corpora lutea (CL), peripheral progesterone (P_4), and estradiol (E_2) increased ($P < .05$) linearly with age. Uterine luminal prostaglandins (PGs) PGE and PGF decreased for gilts treated at 124 d of age or older. The second experiment evaluated pregnancy success for gilts induced to ovulate at 116 vs 151 d of age. The effects of induction of two consecutive estrous cycles also were evaluated. Two of seven (28.6%) and four of nine (44.4%) gilts first treated when 116 and 151 d old but none of seven gilts treated at both 96 and 116 d of age were pregnant 60 d postinsemination. Results indicated that induction of a prior cycle did not improve pregnancy rates. However, some gilts in this population maintained pregnancies to 60 d when induced to ovulate and inseminated at 120 d of age.

(Key Words: Puberty, Induction, Gonadotropin Treatment, Gilt.)

Introduction

Reproductive ability in gilts develops over a prolonged period. Spontaneous puberty is neither the beginning nor the end of the sequence that begins before birth and extends through the postpubertal period. Prepubertal gilts can be induced to ovulate by around 100 d of age by treatment with pregnant mare's serum gonadotropin (PMSG) and human chorionic gonadotropin (hCG). Eggs released at induced puberty can be fertilized and begin development, but pregnancies generally are not maintained in very young gilts. Also, gilts induced to ovulate at young ages do not continue to cycle. Furthermore, gilts mated at spontaneous puberty may have reduced litter size compared to gilts mated at later estruses, and this can be attributed to fewer ovulations at the pubertal estrus and increased embryonic mortality following mating at puberty.

Therefore, development of reproductive ability in gilts includes: (1) attainment of the ability to ovulate in response to exogenous gonadotropins (by 100 d), (2) attainment of the ability to maintain pregnancy and to continue estrous cycles (by 150 d), and (3) increased ovulation rate and embryonic survival rates (through the second or third estrous cycle). An understanding of the multiple and interrelated maturations resulting in fertility in postpubertal gilts is important for decreasing the age at first reproduction to achieve more efficient pork production and for utilizing gonadotropin-treated gilts for embryo donors or recipients in the application of in vitro fertilization, transgenics, nuclear transplantation, and other biotechnologies. Our objectives were to determine the maturation of certain uterine responses relative to the attainment of fertility.

Procedures

Experiment 1. Crossbred gilts (PIC lines C15 × 326) were treated with gonadotropins (PG600®; 400 IU pregnant mare's serum gonadotropin-200 IU human chorionic gonadotropin, Intervet America Inc.) at 84, 104, 124, 144, or 164 d of age and average weights of 95.3, 115.5, 152.0, 184.8, and 225.9 lb, respectively, and received hCG (500 IU) 96 h later. Control gilts were included at 104 (117.9 lb) and 144 d (189.9 lb) and received only saline injections. Blood was collected from the jugular vein before (d 0) and after (d 2, 3, 4, 8, and 16) the first injection, and serum was harvested for assays of progesterone (P_4) and estradiol (E_2). Uteri were removed by hysterectomy on d 16 after initial gonadotropin treatment. Before removing the uterus, blood was collected from a uterine vein, and plasma was harvested for assay of prostaglandins (PGs). The number of corpora lutea (CL) was determined to estimate the number of ovulations, and the uterus was weighed. The length of one uterine horn was measured after trimming it free of the broad ligament, and the other horn was flushed with 20 ml of saline (.85% NaCl). Flushings were collected for PG assays.

Experiment 2. Twenty four crossbred gilts (PIC lines C15 × 326) were assigned to one of three treatments. Seven gilts were injected intramuscularly with gonadotropin at 96 d of age (133.1 lb) and with hCG (500 IU) 96 h later to induce ovulation. At 116 d of age (the predicted time of luteolysis), a second gonadotropin treatment was administered followed 96 h later by hCG. Another seven gilts first were administered gonadotropin at 116 d of age (143.9 lb), and 10 other gilts received gonadotropin at 151 d of age (213.6 lb). Those latter two groups of gilts also received hCG 96 h after gonadotropin treatment. Gilts were housed in outdoor pens and provided with a shed, water, and ad libitum access to feed. Before gonadotropin treatment, on the day of hCG injection, and on d 13 and 21 after hCG treatment, peripheral blood was collected for E_2 and P_4 determinations. Two inseminations were given to all gilts, on the day of hCG treatment and 24 h later. Gilts given gonadotropin at both 96 and 116 d of age were inseminated only after the second hCG injection. Jugular blood was collected 21 d after hCG for assay of P4. Approximately 60 d after hCG, surgeries were performed on gilts that had elevated concentrations of P_4 at 21 d after hCG, and fetuses were collected.

Results and Discussion

Experiment 1. Ovaries of 104-d-old control gilts contained follicles (≤ 3mm), but no CL were present. In the 144-d-old control group, recently regressed or active CL were found in ovaries in two gilts, indicating that they had reached puberty, but no indication of ovulation was seen in the other two control gilts whose ovaries contained only small follicles. In comparison, all gonadotropin-treated gilts had CL (Table 1). For gonadotropin-treated gilts, uterine weight and length exhibited a positive linear relationship with age ($P < .05$). The ovarian response to gonadotropins was reflected in the numbers of CL, which varied from one to 68 and increased linearly ($P < .05$) with age.

The peak of E_2 occurred on d 2 or 3 after gonadotropin. Concentrations of E_2 on d 0 (before treatment) and on d 4 were greater ($P < .05$) for 164-day-old gilts. For gonadotropin-treated gilts, P_4 increased from d 8 to 16 after gonadotropin (d 4 to 12 after hCG). Concentrations of P_4 on d 4 increased ($P < .05$) quadratically with age, and P_4 on d 8 ($P = .06$) and d 16 ($P < .05$) increased linearly with age. Concentrations of P_4 in serum on d 8 and 16 were correlated ($P < .01$) positively with number of CL, and P_4 concentrations on d 4, 8, and 16 tended ($P < .1$) to be correlated positively with uterine weight.

Compared to controls of the same ages, gilts treated at 104- and 144-d of age had heavier (424.0 ± 39.3 vs 99.8 ± 48.1 g) and longer (467.6 ± 21.0 vs 308.0 ± 25.7 mm) ($P < .01$) uteri (Table 1), more ($P < .05$) P_4 on d 8 (8.4 ± 1.7 vs .4 ± 2.1 ng/ml) and 16 (22.2 ± 5.5 vs .3 ± 6.7 ng/ml), and more

E_2 on d 2 (16.7 ± 5.3 vs 1.2 ± 6.5 pg/ml) (P < .1) and d 4 (4.8 ± .6 vs 1.9 ± .8 pg/ml) (P < .05).

For gonadotropin-treated gilts, PGE recovered from the uterine lumen was high for 84- to 104-d-old gilts and then decreased (Table 2), showing a quadratic effect of age (P = .05). Lower concentrations of PGs were recovered from the uterine lumens of gilts 124 d or older at treatment. Uterine luminal PGs/g uterus for 144- and 164-d-old-gilts was approximately 10% that observed for 104-d-old gilts. Concentrations of PGF in uterine venous plasma tended to have a linear relationship with age (P < .10) (Table 3). Interestingly, the amount of PGF exceeded that of PGE in the uterine lumen, but the ranking of the two PGs was reversed in the uterine vein.

Experiment 2. Five of seven gilts first induced to ovulate at 96 d of age had elevated (above 2 ng/ml) concentrations of P_4 4 d after the first hCG treatment. When these gilts were retreated with gonadotropin and hCG and inseminated, six of them had increased P_4 13 d after the second hCG injection. Progesterone concentrations for one gilt in this treatment were elevated (4.2 ng/ml) 21 d after AI, but she was not pregnant at laparotomy on d 60.

All gilts initially treated at 116 d of age had increased P_4 13 d after hCG injection, and three gilts maintained concentrations of P_4 greater than 2 ng/ml at 21 days after AI, which was indicative of pregnancy. All gilts first given gonadotropin at 151 d of age had P_4 concentrations greater than 2 ng/ml 13 days after hCG injection. Six of these gilts maintained greater than 2 ng/ml P_4 21 d after AI. Examination of uteri and ovaries for gilts that had elevated P_4 21 days after AI revealed that two of seven gilts first treated at 116 d of age and four of nine gilts treated at 151 d of age maintained pregnancies. The two gilts treated at 116 d had five and nine fetuses, representing 71% and 60% of CL, respectively. The four gilts 151 d old at treatment had four to 12 fetuses (50 to 91% of CL). Fetal weights and lengths were within the range expected for approximately d 60 of gestation.

Gilts induced to ovulate around 120 d of age in previous studies did not maintain pregnancy unless exogenous hormones were given. However some gilts in the population used in our experiment were able to establish pregnancies when ovulation was induced at 124 d of age (Exp. 2). Two gilts in the 144-d-old control group and three gilts in the 164-d-old treated group had CA and/or CL before treatment, indicating that they had already attained puberty. Therefore, gilts in these latter two age groups that had not ovulated before treatment may be considered peripubertal, and our gilts apparently matured earlier than those reported in earlier studies. Considering these observations, the responses of 124-d-old gilts in our experiments may be important for supporting pregnancy. Prostaglandin content of the uterine lumen, expressed per g uterine weight, dropped markedly by 124 d of age. The effect on pig embryos of residing in an environment with high PG concentrations has not been determined, but studies in postpartum cows suggest that a high PGF concentration in the uterine lumen is toxic to embryos.

Knowledge of the development of reproductive ability in gilts is important to reduce age at first reproduction and to apply biotechnologies utilizing oocytes and embryos. Our data describe the development of uterine PGE and PGF secretions in response to gonadotropin treatment. The data indicate that secretion of PGs into the uterine lumen of gonadotropin-treated gilts declines at the time when pregnancies can be maintained. An understanding of the maturation events leading to decreased PGs and increased proteins in the uterine lumen as gilts are induced to ovulate nearer the time of spontaneous puberty may be useful for reducing the age at first reproduction and, thereby, improving the efficiency of pork production. The relationship of this change to the ability of gilts to maintain pregnancy should be the subject of future investigations

Table 1. CL, Uterine Weight (UTWT), and Uterine Length (UTLG) on Day 16 after PG600/Saline Treatment

Age[a], day	No. of Gilts	CL[b]	UTWT(g)[b]	UTLG(mm)[b]
Controls[c]				
104	4	_	75.6 ± 55.6	285.5 ± 29.7
144[d]	2	_	124.0 ± 78.6	330.5 ± 42.0
Gonadotropin-Treated				
84	4	2.8 ± 6.5	122.1 ± 60.3	306.3 ± 37.0
104	4	11.5 ± 6.5	268.6 ± 60.3	365.8 ± 37.0
124	4	17.8 ± 6.5	500.4 ± 60.3	606.3 ± 37.0
144	4	18.8 ± 6.5	579.5 ± 60.3	569.5 ± 37.0
164[e]	2	45.5 ± 9.1	742.6 ± 85.2	585.0 ± 52.0

[a]Age at PG600 injection.
[b]Linear effect ($P < .05$) of age in gonadotropin-treated gilts.
[c]UTWT and UTLG are less ($P < .05$) than those of gonadotropin-treated gilts of the same ages.
[d]Two controls had reached puberty and are not included.
[e]Three gilts had reached puberty before treatment and are not included.

Table 2. Total Prostaglandin (pg/g) Recovered in Uterine Flushings per Gram Uterine Weight on Day 16 after PG600 Treatment

Age, d	No. of Gilts	PGE[a]	PGF[b]
Controls			
104	4	17.5 ± 7.9	79.7 ± 48.9
144	2	5.0 ± 11.2	43.4 ± 69.2
Gonadotropin-Treated			
84	4	11.2 ± 15.4	83.1 ± 125.7
104	4	36.0 ± 15.4	281.5 ± 125.7
124	4	.8 ± 15.4	9.6 ± 125.7
144	4	1.7 ± 15.4	17.4 ± 125.7
164	2	2.7 ± 21.7	39.6 ± 177.8

[a]Quadratic effect ($P = .05$) of age in gonadotropin-treated gilts.
[b]Quadratic effect ($P < .1$) of age in gonadotropin-treated gilts.

Table 3. Prostaglandin (ng/ml) Concentrations in Uterine Venous Plasma on Day 16 after PG600 Treatment

Age, d	No. of Gilts	PGE	PGF[a]
Controls			
104	4	6.6 ± 1.5	.4 ± .2
144	2	6.3 ± 2.2	1.4 ± .3
Gonadotropin-Treated			
84	4	9.4 ± 2.1	1.3 ± .3
104	4	6.2 ± 2.1	.5 ± .3
124	4	2.2 ± 2.1	.3 ± .3
144	4	7.6 ± 2.1	.5 ± .3
164	2	6.9 ± 3.0	.4 ± .4

[a]Linear effect ($P < .1$) of age in gonadotropin-treated gilts.

INFLUENCE OF DIETARY TRYPTOPHAN LEVELS ON THE GROWTH PERFORMANCE OF SEGREGATED EARLY-WEANED PIGS (10 TO 20 LB)

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Summary

A total of 360 pigs (averaging 13 d of age and 9.4 lb) was used to determine the effects of increasing dietary tryptophan:lysine ratio on the growth performance of segregated early-weaned (SEW) pigs. Two apparent digestible lysine levels (1.15 and 1.50%) and six apparent digestible tryptophan:lysine ratios (12.5, 15, 17.5, 20, 22.5 and 25%) were fed from d 0 to 16 after weaning. Lysine × tryptophan interactions were observed for ADG and F/G. Increasing the tryptophan:lysine ratio in the low lysine diets improved ADG and F/G in a quadratic manner. Increasing the tryptophan level had no effect in the high lysine diets. Results of this trial indicate that optimal apparent digestible tryptophan:lysine ratio is approximately 15%.

(Key Words: SEW Pig, Tryptophan, Lysine.)

Introduction

The use of new technologies, like segregated early weaning (SEW), has helped increase producer profitability. Recent KSU Swine Day Reports of Progress have provided requirement estimates for lysine, methionine, threonine, and isoleucine based upon the growth performance of 10 to 20 lb SEW pigs. However, research evaluating the tryptophan requirement of SEW pigs has not been conducted. Ideal amino acid ratios for nursery weight pigs developed by various researchers have indicated that tryptophan may be limiting in typical SEW diets. Therefore, the objective of this experiment was to determine the apparent digestible tryptophan: lysine ratio that maximizes growth performance of the SEW pig.

Procedures

Three hundred and sixty high lean growth pigs (Newsham Hybrids) were weaned at 13 ± 2 d of age and delivered to the KSU SEW facilities. The pigs were blocked by weight (initially 9.4 lb ± 3 lb) and allotted to one of 12 experimental diets, with five pigs per pen and six replications (pens) per treatment. Treatments were arranged in a 2 × 6 factorial with two levels of dietary lysine (1.15% and 1.50% apparent digestible lysine) and six apparent digestible tryptophan:lysine ratios (12.5, 15, 17.5, 20, 22.5, and 25%). All diets were corn-soybean meal-based with 10% dried whey, 15% lactose, 6% soybean oil, 6% spray-dried animal plasma, and 3% select menhaden fishmeal (Table 1). In addition, DL-methionine, L-isoleucine, L-valine, L-threonine, and L-cysteine were added to maintain a similar ideal pattern for all amino acids except tryptophan. L-tryptophan replaced cornstarch to form the experimental diets. The six 1.15% apparent digestible lysine diets were formulated to contain .144, .173, .201, .230, .259, and .288% apparent digestible tryptophan. Soybean meal was increased to achieve the 1.50% apparent digestible lysine diets, with formulated apparent digestible tryptophan levels of .188, .225, .263, .30, 338, and .375%. The diets were pelleted and fed from d 0 to 16 postweaning. All pigs were housed in the KSU SEW nursery in 4 × 4 ft pens, each with a self-feeder and one nipple waterer to provide ad libitum access to feed and water. The pigs were weighed and feed disappearance was mea-

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sured on d 0, 7, and 16 to determine ADG, ADFI, and F/G.

Data were analyzed in a randomized complete block design in a 2 × 6 factorial arrangement. Pigs were blocked by initial weight, with pen as the experimental unit. Analysis of variance was determined using general linear model procedures, and linear and quadratic polynomial contrasts were used to determine the effects of increasing dietary tryptophan levels.

Table 1. Basal Diet Composition[a]

	Apparent Digestible	
Ingredient, %	1.15	1.50
Corn	46.39	36.69
Soybean meal		
Dried whey	10.00	10.00
Lactose	15.00	15.00
Soybean oil	6.00	6.00
Spray-dried		
Select menhaden fishmeal	3.00	3.00
Monocalcium phosphate	1.76	1.60
Limestone	.77	.79
Salt	.10	.1
Medication[b]	1.00	1.00
Vitamin premix	.25	.25
Trace mineral premix	.15	.15
Zinc oxide	.38	.38
L-Lysine HCl	.43	.58
DL-Methionine	.16	.224
L-Isoleucine	.18	.25
L-Valine	.074	.18
L-Threonine	.15	.25
L-Cystine	.10	.16
Cornstarch[c]	.288	.375

[a]All diets were formulated to contain .9% Ca and .8% P.
[b]Provided 50 g/ton carbadox.
[c]L-tryptophan replaced cornstarch in the 1.15 and 1.50% digestible lysine basal diets to provide .14375, .1725, .20125, .230, .25875, and .2875% apparent digestible tryptophan and .1875, .225, .2625, .30, .3375, and .375% apparent digestible tryptophan, respectively. This provided apparent digestible tryptophan:lysine ratios of 12.5, 15, 17.5, 20, 22.5, and 25% at both lysine levels.

Results and Discussion

Increasing the lysine level from 1.15 to 1.5% apparent digestible lysine improved (P < .01) ADG from d 0 to 7 and F/G for all periods in the study. ADFI was lower (P < .01) for pigs fed the higher lysine diet from d 7 to 16 and 0 to 16.

Lysine × tryptophan interactions (P < .05) were observed for F/G from d 0 to 7 and d 0 to 16 and for ADG from d 7 to 16 and d 0 to 16. Increasing the tryptophan: lysine ratio had no influence on performance of pigs fed the diets containing 1.5% apparent digestible lysine. The lowest level of tryptophan at this lysine level (12.5% of lysine; .188% tryptophan) must have exceeded the pigs' requirement. However, increasing the apparent digestible tryptophan:lysine ratio improved ADG (quadratic, P < .10) from d 7 to 16 and 0 to 16. The greatest response occurred as the apparent digestible tryptophan:lysine ratio was increased from 12.5 to 15%, with a smaller increase as the ratio increased to 17.5%. Quadratic responses also were found for F/G from d 0 to 7 (P < .10), 7 to 15 (P < .10), and 0 to 16 (P < .05). Increasing the apparent digestible tryptophan:lysine ratio from 12.5 to 15% improved F/G, but no further improvement occurred at the higher ratios.

The improvement in growth performance indicates that tryptophan was limiting performance when supplied at levels below 15% of apparent digestible lysine in the low lysine diets. The F/G response observed from d 7 to 16 indicates that 1.15% apparent digestible lysine is not sufficient to maximize growth performance in the SEW pig.

Based on the results of this experiment, the optimal apparent digestible tryptophan: lysine ratio for the 10 lb SEW pig is approximately 15%. This ratio is similar to the apparent digestible tryptophan:lysine ratio suggested by the University of Illinois for 10 to 45 lb pigs.

Table 2. Influence of Increasing Tryptophan:Lysine Ratios on Growth Performance of 10 to 20 lb SEW Pigs[a]

	1.15% Apparent Digestible Lysine						1.50% Apparent Digestible Lysine							Probability (P <)		
Item	12.5	15	17.5	20	22.5	25	12.5	15	17.5	20	22.5	25	CV	Lys	Trp	Lys × Trp
d 0 to 7																
ADG, lb	.24	.27	.30	.31	.31	.30	.35	.32	.31	.34	.30	.35	18.9	.01	.72	.21
ADFI, lb	.32	.32	.37	.34	.33	.35	.33	.32	.33	.34	.32	.34	14.6	.50	.61	.81
F/G[c]	1.32	1.19	1.24	1.10	1.05	1.17	.97	1.00	1.09	1.02	1.09	.97	11.9	.01	.24	.02
d 7 to 16																
ADG, lb[c]	.50	.60	.63	.62	.63	.61	.63	.60	.66	.55	.55	.63	14.4	.85	.31	.05
ADFI, lb	.75	.81	.87	.83	.87	.85	.74	.72	.76	.69	.70	.75	14.1	.01	.69	.60
F/G[c]	1.50	1.36	1.38	1.37	1.38	1.39	1.16	1.22	1.15	1.31	1.27	1.19	10.2	.01	.70	.15
d 0 to 16																
ADG, lb[c]	.39	.45	.49	.48	.49	.48	.51	.48	.50	.45	.45	.51	13.0	.17	.42	.03
ADFI, lb	.56	.60	.65	.61	.63	.63	.56	.55	.57	.54	.53	.57	13.1	.01	.64	.72
F/G[b]	1.45	1.31	1.34	1.28	1.28	1.32	1.10	1.15	1.13	1.20	1.21	1.12	7.7	.01	.80	.01

[a]Three hundred sixty pigs (Newsham Hybrids; initially 14 d of age and 9.4 lb) were used with 5 pigs per pen and 6 replications per treatment.
[bc]Quadratic effect of tryptophan at 1.15% apparent digestible lysine (P < .05, .10, respectively).

DETERMINING THE OPTIMAL TRYPTOPHAN:LYSINE RATIO FOR THE SEGREGATED EARLY-WEANED PIGS (25 TO 50 LB)

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Summary

A 21 d growth trial was conducted to evaluate the effects of increasing the apparent digestible tryptophan:lysine ratio on growth performance of the 25 to 50 lb pig raised in a high-health, segregated early-weaning (SEW) system. Ten diets were fed with two levels of lysine (.75% and 1.10% apparent digestible lysine) and five apparent digestible tryptophan levels (13, 16, 19, 22, or 25% of lysine). Feeding the high dietary lysine consistently improved ADG and F/G and reduced ADFI. Increasing the tryptophan: lysine ratio did not improve overall performance. Based upon our results, the dietary tryptophan level to maximize growth performance in the 25 to 50 lb pig is not greater than 13% of apparent digestible lysine.

(Key Words: Tryptophan, Lysine, SEW Pig.)

Introduction

Since 1981, several ideal amino acid patterns have been suggested. These patterns have different suggested tryptophan:lysine ratios, which leads to uncertainty by industry professionals concerning the appropriate ratio to use. A previous experiment (pg. XX) determined that the optimal apparent digestible tryptophan:lysine ratio for the 10 to 20 lb SEW pig is approximately 15%. However, amino acid requirements change as the pig grows. Previous research with 20 to 50 lb pigs at KSU has evaluated the optimal ratios for methionine, threonine, and isoleucine relative to lysine; however, the optimal tryptophan:lysine ratio has not been determined. The objective of this experiment was to determine the apparent digestible tryptophan:lysine ratio that would optimize the growth performance of the 25 to 50 lb pig raised in an SEW system.

Procedures

Two hundred and sixty high-lean growth pigs (Newsham Hybrids) were blocked by weight (initially 25.3 lb and 37 d of age) and allotted to one of 10 dietary treatments. We used four or five pigs per pen (equal number of pigs per pen by block) and six replicate pens per treatment. The experimental diets consisted of either .75% or 1.10% apparent digestible lysine, with five apparent digestible tryptophan:lysine ratios (13, 16, 19, 22, or 25%) in a 2 × 5 factorial arrangement (Table 1). The pigs used in this trial had been used previously in a trial to determine the optimal apparent digestible tryptophan:lysine ratio for the 10 to 20 lb SEW pig. All pigs were fed a common diet for 7 d prior to being realloted for this trial.

All diets were corn-soybean meal-based with added L-lysine HCl, DL-methionine, and L-threonine. In addition, the 1.10% apparent digestible lysine diets had added L-isoleucine, L-valine, and L-cysteine. The crystalline amino acids were added to maintain all amino acids, except tryptophan, relative to lysine based upon the University of Illinois ideal amino acid pattern. The pattern was formulated on an apparent digestible basis. L-tryptophan replaced cornstarch to provide the increasing apparent digestible tryptophan:lysine ratios. The formulated

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levels of apparent digestible tryptophan in the .75% apparent digestible lysine diets were: .098, .12, .143, .165, and .188%. The formulated levels of apparent digestible tryptophan in the 1.10% apparent digestible lysine diets were: .143, .176, .209, .242, and .275%. All diets in this experiment were fed in meal form for 21 d.

Pigs were housed in the KSU SEW nursery in 4 × 4 pens. They were allowed ad libitum access to feed and water through a four-hole dry feeder and one nipple waterer per pen. The pigs were weighed and feed disappearance was measured at 7-d intervals to determine ADG, ADFI, and F/G.

The data were analyzed as a randomized complete block design in a 2 × 5 factorial arrangement. Pigs were blocked by initial weight with pen as the experimental unit. Analysis of variance was performed using general linear model procedures, and linear and quadratic polynomial contrasts were used to determine the effects of increasing dietary tryptophan levels on pig performance.

Results and Discussion

Increasing the apparent digestible lysine level from .75 to 1.10% improved ($P < .01$) ADG and F/G for all 3 weeks of the trial. Feed intake also was reduced ($P < .05$) from d 7 to 14, 14 to 21, and 0 to 21. These data confirmed that the diets containing .75% apparent digestible lysine were below the pigs' requirement.

Increasing the tryptophan level had no influence on ADG or ADFI during any week of the study. No tryptophan × lysine interactions were observed; however, a tendency ($P < .10$) for an interaction was found for F/G from d 7 to 14. In practical terms, this interaction is of little importance because of the lack of consistent improvement in F/G as the tryptophan:lysine ratio increased at either level of lysine. A linear improvement in F/G from d 0 to 7 was found as the apparent digestible tryptophan:lysine ratio was increased from 13 to 25%. However, this response was lost during the following weeks, and pigs fed the lowest apparent digestible tryptophan:lysine ratio (13%) had similar or better F/G compared to pigs fed higher tryptophan levels.

The quadratic ($P < .05$) change in F/G measured from d 0 to 21 F/G was primarily a result of poorer F/G with increasing tryptophan:lysine ratios at .75% apparent digestible lysine.

The response to increasing apparent digestible lysine from .75% to 1.10% indicates that the apparent digestible lysine requirement of the high-health, SEW-reared, 25 to 50 lb pig is greater than .75%. This response is consistent with research reported in the 1994 KSU Swine Day Report of Progress. In that study, between 1.05 and 1.15% apparent digestible lysine was required to maximize growth performance of high health, SEW-reared pigs from 25 to 50 lb.

Based on the lack of consistent improvement in performance from tryptophan level, we conclude that the apparent digestible tryptophan requirement for 25 to 50 lb, high-health, SEW-reared pigs is not greater than 13% of apparent digestible lysine. This level is slightly lower than the 15% apparent digestible tryptophan:lysine ratio suggested by the University of Illinois.

Table 1. Basal Diet Composition[a]

	Apparent Digestible Lysine, %	
Ingredient, %	.75	1.10
Corn	79.20	68.45
Soybean meal (46.5% CP)	13.17	23.12
Soybean oil	2.50	2.90
Monocalcium phosphate	1.87	1.71
Limestone	.91	.93
Salt	.35	.35
Medication[b]	1.00	1.00
Vitamin premix	.25	.25
Trace mineral premix	.15	.15
Copper sulfate	.075	.075
L-Lysine HCl	.363	.51
DL-Methionine	.018	.09
L-Isoleucine	--	.054
L-Valine	--	.076
L-Threonine	.072	.165
L-Cystine	--	.047
Cornstarch[c]	.90	.132

[a]Diets were formulated to contain all essential amino acids in an ideal amino acid ratio, adjusted on an apparent digestible basis. Diets also were formulated to contain .9% Ca and .8% P.
[b]Provided 50 g/ton carbadox.
[c]L-tryptophan replaced cornstarch in the .75% and 1.10% digestible lysine basal diets to provide .0975, .12, .1425, .165, and .1875% apparent digestible tryptophan and .143, .176, .209, .242, and .275% apparent digestible tryptophan, respectively. This provided 10 experimental diets in a 2 **x** 5 factorial arrangement, with two levels of lysine and five apparent digestible tryptophan:lysine ratios (13, 16, 19, 22, and 25%).

Table 2. Influence of Increasing Tryptophan:Lysine Ratios on the Growth Performance of 25 to 50 lb SEW Pigs[a]

	.75% Apparent Digestible Lysine					1.10% Apparent Digestible Lysine						Probability (P <)		
Item	13	16	19	22	25	13	16	19	22	25	CV	Lys	Trp	Lys × Trp
d 0 to 7														
ADG, lb	.84	.85	.88	.92	.94	1.24	1.25	1.25	1.22	1.28	12.3	.01	.71	.87
ADFI, lb	1.76	1.99	1.89	1.82	1.85	1.83	1.91	1.88	1.80	1.89	9.4	.99	.23	.86
F/G[b]	2.24	2.37	2.17	2.01	1.98	1.49	1.53	1.50	1.48	1.49	14.1	.01	.22	.44
d 7 to 14														
ADG, lb	1.24	1.35	1.17	1.30	1.27	1.39	1.46	1.48	1.53	1.54	11.7	.01	.32	.54
ADFI, lb[d]	2.28	2.46	2.54	2.54	2.44	2.28	2.36	2.40	2.30	2.39	8.0	.04	.16	.58
F/G	1.86	1.83	2.21	1.97	1.93	1.65	1.63	1.63	1.53	1.55	10.7	.01	.10	.10
d 14 to 21														
ADG, lb	1.17	1.21	1.22	1.30	1.19	1.43	1.47	1.46	1.36	1.39	11.1	.01	.84	.41
ADFI, lb	2.35	2.62	2.53	2.51	2.52	2.29	2.31	2.47	2.28	2.38	9.4	.01	.35	.63
F/G	2.06	2.19	2.08	1.95	2.15	1.60	1.57	1.70	1.68	1.71	9.9	.01	.50	.24
d 0 to 21														
ADG, lb	1.08	1.14	1.08	1.17	1.13	1.35	1.39	1.39	1.37	1.40	6.6	.01	.39	.60
ADFI, lb	2.13	2.35	2.31	2.29	2.27	2.13	2.19	2.24	2.12	2.22	7.2	.04	.18	.66
F/G[c]	1.98	2.07	2.14	1.96	2.01	1.58	1.58	1.61	1.55	1.58	4.5	.01	.01	.22

[a]Two hundred and sixty pigs (Newsham Hybrids; initially 37 d of age and 25.3 lb) were used with 4 or 5 pigs per pen and 6 replications (pens) per treatment.
[b]Linear effect of tryptophan (P < .05).
[cd]Quadratic effect of tryptophan (P < .05; .10, respectively).

THE INTERACTIVE EFFECTS AMONG DIET COMPLEXITY, ZINC OXIDE, AND FEED GRADE ANTIBIOTIC ON PERFORMANCE OF SEGREGATED EARLY-WEANED PIGS[1]

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Summary

A 27-d growth trial was conducted to evaluate the interactive effects among diet complexity, added zinc oxide, and feed grade antibiotic on growth performance of segregated early-weaned (SEW) pigs. For the overall trial, pigs fed the complex diets had improved ADG and ADFI, but not feed efficiency. Pigs fed diets with an antibiotic had better ADG and ADFI than did pigs fed diets without antibiotic, as was the case for those pigs fed zinc oxide. The complexity response was greatest in the first five-days after weaning but was significant for all time periods. The responses to zinc oxide occurred primarily during the first 10 d of the experiment, whereas the responses to antibiotic occurred in the latter half of the growth trial. These data indicate that both zinc oxide and antibiotic are beneficial in the diets of SEW pigs.

(Key Words: SEW Pigs, Zinc Oxide, Antibiotic, Diet Complexity.)

Introduction

Numerous experiments have been conducted at the Kansas State University segregated early-weaning (SEW) facilities to evaluate pig growth performance under high-health conditions. Because of this high-health status, some have questioned the value of growth promoters such as zinc oxide and even feed grade antibiotics in diets for SEW pigs. Therefore, we conducted an experiment designed to compare the interactive effects among diet complexity, added zinc oxide, and feed grade antibiotic (neomycin) on growth performance of SEW pigs in order to start to develop a baseline model for optimal SEW diets that will both maximize performance and minimize cost.

Procedures

A total of 320 SEW barrows (initially 9.9 lb and 12 to 15 d of age) was used in a 27-d growth trial. Pigs were blocked on the basis of weight and randomly allotted to one of eight dietary treatments with five pigs per pen and eight replications (pens) per treatment. Treatments were arranged in a $2 \times 2 \times 2$ factorial with main effects of diet complexity (simple or complex), added zinc oxide (165 or 3,000 ppm), and feed grade antibiotic (none or 50 g/ton of neomycin).

All diets were fed in a meal form. The SEW diets were fed from d 0 to 5, followed by the transition diets from d 5 to 10, then the phase II diets from d 10 to 20, and finally the common phase III diet from d 20 to 27 postweaning. The common phase III diet did not contain zinc oxide, copper sulfate, or antibiotic. The nutritional compositions of these diets are given in Table 1. Zinc oxide and antibiotic replaced cornstarch in diet formulation. Within each phase, dietary lysine, methionine, Ca, and P were kept constant.

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

[2]Food Animal Health and Management Center.

Pigs were housed in environmentally controlled nurseries in 4 × 4 ft pens with tri-bar flooring and were allowed ad libitum access to feed through a five-hole self-feeder and water through a single water nipple. Weight gain and feed intake were determined on d 5, 10, 20, and 27 postweaning and were used to determine ADG, ADFI, and feed efficiency (F/G).

Data were analyzed as a 2 × 2 × 2 factorial in a randomized complete block design using the general linear model (GLM) procedures of SAS. The pen was the experimental unit for all measurements. Diet complexity, zinc oxide, and antibiotic were the main effects, and the experimental model included the main effects and all possible interactions of the main effects. Growth performance means and CV values are given in Table 2, and statistical P-values for interactions and main effects are given in Table 3.

Results and Discussion

From d 0 to 5 postweaning, the presence of specialty proteins in the complex diets greatly improved ADG, ADFI, and F/G ($P < .01$) as illustrated by the performance means in Table 2. Antibiotic had no effect ($P > .25$) on ADG, ADFI, or F/G from d 0 to 5 postweaning. Conversely, zinc oxide tended to improve ADG but only in the pigs fed the simple diets (Zn by diet complexity interaction, $P < .08$). The extremely high degree of variability in d 0 to 5 performance can be explained by the loss of weight and its subsequent effects on F/G by some pens of pigs fed the simple diets, as well as the wide initial weight range across the replications from the heavy to light blocks.

From d 5 to 10, supplemental zinc oxide improved ADG and ADFI ($P < .01$), whereas antibiotic had no effect ($P > .10$) on ADG, ADFI, or F/G.

When the performance means were analyzed for the combined d 0 to 10 period, a three-way interaction was observed for ADG ($P = .02$). This appeared to be a result of an additive response to both zinc oxide and the antibiotic in simple diets, whereas in complex diets, either zinc oxide or an antibiotic was equally effective in improving ADG.

From d 10 to 20, the presence of antibiotic improved ADG ($P < .01$) in both diet types and F/G ($P = .01$) in the simple diets (complexity by antibiotic interaction ($P = .10$)).

From d 0 to 20, zinc oxide, antibiotic, and complex diets all improved ($P < .01$) ADG, whereas zinc oxide ($P = .05$) and complex diets ($P < .01$) improved ADFI. Feed efficiency improved in response to antibiotic ($P = .02$) and complex diets ($P = .01$).

From d 20 to 27, the prior presence of antibiotic improved ADFI ($P = .01$) and F/G ($P = .03$), whereas zinc oxide had no effect ($P > .15$) on ADG, ADFI, or F/G. As the common phase III diet was fed, pigs previously fed complex diets still had improved ADFI ($P < .01$) but a poorer F/G ($P < .01$). This was especially evident when pigs were changed from diets containing antibiotic and zinc oxide to the common diet containing neither.

For the overall trial (d 0 to 27 postweaning), complexity, antibiotic, and zinc oxide all improved ADG ($P \leq .02$). Complexity ($P < .01$), antibiotic ($P = .06$), and zinc oxide ($P = .07$) all improved ADFI, but F/G was not affected when measured over the total trial.

Prior results from Kansas State University indicate that pigs reared in an SEW environment can be fed simpler diets than traditionally thought. In this experiment, complex diets with zinc oxide and antibiotic or both were clearly superior. The improved growth performance from increased diet complexity was most dramatic in the early period (d 0 to 5) postweaning; however, it was maintained throughout the duration of the study. It is also clear that zinc oxide and antibiotic are necessary in SEW pig diets. Zinc oxide appears to be beneficial mainly in the first 10 d postweaning, whereas antibiotic appears to be most beneficial after d 10.

Table 1. Compositions of Basal Diets (As-Fed Basis)

	SEW[a]		Transition[b]		Phase II[c]		Common
Ingredients, %	Simple	Complex	Simple	Complex	Simple	Complex	Phase III[d]
Corn	44.70	38.41	50.07	45.53	54.58	51.76	53.32
Dried whey	----	25.00	----	20.00	----	10.00	----
Soybean meal, 46.5%	48.84	12.21	43.41	21.31	38.05	28.52	37.15
Spray-dried animal plasma	----	6.75	----	2.50	----	----	----
Select menhaden fish meal	----	6.00	----	2.50	----	----	----
Lactose	----	5.00	----	----	----	----	----
Soybean oil	2.00	2.00	2.00	2.00	3.00	3.00	6.00
Spray-dried bloodmeal	----	1.75	----	2.50	----	2.50	----
Monocalcium phosphate	1.70	0.70	1.80	1.27	1.90	1.84	1.73
Limestone	0.99	0.33	0.98	0.59	0.83	0.70	0.86
Cornstarch[e]	0.88	0.88	0.88	0.88	0.75	0.75	----
Premix	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Salt	0.25	0.25	0.25	0.25	0.30	0.30	0.35
DL-Methionine	0.09	0.17	0.06	0.12	0.04	0.08	0.04
L-Lysine	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[a]SEW diets were formulated to contain 1.70% lysine, .48% methionine, .90% Ca, and .80% P and were fed from d 0 to 5 postweaning.
[b]Transition diets were formulated to contain 1.55% lysine, .44% methionine, .90% Ca, and .80% P and were fed from d 5 to 10 postweaning.
[c]Phase II diets were formulated to contain 1.40% lysine, .38% methionine, .90% Ca, and .80% P and were fed from d 10 to 20 postweaning.
[d]Phase III diet was formulated to contain 1.35% lysine, .38% methionine, .90% Ca, and .80% P and was fed from d 20 to 27 postweaning.
[e]Cornstarch was replaced on an equal weight basis with antibiotic (providing 50 g/ton of a mixture of neomycin and oxytetracycline) and zinc oxide (3,000 ppm) to provide the experimental diets.

Table 2. Growth Performance of Pigs Fed Simple or Complex Diets With or Without Zinc Oxide, Antibiotic, or Both[a]

	Simple				Complex				
	-Zinc oxide		+Zinc Oxide		-Zinc Oxide		+Zinc Oxide		
Item	-Antibiotic	+Antibiotic	-Antibiotic	+Antibiotic	-Antibiotic	+Antibiotic	-Antibiotic	+Antibiotic	CV
d 0 to 5									
ADG, lb	.03	-.09	.05	.09	.21	.24	.23	.22	85.3
ADFI, lb	.14	.12	.15	.18	.25	.23	.24	.23	23.4
F/G	4.67	----	3.00	2.00	1.19	.96	1.04	1.06	278.8
d 5 to10									
ADG, lb	.23	.25	.30	.38	.31	.44	.54	.49	32.1
ADFI, lb	.39	.41	.50	.54	.57	.59	.71	.70	14.4
F/G	1.70	1.64	1.67	1.42	1.84	1.34	1.31	1.43	46.5
d 0 to 10									
ADG, lb	.13	.08	.18	.23	.26	.34	.38	.36	34.7
ADFI, lb	.27	.27	.33	.36	.41	.41	.47	.46	15.2
F/G	2.08	3.38	1.83	1.57	1.58	1.21	1.24	1.28	56.0
d 10 to 20									
ADG, lb	.68	.79	.74	.85	.79	.91	.81	.89	12.4
ADFI, lb	1.02	1.01	1.03	.96	.98	1.14	1.09	1.14	15.4
F/G	1.50	1.28	1.39	1.13	1.24	1.25	1.35	1.28	16.7
d 0 to 20									
ADG, lb	.41	.44	.46	.54	.53	.63	.60	.62	14.1
ADFI, lb	.64	.64	.68	.66	.70	.77	.78	.80	12.5
F/G	1.56	1.45	1.48	1.22	1.32	1.22	1.30	1.29	14.5
d 20 to 27									
ADG, lb	1.01	1.07	1.01	1.06	.99	1.02	1.07	.94	10.9
ADFI, lb	1.55	1.69	1.66	1.76	1.67	1.97	1.83	1.85	11.0
F/G	1.53	1.58	1.64	1.66	1.69	1.93	1.71	1.97	12.6
d 0 to 27									
ADG, lb	.56	.60	.60	.68	.65	.73	.72	.71	10.8
ADFI, lb	.87	.91	.93	.94	.95	1.08	1.05	1.07	10.5
F/G	1.55	1.52	1.55	1.38	1.46	1.48	1.46	1.51	11.1

[a]Means represent a total of 320 pigs (initially 9.9 lb and 12-15 d of age) with 5 pigs per pen and 8 replicate pens per treatment.

Table 3. Interactions and Main Effects for Growth Performance

Item	Comp × Ab × Zn[a]	Ab × Zn	Comp × Zn	Comp × Ab	Zn	Ab	Comp
d 0 to 5							
ADG	.07	.26	.08	.38	.07	.53	< .01
ADFI	.30	.30	.10	.30	.21	.58	< .01
F/G	.10	.22	.04	.15	.03	.29	< .01
d 5 to 10							
ADG	.06	.35	.48	.85	< .01	.14	< .01
ADFI	.61	.90	.87	.62	< .01	.43	< .01
F/G	.19	.64	.89	.82	.21	.51	.21
d 0 to 10							
ADG	.02	.96	.54	.67	< .01	.52	< .01
ADFI	.43	.74	.58	.45	< .01	.75	< .01
F/G	.09	.80	.22	.43	.05	.99	< .01
d 10 to 20							
ADG	.71	.72	.23	.82	.27	< .01	< .01
ADFI	.76	.30	.41	.09	.66	.45	.05
F/G	.78	.36	.17	.10	.67	.01	.52
d 0 to 20							
ADG	.10	.82	.24	.93	< .01	< .01	< .01
ADFI	.62	.38	.60	.20	.05	.40	< .01
F/G	.19	.50	.14	.31	.22	.02	.01
d 20 to 27							
ADG	.18	.16	.98	.06	.99	.96	.21
ADFI	.23	.11	.47	.66	.25	.01	< .01
F/G	.69	.80	.48	.11	.18	.03	< .01
d 0 to 27							
ADG	.07	.44	.33	.46	.02	.01	< .01
ADFI	.38	.17	.97	.31	.07	.06	< .01
F/G	.28	.52	.53	.15	.72	.50	.76

[a]Abbreviations are Comp = diet complexity, Ab = antibiotic, and Zn = zinc oxide.

EFFECT OF TIME OF INTRODUCTION AND LEVEL OF SOYBEAN MEAL ON PERFORMANCE OF SEGREGATED EARLY-WEANED PIGS [1]

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Summary

A growth trial was conducted utilizing segregated early weaned (SEW) pigs to evaluate the effects of time of introduction and level of soybean meal on growth performance. Few differences were observed in growth performance indicating that including up to 40% soybean meal in the diet will not adversely affect growth of high-health status, SEW-reared pigs.

(Key Words: SEW Pigs, Soybean Meal, Growth Performance.)

Introduction

Recent studies from Kansas State University have investigated the effects on performance of including higher levels of soybean meal (SBM) in the diets of SEW-reared pigs. They have shown that these high-health pigs can tolerate much higher levels of dietary SBM than can conventionally reared nursery pigs. This nutritional adaptation has the potential to tremendously lower diet cost for producers by decreasing the amount of specialty products needed without affecting growth performance. The mechanism(s) behind the ability of these pigs to tolerate these higher levels of SBM is not well understood. The objective of this experiment was to evaluate the effects of time of introduction and level of SBM on growth performance of SEW pigs.

Procedures

A total of 175 SEW barrows (initially 8.8 lb and 12 to 15 d of age) were used in a 35 d growth trial. Pigs were blocked on the basis of weight and randomly allotted to one of seven dietary treatments with five pigs per pen and five replications (pens) per treatment.

The experimental SEW diets were pelleted to a diameter of 3/32 in. and were fed for 21 d postweaning. These diets contained 1.60% lysine, .90% Ca, .80% P, and .44% methionine (Table 1). The trial consisted of three times of introduction to SBM (0, 7, or 14 d postweaning) and two levels of SBM (20% or 40%) within each time (Table 2). A positive control with no SBM was included as a seventh treatment. A combination of skim milk, fish meal, and blood meal was used to replace the SBM in the experimental diets. The levels of dried whey and spray-dried plasma protein were kept constant in all diets, whereas lactose was added with added levels of SBM. The levels of soybean oil were increased with increasing levels of SBM in order to keep the energy content of all diets constant.

A common phase diet, in meal form, was fed to all pigs for the remainder of the growth trial (d 21 to 35 postweaning). This simple corn-SBM based diet contained 1.40% lysine, .80% Ca, .70% P, and .39% methionine (Table 1).

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

Pigs were housed in an environmentally controlled nursery in 4 × 4 ft pens with tri-bar flooring and allowed ad libitum access to feed through a five-hole self-feeder and water through a single water nipple. Weekly weight gains and feed intakes were measured and used to determine ADG, ADFI, and feed efficiency (F/G).

Data were analyzed as a randomized complete block design using the general linear model (GLM) procedures of SAS. The pen was the experimental unit for all measurements. Single degree of freedom contrasts were used to determine the significance of all possible dietary comparisons. Linear and nonlinear contrasts also were included for d 0 to 7. Performance means and CV values are presented in Table 3, and the associated probability values are presented in Table 4.

Results and Discussion

From d 0 to 7, no effect of treatment ($P > .20$) was found on ADG, ADFI, or G/F (Table 3). From d 0 to 14, the change from the control diets to diets containing SBM adversely affected ($P < .10$) ADFI. However, feed efficiency was improved ($P = .01$) during this same interval by changing from the control diet to the diet containing 20% SBM. No effect of treatment ($P > .10$) was observed from d 0 to 21 or d 0 to 35 for ADG, ADFI, or F/G other than a small ($P < .10$) decrease in ADFI over the total trial for pigs fed the control diet for 1 week followed by 20% SBM as compared to pigs fed 20% SBM throughout.

Numerous research reports have evaluated soybean protein in the form of SBM in all stages of swine diets. However, complex proteins in SBM have been implicated as a cause of transient hypersensitivity in the early weaned pig. To avoid detrimental hypersensitivity responses such as increased crypt cell division and reduced digestive and absorptive capacities associated with SBM, postweaning diets typically have been very complex (containing milk and animal protein products), albeit involving a much greater cost than the much simpler SBM-type diets.

In the current experiment, including up to 40% SBM in these complex, nutrient dense diets did not adversely affect growth performance. Spray-dried animal plasma may help mask the effects of dietary SBM. Previous research (1996 KSU Swine Day Report of Progress 772, p 34) found that SBM could effectively replace a portion of the spray-dried animal plasma in diets for SEW pigs. Interestingly, in the current study, no reduction in performance occurred when pigs were changed from the control diet to the SBM diets at any point throughout the experiment. This suggests that these high-health status, SEW-reared pigs have the immune capacity to tolerate high dietary inclusion levels of SBM, whereas conventionally reared nursery pigs do not. Although not statistically significant, an overall comparison of the control pigs and the pigs fed 40% SBM showed that the control pigs had approximately 2% higher ADG, 4% higher ADFI, and 2% poorer feed conversion efficiency.

In conclusion, these data suggest that high-health status, SEW-reared pigs can effectively utilize dietary inclusion levels of up to 40% SBM without any reduction in growth performance.

Table 1. Compositions of Diets (As-Fed Basis)

	Soybean Meal Level, %[a]			Common
Ingredient, %	0	20	40	Phase III[b]
Corn	43.17	30.40	17.61	54.36
Soybean meal (46.5%)	---_	20.00	40.00	38.07
Dried skim milk	23.01	11.50	----	----
Dried whey	15.00	15.00	15.00	---
Select menhaden fish meal	6.00	3.00	----	----
Lactose	---_	5.75	11.50	----
Soybean oil	5.00	6.60	8.20	3.00
Spray-dried plasma protein	3.00	3.00	3.00	----
Spray-dried blood meal	2.00	1.00	----	----
Monocalcium phosphate	.52	1.05	1.59	1.43
Limestone	.14	.55	.96	1.11
Antibiotic[c]	1.00	1.00	1.00	1.00
Zinc oxide	.38	.38	.38	----
Premix	.40	.40	.40	.40
L-Lysine	.15	.12	.09	.15
Salt	.15	.15	.15	.35
DL-Methionine	.08	.10	.12	.05
Copper sulfate	----	---_	--_-	.08
Total	100.00	100.00	100.00	100.00

[a]Diets were formulated to contain 1.60% lysine, .44% methionine, .90% Ca, and .80% P and were fed from d 0 to 21 postweaning.
[b]Common diet was formulated to contain 1.40% lysine, .39% methionine, .80% Ca, and .70% P and was fed from d 21 to 35 postweaning.
‘Provided 50 g/ton carbadox.

Table 2. Timeline for Introduction to Soybean Meal

	Treatment (% Soybean Meal)							Pig
Trial (d)	1	2	3	4	5	6	7	Age (d)
0 to 7	0	20	40	0	0	0	0	12-15
7 to 14	0	20	40	20	40	0	0	19-22
14 to 21	0	20	40	20	40	20	40	26-29

Table 3. Effect of Soybean Meal Level and Tie of Introduction on SEW Pig Performance[a]

	Dietary Treatment Combination (% Soybean Meal)							
Item	1	2	3	4	5	6	7	CV
d 0 to 7								
Treatment:	0	20	40					
ADG, lb	.41	.45	.39					19.49
ADFI, lb	.37	.38	.34					17.78
F/G	.92	.86	.89					20.41
d 0 to 14								
Treatment:	0-0	20-20	40-40	0-20	0-40			
ADG, lb	.59	.61	.57	.60	.57			12.81
ADFI, lb	.64	.63	.59	.57	.56			12.32
F/G	1.09	1.06	1.04	.94	1.00			10.81
d 0 to 21								
Treatment:	0-0-0	20-20-20	40-40-40	0-20-20	0-40-40	0-0-20	0-0-40	
ADG, lb	.73	.72	.68	.71	.68	.69	.72	9.72
ADFI, lb	.79	.79	.76	.74	.74	.73	.77	9.94
F/G	1.09	1.10	1.12	1.04	1.09	1.06	1.07	8.28
d 0 to 35								
Treatment:	0-0-0	20-20-20	40-40-40	0-20-20	0-40-40	0-0-20	0-0-40	
ADG, lb	.95	.97	.93	.89	.92	.93	.96	8.00
ADFI, lb	1.21	1.21	1.16	1.13	1.19	1.18	1.19	6.54
F/G	1.28	1.26	1.25	1.27	1.30	1.27	1.24	5.81

[a]Means represent a total of 175 pigs (initially 8.8 lb and 12-15 d of age) with five pigs per pen and five replicate pens per treatment.

Table 4. Probability Values for Growth Performance Contrasts

	Probability (P <)																				
Contrast	1 v 2	1 v 3	1 v 4	1 v 5	1 v 6	1 v 7	2 v 3	2 v 4	2 v 5	2 v 6	2 v 7	3 v 4	3 v 5	3 v 6	3 v 7	4 v 5	4 v 6	4 v 7	5 v 6	5 v 7	6 v 7
d 0 to 7[a]																					
ADG	.29	.57					.21														
ADFI	.60	.34					.25														
F/G	.48	.71					.80														
d 0 to 14																					
ADG	.65	.59	.74	.59			.42	.92	.42			.47	.99			.48					
ADFI	.83	.16	.06	.05			.32	.17	.15			.69	.65			.96					
F/G	.52	.38	.01	.12			.85	.12	.44			.17	.56			.42					
d 0 to 21																					
ADG	.88	.23	.70	.29	.37	.83	.30	.82	.37	.46	.95	.41	.89	.76	.33	.50	.60	.87	.87	.40	.49
ADFI	.93	.43	.25	.28	.21	.63	.48	.28	.32	.24	.69	.71	.77	.62	.76	.93	.91	.49	.84	.55	.43
F/G	.81	.57	.36	.99	.64	.77	.74	.25	.81	.48	.59	.15	.57	.30	.39	.37	.66	.54	.64	.77	.86
d 0 to 35																					
ADG	.62	.78	.26	.56	.80	.71	.44	.11	.28	.45	.90	.39	.76	.98	.52	.58	.38	.14	.74	.35	.53
ADFI	.92	.38	.12	.66	.63	.71	.32	.09	.58	.55	.63	.47	.65	.69	.60	.25	.27	.22	.96	.94	.91
F/G	.67	.60	.87	.70	.83	.40	.92	.79	.41	.83	.67	.71	.36	.75	.74	.58	.96	.49	.55	.22	.52

[a]Linear and nonlinear contrasts during d 0 to 7 were nonsignificant (P > .20).

EFFECTS OF TETRACYCLINE ON SHEDDING OF SUSCEPTIBLE AND RESISTANT *SALMONELLA* SPP. EXPERIMENTALLY INOCULATED INTO PIGS [1]

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Summary

The objective of this experiment was to study the influence of tetracycline on the transfer of antibiotic resistance in an *in vivo* swine model experimentally infected with antibiotic-resistant and antibiotic-susceptible *Salmonella* spp. Tetracycline reduced the amount and duration of shedding of tetracycline-susceptible *Salmonella*. However, tetracycline had no effect on shedding of resistant *Salmonella*. We also have evidence that resistance was transferred from the resistant to the susceptible strain of *Salmonella*.

(Key Words: *Salmonella typhimurium*, Antibiotics, Resistance.)

Introduction

Antibiotics are used commonly to treat infections in animals and humans and frequently are fed at subtherapeutic levels to food animals for growth promotion. These practices may be associated with the development of antibiotic resistance, but little information is available about the mechanism involved. Infections caused by antibiotic-resistant *Salmonella*, such as the multidrug-resistant *Salmonella t yphimurium* Definitive Type 104 (DT 104), are increasing and have become a cause for public health concern. Our arsenal of effective antibiotic therapy is diminishing as resistance increases and the cost of developing new antibiotics escalates. Thus, it is urgent to study and better understand the acquisition of resistance factors so that antibiotics currently available can be used more effectively. Therefore, our objective was to study the influence of tetracycline on the transfer of antibiotic resistance in an *in vivo* swine model.

Procedures

Twenty pigs (10 barrows and 10 gilts) were assigned randomly to one of two groups 3 days prior to the start of the experiment. At the time of randomization, pigs were 35 d of age. Five barrows and five gilts were assigned to each group, tetracycline-treated and control. Results of randomization yielded a design balanced on treatment, gender, and body weight within gender.

All pigs had *ad libitum* access to control feed (without growth-promoting antibiotics) and nipple waterers for the 3 d acclimation period and were housed in pens in an environmentally controlled building (temperature ranged from 68°C to 78°C). On the d 0 of the experiment, the treatment group was switched to a diet containing chlortetracycline (200 g/ton of feed). The treatment group also was given 5 mg/lb BW of oxytetracycline IM on d 3, 4, 5, and d 17, 18, 19. The injections were alternated between the left and right sides of the pig.

[11]Appreciation is expressed to the American Veterinary Medical Association Foundation for providing partial financial support. Appreciation also is expressed to Dave Steuver, Stacy Stoltenberg, and Mike Hornback for technical assistance.

[2]Food Animal Health and Management Center.

[3]Department of Diagnostic Medicine/Pathobiology.

On d 0, just prior to inoculation, rectal swabs were collected from all pigs. On d 0 and 14, all pigs were inoculated intra-gastrically by oral catheter with a mixture of 10^9 *Salmonella typhimurium* (tetracycline susceptible) and 10^9 *Salmonella anatum* (tetracycline resistant. Pigs were observed daily for clinical signs of lethargy, inappetence, and diarrhea.

Rectal swabs also were collected on d 2, 4, 7, 9, and 11. Fecal samples were collected by rectal palpation on d 14, 16, 18, 21, 23, 25, 28, 30, 32, and 35. Samples were cultured according to standard microbial isolation techniques.

Any isolated *Salmonella* colonies were counted, and colony forming units (cfu) per ml were calculated. On all plates with suspected *Salmonella* spp., up to six individual colonies were selected and serotyped by agglutination procedures using *Salmonella* O Antiserum Groups E and B. All isolates then were streaked onto a brain-heart infusion (BHI) agar slant, cataloged, and refrigerated.

On d 35, all pigs were euthanized and necropsied. Using sterile technique, the following tissues were collected: spleen, liver, kidney, ileocecal lymph node, ileocecal wall, bone marrow, tonsils, and lung. Swab samples were obtained from the jejunum, ileum, cecum, ileocecal junction, colon, and spiral colon contents for culturing of *Salmonella* as previously described.

A subsampling of 163 isolates was checked for tetracycline sensitivity by the Sensititre Microbiology method. Isolates from the first and last day of *Salmonella* spp. shedding (1 or 2 isolates per pig per d depending on whether one or both *Salmonella* spp. strains were present) as well as the tissue swabs taken at necropsy were tested.

The pig was considered the experimental unit for all statistical analysis. A pig was considered to be shedding *Salmonella* spp. each day when at least one *Salmonella* spp. isolate was obtained. The effect of tetracycline on shedding rate was analyzed as a split plot design with the control or medicated group as the whole plot and day of sampling as the subplot.

Results

Few signs of clinical salmonellosis were observed. We failed to isolate any *Salmonella* spp. from the swabs obtained prior to inoculation. A total of 1,247 *Salmonella* spp. isolates was collected. These isolates were characterized as *S. anatum* (n = 975) or *S. typhimurium* (n = 272).

Medication by day interactions were not noted. *S. anatum* (tetracycline resistant) was shed in a greater number than was *S. typhimurium* (tetracycline susceptible; Table 1). *S. anatum* was shed in higher numbers immediately after both inoculations and then the number shed declined (Figure 1).

Table 1. Percentage of Samples from Which the Specified *Salmonella* sp. was Isolated

Species Isolated	Control	Tetracycline	SE
S. typhimurium only[a]	10.0%	2.0%	2.7%
S. anatum only	37.3%	32.7%	5.1%
Both[b]	12.0%	2.0%	2.4%
None[b]	40.7%	63.3%	5.3%

[a]Control vs. tetracycline ($P < .06$).
[b]Control vs. tetracycline ($P < .01$).

A total of 112 isolates were extracted from the ileocecal lymph node, ileocecal wall, and tonsil tissues taken at necropsy. The isolates were characterized as *S. anatum* (n = 94) or *S. typhimurium* (n = 18) and further broken down into treatment groups. The medicated treatment group had 36 *S. anatum* and 6 *S. typhimurium* isolates. The control treatment group had 58 *S. anatum* and 12 *S. typhimurium* isolates.

Of the 163 fecal isolates tested for antibiotic resistance, 74 were *S. anatum* and 89 were *S. typhimurium*. Of the 74 *S. anatum*, 2 were susceptible and 72 were resistant to tetracycline. Results for S. *typhimurium* included 40 susceptible, 13 intermediate susceptible, and 36 resistant isolates. The medicated treatment group had 3 susceptible, 8 intermediate susceptible, and 9 resistant S. *typhimurium.* Ten susceptible, 32 intermediate susceptible, and 27 resistant S. *typhimurium* were isolated from the control treatment group.

Discussion

The overall pattern of shedding showed that *S. anatum* was shed by a greater number of pigs than was *S. typhimurium* (Figure 1). This was expected, because *S. anatum* was antibiotic resistant and *S. typhimurium* was antibiotic susceptible. The pattern was especially evident when shedding was compared by treatment group within *Salmonella sp.* (Figures 2 and 3). More nonmedicated pigs than medicated pigs shed *S. typhimurium.* When shedding of *S. anatum* was compared between treatment groups, no difference was detected (Table 1). Although no conclusions can be made about whether the competition between the two strains *in vivo* was influenced by the presence of a resistance factor, the strain with the R factor was detected in a greater number of samples irrespective of the presence of tetracycline.

In conclusion, tetracycline had an impact on the amount and duration of fecal shedding of *Salmonella typhimurium.* In contrast, tetracycline did not have an effect on shedding rates of *Salmonella anatum.* Because the low numbers of samples and pigs from which S. *typhimurium* was isolated in the medicated group, we were unable to determine if tetracycline had an influence on resistance transfer. Preliminary results indicate the possibility of transfer of tetracycline resistance occurring between *S. anatum* and S. *typhimurium.*

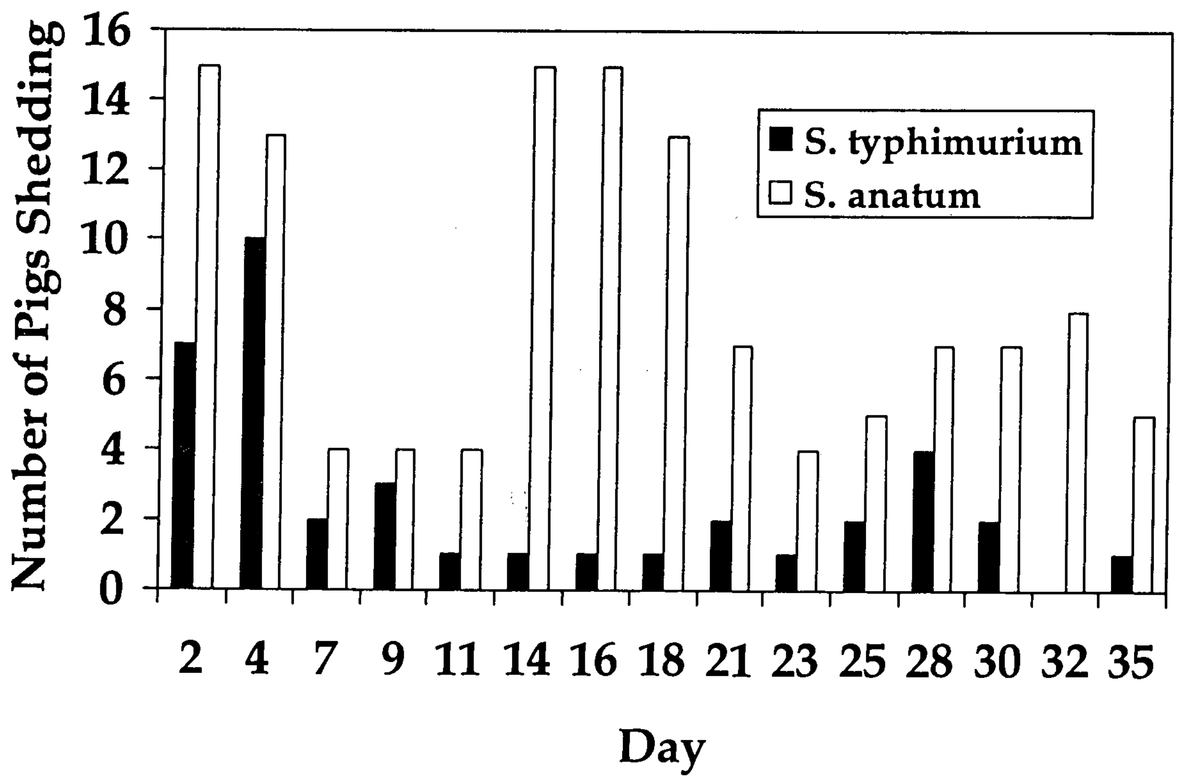

Figure 1. Pattern of *Salmonella* spp. Shedding over Time

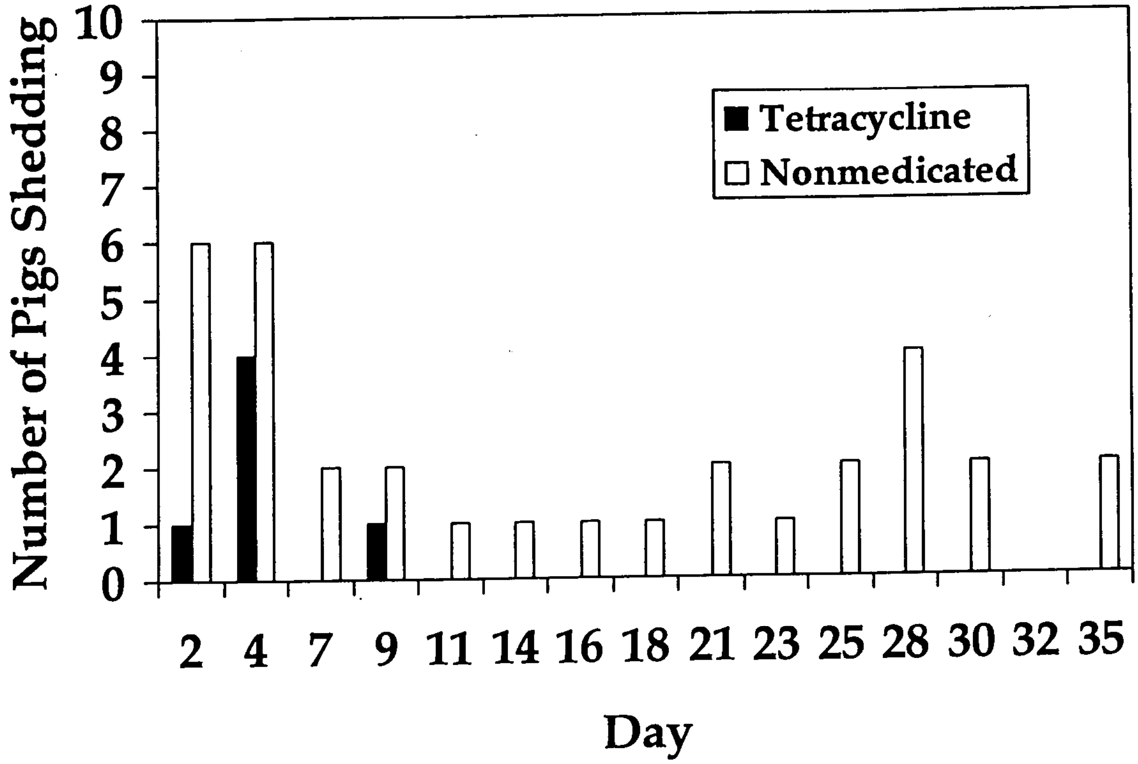

Figure 2. Influence of Tetracycline on Pattern of *Salmonella typhimurium* (Tetracycline Susceptible) Shedding over Time

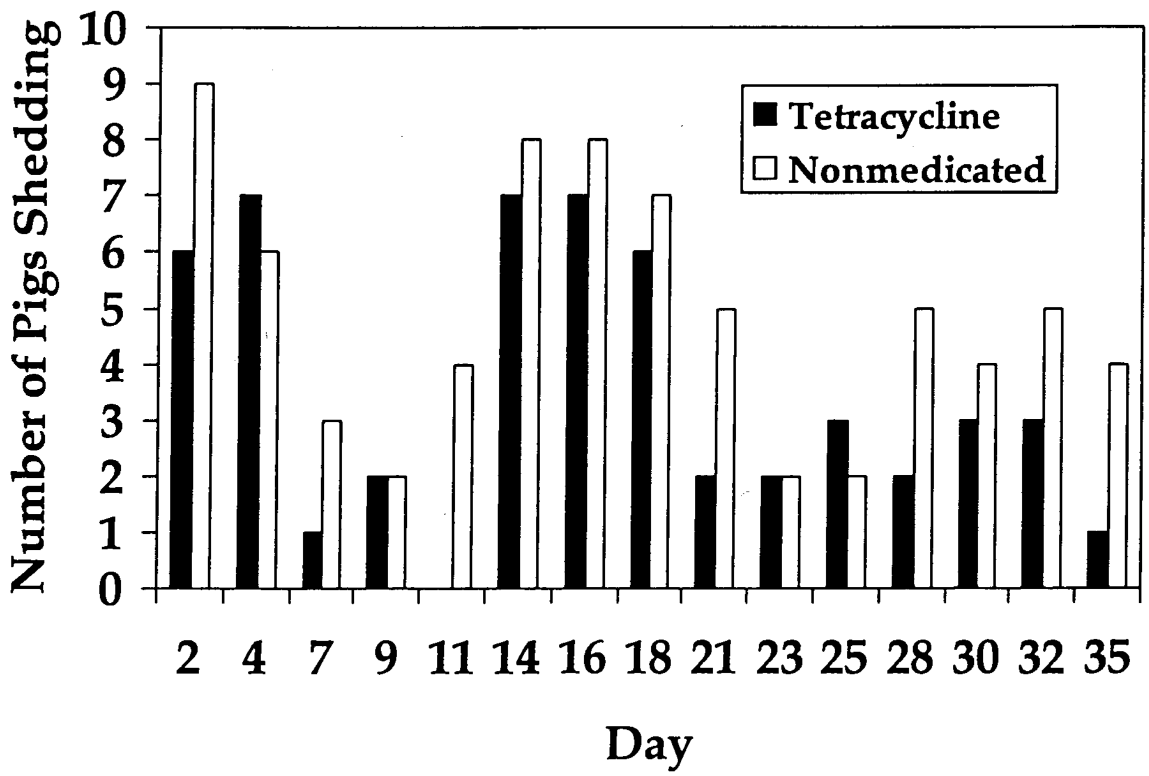

Figure 3. Influence of Tetracycline on Pattern of *Salmonella anatum* (Tetracycline Resistant) Shedding over Time

PYRIDOXINE, BUT NOT THIAMIN, IMPROVES GROWTH PERFORMANCE OF WEANLING PIGS [1]

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Summary

Two trials were conducted to determine whether pyridoxine or thiamine needs to be added to the diet for weanling pigs. In the first trial, weanling pigs were fed either a control diet or diets containing added thiamin (2.5 or 5.0 g/ton) or pyridoxine (3.5 or 7.0 g/ton). From d 0 to 14 after weaning, pigs fed added pyridoxine had increased ADG and ADFI, with pigs fed 3.5 g/ton of added pyridoxine having the greatest response. Growth performance was not improved by added thiamin. In a second trial, weanling pigs were fed a control diet or diets containing 1, 2, 3, 4, or 5 g/ton added pyridoxine. From d 0 to 14 after weaning, increasing pyridoxine increased ADG and ADFI, with pigs fed 3 g/ton of added pyridoxine having the greatest ADG. Pyridoxine level had no influence on growth performance from d 14 to 35 after weaning. These results suggest that adding between 2 and 3 g/ton of pyridoxine to the diet maximizes ADG and ADFI from d 0 to 14 after weaning.

(Key Words: Weanling Pigs, Growth, Pyridoxine, Thiamin.)

Introduction

Thiamin and pyridoxine are two B-vitamins that are abundant in grain-soybean meal diets. For this reason, supplementation in starter pig diets has not been widely recommended. Recently, several breeding-stock companies and vitamin manufacturers have recommended the addition of thiamin (vitamin B_1) and pyridoxine (vitamin B_6) to diets to achieve maximum growth potential. Therefore, the objective of this experiment was to evaluate the effects of added thiamin or pyridoxine on weanling pig growth performance.

Procedures

Experiment 1. A total of 180 weanling pigs (initially 11.02 lb and 21 d of age) was used in a 35-d growth assay. Pigs (PIC Line C22 × 326) were blocked by initial weight, equalized for sex and ancestry, and allotted randomly to each of five dietary treatments in a randomized complete block design. Each treatment had six pigs per pen and six replications (pens) per treatment.

All experimental diets were fed in meal form. Diets fed from d 0 to 14 after weaning were formulated to contain 1.6% lysine, .44% methionine, .90% Ca, and .80% P (Table 1). Diets fed from d 14 to 35 were formulated to contain 1.35% lysine, .38% methionine, .85% Ca, and .75% P. The control diet contained a standard vitamin premix (Table 1) without added thiamin or pyridoxine. Experimental treatments were provided by adding either thiamin mononitrate (2.5 or 5.0 g/ton) or pyridoxine HCl (3.5 or 7.0 g/ton) to the control diet. Pigs were fed the same experimental vitamin concentrations throughout the 35-d study.

[1]The authors thank Daiichi Pharmaceutical Company LTD, Tokyo, Japan for partial financial support for these experiments and to Feed Specialties Co. Inc., Des Moines, IA for providing the pyridoxine HCL and thiamin mononitrate.

Pigs were weighed and feed disappearance was determined weekly after weaning to calculate ADG, ADFI, and G/F.

Experiment 2. A total of 216 weanling pigs (initially 13.6 lb and 21 d of age) was used in a 35 d growth assay to determine the optimum level of pyridoxine to maximize growth performance. Pigs (PIC Line C22 × 326) were blocked by initial weight, equalized for sex and ancestry, and allotted randomly to each of six dietary treatments. Each treatment had six pigs per pen and six replications (pens) per treatment.

The control diet was identical to that used in Exp. 1 (Table 1). The experimental treatments were formed by adding pyridoxine at 1, 2, 3, 4, or 5 g/ton. As in Exp. 1, pigs were weighed and feed disappearance was determined weekly after weaning to calculate ADG, ADFI, and G/F.

Feed samples from both experiments were collected and analyzed for concentrations of thiamin (Exp. 1) and pyridoxine (Exp. 1 & 2) (Tables 2 and 3). Analyzed concentrations generally increased with increasing supplementation. However, analyzed values showed considerable variation from calculated values. We believe that this difference was a result of analytical variation in vitamin analysis. The range in permitted analytical variation for some vitamins ranges from 25 to 45%.

Data were analyzed as a randomized complete block design with pen as the experimental unit. Pigs were blocked on the basis of initial weight and ANOVA was performed using the GLM procedure of SAS.

Results and Discussion

Experiment 1. From d 0 to 14 after weaning, ADG increased then decreased with increasing pyridoxine (quadratic, $P < .05$; Table 4). Pigs fed 3.5 g/ton of added pyridoxine had the greatest ADG. Surprisingly, for pigs fed thiamin, ADG decreased then increased (quadratic, $P < .05$). Average daily gain was decreased for pigs fed 2.5 g/ton of added thiamin but was identical between those fed the control diet and 5.0 g/ton of added thiamin. Average daily feed intake increased then decreased with increasing thiamin and pyridoxine (quadratic, $P < .10$ and .05, respectively). However, F/G decreased then increased (quadratic, $P < .05$) with increasing thiamin. This appeared to be a result of the high feed intake and poor growth of pigs fed 2.5 g/ton of added thiamin. Feed:gain ratio was unaffected by increasing pyridoxine.

From d 14 to 35 after weaning, added thiamin or pyridoxine had no effect on ADG or F/G; however, ADFI increased (linear, $P < .05$) with increasing pyridoxine.

Cumulative results (d 0 to 35) showed quadratic ($P < .05$) responses in ADG and F/G with increasing added thiamin. As for the period from d 0 to 14 after weaning, pigs fed 2.5 g/ton of added thiamin had decreased ADG, but pigs fed the 5.0 g/ton had similar ADG to those fed the control diet. Pigs fed increasing pyridoxine had increased ADFI (linear, $P < .05$) from d 0 to 35. Although ADG and F/G were not significantly improved, ADG was numerically highest for pigs fed the diet containing 3.5 g/ton added pyridoxine, reflecting the response from d 0 to 14.

Experiment 2. Based on the results of Exp. 1, we conducted a second study to determine the pyridoxine requirement of weanling pigs. From d 0 to 14 after weaning, increasing pyridoxine increased then decreased (quadratic, $P < .05$) ADG and ADFI (Table 5). Pigs fed 3 g/ton of added pyridoxine had the maximum ADG and ADFI. The increases in ADG appeared to be a result of increased feed intake, because increasing pyridoxine had no affect on F/G.

From d 14 to 35 or 0 to 35, increasing pyridoxine had no effect ($P > .05$) on pig growth performance; however, ADG and ADFI tended to numerically increase with increasing pyridoxine.

In conclusion, our results suggest that adding thiamin had no positive effect on growth performance of weanling pigs. However, adding pyridoxine improved ADG and

ADFI of pigs from d 0 to 14 after weaning. The data suggest a requirement of 2 to 3 g/ton of added pyridoxine in diets fed from d 0 to 14 after weaning. For practical applications of this research, the SEW and transition diets should contain 3 g/ton of added pyridoxine.

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

Ingredients, %	d 0 to 14[b]	d 14 to 35[c]
Corn	41.84	50.72
Dried whey	20.00	10.00
Soybean meal (46.5% CP)	19.63	26.94
Spray-dried animal plasma	5.00	-
Soybean oil	5.00	5.00
Select menhaden fish meal	2.55	-
Spray-dried blood meal	1.75	2.50
Monocalcium phosphate	1.20	1.66
Medication[d]	1.00	1.00
Limestone	.80	.98
Zinc oxide	.38	.25
Vitamin premix[e]	.25	.25
Salt	.20	.25
L-Lysine HCl	.15	.15
Trace mineral premix[f]	.15	.15
DL-Methionine	.15	.15
Total	**100.00**	**100.00**

[a]In Exp. 1, diets contained added thiamin (2.5 or 5 g/ton) or pyridoxine (3.5 or 7.0 g/ton), and in Exp. 2, diets contained added pyridoxine (1, 2, 3, 4, and 5 g/ton).
[b]Diets were formulated to contain 1.60% lysine, .44% methionine, .90% Ca, and .80% P and were fed from d 0 to 14 after weaning.
[c]Diets were formulated to contain 1.35% lysine, .38% methionine, .85% Ca, and .75% P and were fed from d 14 to 35. Vitamin additions were identical to those from d 0 to 14.
[d]Provided 50 g/ton carbadox.
[e] Provided per ton of complete feed: 10,000,000 IU vitamin A; 1,500,000 IU vitamin D; 40,000 IU vitamin E; 4 g menadione; 9 g riboflavin; 30 g d-pantothenic acid; 50 g niacin; and 40 mg vitamin B_{12}.
[f] Provided per ton of complete feed: 36 g Mn; 150 g Fe; 150 g Zn; 15 g Cu; 270 mg I; and 270 mg Se.

Table 2. Analyzed Thiamin and Pyridoxine Concentrations, (Exp. 1)[a]

		Added Thiamin, g/ton		Added Pyridoxine, g/ton	
Item	Control	2.5	5.0	3.5	7.0
d 0 to 14					
Thiamin	1.8	4.0	7.1	2.2	2.0
Pyridoxine	2.2	2.9	2.2	9.8	7.3
d 14 to 35					
Thiamin	2.3	7.1	10.6	2.1	2.0
Pyridoxine	3.2	3.1	4.2	3.6	5.3

[a]Values (as-fed basis) represent analysis of one sample per diet for each time period.

Table 3. Analyzed Pyridoxine Concentrations, (Exp. 2)[a]

	Added Pyridoxine, g/ton					
Item	0	1	2	3	4	5
d 0 to 14						
Pyridoxine	3.6	4.6	6.7	6.9	7.4	10.1
d 14 to 35						
Pyridoxine	4.1	5.0	6.5	7.9	8.4	11.1

[a]Values (as-fed basis) represent analysis of one sample per diet for each time period.

Table 4. Effects of Added Thiamin and Pyridoxine on Starter Pig Performance (Exp. 1)[a]

		Added Thiamin, g/ton		Added Pyridoxine, g/ton		
Item	Control	2.5	5.0	3.5	7.0	CV
d 0 to 14						
ADG, lb[bc]	.81	.66	.81	.91	.86	7.9
ADFI, lb[bd]	.96	1.00	.96	1.05	1.00	5.4
F/G[c]	1.18	1.52	1.18	1.15	1.16	5.4
d 14 to 35						
ADG, lb	1.34	1.36	1.40	1.40	1.42	5.1
ADFI, lb[e]	2.15	2.13	2.19	2.22	2.27	4.2
F/G	1.61	1.56	1.56	1.59	1.59	4.9
d 0 to 35						
ADG, lb[c]	1.13	1.08	1.16	1.20	1.19	4.7
ADFI, lb[e]	1.67	1.68	1.70	1.75	1.76	3.5
F/G[c]	1.49	1.56	1.47	1.45	1.47	3.9

[a]A total of 180 weanling pigs (initially 11.02 lb and 21 d of age), six pigs per pen and six pens per treatment.
[b]Quadratic effect of pyridoxine (P < .05).
[c]Quadratic effect of thiamin (P < .05).
[d]Quadratic effect of thiamin (P < .10).
[e]Linear effect of pyridoxine (P < .05).

Table 5. Effects of Added Pyridoxine on Starter Pig Performance (Exp. 2) a

	Added Pyridoxine, g/ton							Probability (P <)	
Item	0	1	2	3	4	5	CV	Linear	Quadratic
d 0 to 14									
ADG, lb	.79	.80	.88	.93	.84	.85	9.8	.13	.05
ADFI, lb	.92	.94	1.00	1.01	.99	.93	8.8	.41	.03
F/G	1.16	1.18	1.14	1.09	1.19	1.10	6.3	.18	.99
d 14 to 35									
ADG, lb	1.32	1.26	1.35	1.33	1.33	1.33	6.6	.42	.87
ADFI, lb	2.17	2.10	2.23	2.19	2.22	2.23	5.2	.13	.97
F/G	1.64	1.67	1.67	1.67	1.67	1.67	5.5	.68	.93
d 0 to 35									
ADG, lb	1.10	1.08	1.16	1.17	1.13	1.14	5.6	.13	.21
ADFI, lb	1.66	1.63	1.74	1.72	1.73	1.71	4.9	.09	.30
F/G	1.52	1.52	1.49	1.47	1.52	1.49	4.1	.88	.69

[a]A total of 216 weanling pigs (initially 13.6 lb and 21 d of age), six pigs per pen and six pens per treatment.

Swine Day 1997

EFFECTS OF ADDED CHOLINE ON PERFORMANCE OF WEANLING PIGS

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Summary

A 28-d growth assay was conducted to determine the effects of added choline on weanling pig performance. Pigs were fed a control diet without added choline or diets containing 150 g/ton of added choline. No differences in pig growth performance were observed. These results suggest that added choline can be removed from weanling pig diets.

(Key Words: Weanling Pigs, Choline.)

Introduction

Choline is an expensive vitamin that until recently, has been added routinely to all swine diets. However, recent research with finishing pigs suggested no improvements in performance from added choline. Perhaps the choline in natural ingredients such as grain and soybean meal, although not totally available to the pig, is enough to meet their requirement. Eliminating the added choline can save approximately $.50 to $.60/ton of complete feed. Therefore, the objective of this study was to determine if added choline is necessary for maximum growth performance of weanling pigs.

Procedures

Seventy two weanling pigs (initially 11 ± 2 lb and 21 d of age) were used. Pigs were blocked by initial weight to one of two dietary treatments, with six pigs per pen and six replications (pens) per treatment. Treatments (with or without 150 g/ton of added choline) were arranged in a randomized complete blocked design.

The trial was divided into two phases (Table 1). From d 0 to 7 after weaning, diets contained 20% dried whey and 5% spray-dried animal plasma and were formulated to 1.5% lysine with all other amino acids above suggested estimates. During d 7 to 28 after weaning, pigs were fed a less complex diet containing 10% dried whey and 2.5% spray-dried blood meal. Diets fed from d 0 to 7 were pelleted, and diets fed from d 7 to 28 were in a meal form.

During the experiment, pigs were housed in raised-deck pens in an environmentally controlled room and allowed ad libitum access to water and feed. Temperature was maintained at 95°F for the first week and then gradually reduced each week thereafter for pig comfort. The pigs were weighed and feed disappearance were determined weekly to calculate ADG, ADFI, and F/G.

Results and Discussion

In this study, growth performance was not affected ($P > .32$) at any time by the addition of 150 g/ton of added choline (Table 2). Therefore, these results suggest that with diets similar in composition to the ones used herein, added choline is not necessary for weanling pigs. Furthermore, these data and those previously obtained with growing-finishing pigs suggest that added choline can be eliminated from vitamin premixes used in grain-soybean meal diets. However, we emphasize that added choline is still needed in diets for gestating and lactating sows.

Table 1. Compositions of Experimental Diets

Ingredient, %	Day 0 to 7[a]	Day 7 to 28[b]
Corn	45.66	52.82
Dried whey	20.00	10.00
Soy bean meal	15.99	26.77
Spray-dried animal plasma	5.00	
Soybean oil	5.00	3.00
Fish meal	2.50	-----
Spray-dried blood meal	1.75	2.50
Monocalcium phosphate	1.27	1.88
Limestone	0.79	1.00
Zinc oxide	0.38	0.25
Vitamin premix[c]	0.13	0.13
L-Lysine-HCL	0.15	0.15
DL-Methionine	0.13	0.10
Trace mineral premix	0.15	0.15
Salt	0.10	0.25
Antibiotic[d]	1.00	1.00
Choline Chloride, 60%[e]	-----	-----
Total	100.00	100.00

[a]Diets were pelleted and formulated to contain 1.50% lysine, .42% methionine, .90% Ca and .80% P.
[b]Diets were fed in a meal form and formulated to contain 1.35% lysine, .38% methionine, .90% Ca, and .80% P.
[c]Premix provide the KSU suggested vitamin concentrations with the exception of no added choline.
[d]Provided 50 g/ton carbadox.
[e]Provided 150 g/ton of added choline added in place of corn.

Table 2. Effects of Added Choline on Weanling Pig Performance[a]

Item	Control	Added Choline, 150 g/ton	P Value (P <)	CV
d 0 to 7				
ADG, lb	0.73	0.77	0.32	8.3
ADFI, lb	0.61	0.64	0.46	9.7
F/G	.84	.83	0.83	9.0
d 7 to 14				
ADG, lb	0.62	0.63	0.88	19.7
ADFI, lb	1.12	1.05	0.48	13.8
F/G	1.82	1.67	0.33	14.4
d 14 to 21				
ADG, lb	1.16	1.21	0.34	7.3
ADFI, lb	1.67	1.74	0.52	10.3
F/G	1.43	1.43	0.99	6.8
d 21 to 28				
ADG, lb	1.17	1.20	0.61	7.8
ADFI, lb	1.97	2.05	0.36	7.4
F/G	1.67	1.69	0.79	9.0
d 0 to 28				
ADG, lb	0.93	0.96	0.47	7.7
ADFI, lb	1.37	1.40	0.69	9.1
F/G	1.47	1.45	0.59	5.0

[a]A total of 72 weanling pigs (initially 11 ± 2 lb, and 21 d of age) were used with 6 pigs/pen with 6 replicate pens/treatment.

EFFECTS OF SOURCE AND LEVEL OF ADDED CHROMIUM ON GROWTH PERFORMANCE OF STARTER PIGS [1,2]

P. R. O'Quinn, J. L. Nelssen, M. D. Tokach, R. D. Goodband, R. E. Musser, K. Q. Owen [3], and S. A. Blum [3]

Summary

A 35-d growth trial was conducted with conventionally weaned nursery pigs to evaluate the efficacy of supplemental chromium (Cr) as either chromium nicotinate (CrNic) or chromium picolinate (CrPic). Neither source nor level of supplemental Cr had any effect on weanling pig growth performance or immune status. Equal levels of CrNic and CrPic produced similar results, except that pigs fed CrPic had higher serum Cr concentrations than pigs fed CrNic. These data suggest no beneficial responses to supplemental CrNic or CrPic in nursery pig diets.

(Key Words: Starter Pigs, Chromium, Chromium Nicotinate, Growth Performance.)

Introduction

Chromium (Cr) is a trace mineral that is actively involved in the metabolism of carbohydrates, lipids, proteins, and nucleic acids. In nursery pigs, Cr supplementation has been reported to increase daily gain and improve feed efficiency. Chromium also is thought to improve immune function in stressed animals (e.g., after weaning). However, these positive results of Cr supplementation have been inconsistent. Several forms of Cr have been evaluated, including yeast cultures and chromium picolinate (CrPic) which has received the most attention in the scientific literature. Recently, a newer form, chromium nicotinate (CrNic), has been developed and is thought to be more biologically available than CrPic. For these reasons, a feeding trial was designed to evaluate the efficacy of CrNic supplementation and to compare the effects of CrNic and CrPic on growth performance.

Procedures

A total of 180 weanling pigs (initially 12.5 lb and 17 to 21 d of age) was used in a 35 d growth trial. Pigs were blocked on the basis of initial weight and randomly allotted to one of six dietary treatments with six pigs per pen and five replications (pens) per treatment. The numbers of barrows and gilts were equalized across pens within each block.

All diets were fed in meal form. A high nutrient dense diet was fed for 14 d postweaning and a less complex diet was fed for the remaining 21 d (Table 1). Chromium was added to the basal diet at 50, 100, 200, or 400 ppb as CrNic or 200 ppb CrPic. The Cr additions were prepared first as a 20 lb premix and then blended with the other dietary ingredients to ensure proper mixing.

Pigs were housed in an environmentally controlled nursery in 5 × 5 ft pens with one self-feeder and nipple waterer to allow ad libitum access to feed and water.

[1]Appreciation is extended to Lonza Inc., Fair Lawn, NJ for financial support and for providing the chromium nicotinate used in this experiment.

[2]The authors would like to thank Colin Bradley of the London Health Sciences Centre, London, Ontario, Canada for conducting the serum chromium assays.

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

Table 1. Compositions of Basal Diets (As-Fed Basis)[a]

Ingredient, %	Phase I[b]	Phase II[c]
Corn	41.83	50.66
Dried whey	20.00	10.00
Soybean meal, (46.5% CP)	19.63	26.95
Spray-dried animal plasma	5.00	----
Soybean oil	5.00	5.00
Select menhaden fish meal	2.50	----
Spray-dried blood meal	1.75	2.50
Monocalcium phosphate	1.21	1.66
Antibiotic[d]	1.00	1.00
Limestone	.80	.98
Vitamin/trace mineral premix	.40	.40
Zinc oxide	.38	.25
Salt	.20	.35
L-Lysine	.15	.15
DL-Methionine	.15	.10
Total	100.00	100.00

[a]Graded levels of Cr were added to the basal diet to provide concentrations of 50, 100, 200, or 400 ppb.
[b]The phase I diets were formulated to 1.60% lysine, .44% methionine, .90% Ca, and .80% P, and were fed for 14 d postweaning.
[c]The phase II diets were formulated to contain 1.35% lysine, .38% methionine, .85% Ca, and .75% P and were fed from d 14 to 35 postweaning.
[d]Provided 50 g/ton carbadox.

Pigs and feeders were weighed weekly to determine ADG, ADFI, and feed efficiency (F/G). On d 28 postweaning, two randomly selected pigs per pen were bled, and the serum was analyzed to determine Cr and haptoglobin concentrations. Haptoglobin is an acute-phase protein that binds with free hemoglobin and is produced following an immune challenge. The concentration of haptoglobin in our assays is expressed as the amount of methemoglobin bound per milliliter (mgHgb/mL). Thus, lower haptoglobin levels should be indicative of less immune challenge.

Data were analyzed as a randomized complete block. The pen was the experimental unit for all calculations. Because of the unequal spacing of CrNic concentrations, a regression model within the REG procedure of SAS was used to determine the linear and quadratic effects of added CrNic. The GLM procedure of SAS was used for the single degree of freedom contrasts between pigs fed 200 ppb CrNic and 200 ppb CrPic and between pigs fed the control diet and 200 ppb CrPic.

Results and Discussion

Increasing levels of Cr as CrNic had no effect ($P > .20$) on ADG, ADFI, or F/G from d 0 to 14, 14 to 35, or 0 to 35 postweaning (Table 2). Similarly, no differences ($P > .10$) were observed in any of the growth performance parameters for any of the time periods between pigs fed 200 ppb of CrNic and CrPic. Immune status, as measured by haptoglobin concentration, was not affected ($P > .50$) by source or level of supplemental Cr (Table 3). Serum Cr levels were not affected (P > .80) by increasing levels of CrNic; however, pigs fed 200 ppb CrPic tended to have higher (P= .09) serum Cr levels than pigs fed 200 ppb CrNic.

Previous research reports from other universities have observed sporadic effects of supplemental Cr on either growth performance or immune status.

The different serum Cr levels with the two sources of Cr may indicate the metabolic bioavailabilities of the two sources. Chromium nicotinate is thought to be more metabolically available to the pig than CrPic. Chromium is cleared rapidly from the blood into the tissues. Any Cr not used or stored by thetissues is excreted back to the blood for excretion from the body via the urine. Thus, higher serum Cr levels (CrPic) may indicate a lower metabolic availability as compared to CrNic. Another possibility is that CrNic may be less digestible than CrPic, leading to lower serum Cr levels. Tissue biopsies would be needed to confirm or disprove this hypothesis.

In conclusion, these data suggest no beneficial responses in nursery pig performance to either supplemental CrNic or CrPic.

Table 2. Growth Performance and Serum Chemistry of Pigs Fed Increasing Chromium[a]

	CrNic, ppb					CrPic, ppb		Probability		
Item	0	50	100	200	400	200	CV	Lin.[b]	Quad.[b]	Cont.[c,d]
d 0 to 14										
ADG, lb	.60	.56	.63	.62	.61	.62	16.77	.64	.70	**.92**
ADFI, lb	.81	.82	.85	.81	.81	.83	11.99	.86	.78	**.93**
F/G	1.36	1.47	1.34	1.32	1.33	1.33	10.28	.53	.70	**.90**
d 14 to 35										
ADG, lb	1.37	1.42	1.36	1.33	1.42	1.43	6.98	.34	.26	.14
ADFI, lb	2.04	2.02	2.01	1.99	2.05	2.06	7.55	.58	.54	.55
F/G	1.49	1.42	1.47	1.49	1.45	1.44	4.83	.71	.63	.35
d 0 to 35										
ADG, lb	1.06	1.08	1.07	1.05	1.09	1.11	7.58	.64	.55	.34
ADFI, lb	1.55	1.54	1.54	1.52	1.55	1.57	7.78	.71	.69	.66
F/G	1.46	1.43	1.44	1.45	1.42	1.42	3.96	.98	.88	.45
Serum paramters:[e]										
Hapto.[f]	22.76	17.98	22.86	18.82	23.68	20.04	45.88	.62	.54	.37
Cr[g]	62.16	56.70	73.64	56.12	60.24	68.42	21.07	.98	.88	.09

[a]Growth performance values are means for 180 pigs, initially weighing 12.5 lb (six pigs/pen and five replications/treatment).
[b]Contrasts refer to the linear and quadratic comparisons of increasing CrNic.
‘Contrast refers to the comparison of 200 ppb CrNic and 200 ppb CrPic.
[d]The contrast between pigs fed the control diet and 200 ppb CrPic was nonsignificant (P > .30) for all comparisons.
[e]Values are pooled means for two pigs/pen and five replications/treatment.
[f]Haptoglobin concentrations are expressed as mgHgb/mL.
[g]Chromium concentrations are expressed as nmol/L.

EFFECTS OF SORGHUM GENOTYPE AND PROCESSING METHOD ON PRODUCTION CHARACTERISTICS AND GROWTH PERFORMANCE OF NURSERY PIGS

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Summary

Three sorghum varieties that varied in starch composition were fed to Phase II and Phase III pigs to determine if feeding sorghum high in waxiness provided a benefit. In addition, each variety was fed as a meal, standard pellet, and an expanded pellet. As level of waxiness increased, pellet durability index increased numerically and the amount of fines produced decreased numerically. In addition, thermal processing of the diets increased the feeding value. Sorghum genotype had little effect on pig performance.

(Key Words: Sorghum, Waxy Sorghum, Expanded Pellet, Nursery Pigs.)

Introduction

Sorghum (*Sorghum bicolor*) is a grain that is grown extensively in the Great Plains of the United States. Traditionally, it has been looked upon as a replacement for corn in animal diets. However, it is viewed as having a feeding value of 95% when compared to corn. Breeders have been developing hybrids in an attempt to improve feeding value. Some of these hybrids have been bred to change the starch composition. Currently, KSU is evaluating two hybrids that vary in starch composition from a commercial hybrid, which has a starch composition of approximately 25% amylopectin and approximately 75% amylose. One hybrid, termed heterowaxy, has a starch composition of approximately 50% amylose and 50% amylopectin. The other hybrid, termed waxy, has a starch composition of more than 75% amylopectin. The question was whether the heterowaxy or waxy hybrid would outperform the normal hybrid when fed to nursery pigs and when processed using pelleting and expanding. Therefore, we designed an experiment to evaluate the two experimental sorghum varieties against a commercial sorghum hybrid.

Procedures

A total of 216 weanling pigs, averaging 15 days and 12 lb initial wt, was used in a 28-d growth assay. Pigs were blocked by weight and allotted randomly to treatment by sex and ancestry. We used four pens/treatment and six pigs/pen. Three sorghum hybrids were obtained from NC+ Hybrids, Colwich, KS. They included: 1) normal starch type, 2) heterowaxy starch type, and 3) waxy starch type. The processing methods included: 1) meal, 2) standard pellet, and 3) expanded pellet. Diets (Table 1) were formulated to 1.50% lysine for Phase II (d 7 to 21) and 1.30% lysine for Phase III (d 21 to 35). The pigs were fed a common pelleted Phase I diet from d 0 to 7 to adjust them to feed. Pigs were housed in 3.5 ft × 5 ft pens. Each pen had a self-feeder and nipple waterer to allow ad libitum consumption of feed and water. Feeders were adjusted daily to minimize feed wastage. Pigs and feeders were weighed at the end of each phase for the determination of average daily gain (ADG), average daily feed intake (ADFI), and feed-to-gain ratio (F/G).

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Table 1. Diet Composition

	Percent	
Item	Phase II[a]	Phase III[b]
Sorghum	77.53	83.51
Soybean meal	9.71	7.33
Soybean oil	3.00	3.00
Monocalcium		
Spray dried		
Fishmeal	2.00	-
Lysine-HCl	1.04	1.13
Antibiotic[c]	1.00	1.00
Limestone	.48	.62
Salt	.30	.35
Vitamin premix	.25	.25
DL-Methionine	.20	.19
Trace mineral		
L-Threonine	.14	.21
Total	100.00	100.00

[a]Diets for d 7 to 21 were formulated to 1.50% lysine, .85% Ca, and .75% P.
[b]Diets for d 21 to 35 were formulated to 1.30% lysine, .80% Ca, and .70% P.
[c]Supplied 150 g/ton apramycin. Diets for d 7 to 21 and 50 g/ton carbodox from d 21 to 35

Diets were manufactured at the KSU Feed Processing Center. An Amandus Kahl 3.16OE 15.2 annular gap expander (100 hp) was used to process the expanded diets. After expanding, the diets were pelleted using a CPM Master Model HD pellet mill (30 hp). The standard pellet diets were manufactured using the same pellet mill. The pellet mill was equipped with a 3/16 in. × 1 1/4 in. die for both processes. Diets were conditioned to 170°F prior to expanding and/or pelleting. Cone pressure and production rate were held constant. Data were collected to allow for the determination of production rate, total and specific energy consumption, percent fines, and pellet durability index. Specific energy is the difference between full load and empty load current.

Results and Discussion

The amount of total and specific energy required to process the standard pellets increased as waxiness increased (Table 2). This response was expected, because waxy sorghums have a high percentage of branched starch chains, which require more energy to process. However, high shear conditioning (expanded pellets) decreased the amount of specific energy needed to process the diets as waxiness increased. This would suggest that waxy sorghums respond more favorably to severe thermal processing than to standard pelleting. Fines returned is a good general indicator of pellet quality. As waxiness increased, fines produced decreased. This held true for both standard pelleting and high shear conditioning. Pellet durability index (PDI) is an even better indicator of pellet quality. As waxiness increased, so did pellet quality. In addition, each sorghum genotype increased in PDI as processing method became more severe. Overall, as waxiness increased, we saw increases in pellet quality and a trend for a decrease in the amount of specific energy required to process the diet.

Overall, no negative effect on growth performance of Phase II pigs occurred as waxiness increased. In fact, as waxiness increased, ADFI increased numerically. However, as thermal processing was applied to the diet, ADFI decreased ($P < .001$). This is consistent with the results published by Traylor et al. (1996 KSU Swine Day Report of Progress), who found that thermal processing generally will decrease ADFI. No real differences in ADG occurred as waxiness increased or thermal processing became more severe. However, there was a tendency for a linear decrease in F/G as both waxiness and thermal processing increased ($P < .10$). Pelleting the diet improved F/G in the normal genotype ($P < .05$), and as waxiness increased, high shear conditioning had a tendency to improve F/G ($P < .10$).

For Phase III pigs, we saw a quadratic effect for ADFI ($P < .02$) as waxiness inreased. In addition, ADFI decreased as severity of thermal processing increased (meal vs. standard pellet, $P < .001$), (standard pellet vs. expanded pellet, $P < .02$). When ADG was evaluated, we saw a quadratic trend as waxiness increased ($P < .06$). In addition, ADG increased ($P < .02$) as severity of thermal processing increased. A linear improvement in F/G as waxiness and severity of thermal processing increased (genotype × standard pellet vs. expanded pellet, $P < .001$).

Although animal performance was not increased dramatically by increasing waxiness of the sorghum, we demonstrated that thermal processing will improve both the processing characteristics and feeding value of waxy sorghum varieties, thereby making them a possibility for feeding of livestock. However, the decision to plant these varieties should be based not only on the data presented here, but also on production yields in the field.

Table 2. Production Characteristics for Phase II and Phase III Diets

	Normal		Heterowaxy		Waxy	
		Expanded		Expanded		Expanded
Phase II						
Production rate, lbs/hr	2,711	1,945	2,683	2,617	2,522	1,823
Pellet mill energy						
Total	8.44	10.91	8.86	8.18	9.37	10.74
Specific[a]	3.03	3.49	3.38	2.66	3.53	2.85
Expander energy						
Total	-	32.85	-	23.17	-	31.70
Specific[a]	-	7.85	-	4.63	-	5.17
Pellet durability index, %						
Standard[b]	80.8	94.7	84.9	95.2	90.3	97.2
Modified[c]	67.0	92.3	74.4	92.9	84.6	96.6
Fines, %	11.7	5.1	8.9	3.9	6.7	4.4
Phase III						
Production rate, lbs/hr	3,132	2,021	3,265	2,035	3,089	1,934
Pellet mill energy						
Total	8.23	9.83	8.53	10.01	8.99	9.89
Specific	3.62	2.64	4.09	2.85	4.28	2.33
Expander energy						
Total	-	31.52	-	32.18	-	30.05
Specific	-	7.83	-	8.56	-	5.15
Pellet durability index, %						
Standard	73.3	94.9	79.9	96.1	87.8	97.2
Modified	58.1	92.7	67.7	93.7	83.9	96.7
Fines, %	11.7	6.4	10.0	4.7	6.9	4.2

[a]Expressed as the difference between full load and empty load current.
[b]Am. Society of Ag. Eng. S269.3.
[c] Am. Society of Ag. Eng. S269.3 with the addition of five ½ in. hexagonal nuts.

Table 3. Growth Performance of Pigs Fed Three Sorghum Genotypes

	Normal			Heterowaxy			Waxy		
Item	Meal	Pellet	Expanded Pellet	Meal	Pellet	Expanded Pellet	Meal	Pellet	Expanded Pellet
Phase II									
ADG, lb	.66	.72	.64	.68	.63	.64	.70	.68	.67
ADFI, lb[ab]	1.18	1.09	.98	1.19	1.12	.99	1.16	1.16	1.03
F/G[cde]	1.78	1.52	1.54	1.75	1.78	1.56	1.64	1.69	1.54
Phase III									
ADG, lb[fh]	.73	.75	.79	.73	.67	.74	.78	.70	.77
ADFI, lb[afg]	1.28	1.16	.93	1.10	1.01	.84	1.33	1.12	.97
F/G[ij]	1.52	1.52	1.16	1.49	1.49	1.12	1.64	1.59	1.23

[a]Meal × standard pellet ($P < .001$).
[b]Standard pellet × expanded pellet ($P < .001$).
[c]Meal × standard pellet ($P < .05$).
[d]Sorghum genotype × meal vs. standard pellet (linear, $P < .10$).
[e]Standard pellet × expanded pellet ($P < .10$).
[f]Standard pellet × expanded pellet ($P < .02$).
[g]Normal × heterowaxy vs. waxy (quadratic, $P < .02$).
[h]Normal × heterowaxy vs. waxy (quadratic, $P < .06$).
[i]Meal × standard pellet ($P < .01$).
[j]Genotype × standard pellet vs. expanded pellet ($P < .001$).

EFFECTS OF STARCH GELATINIZATION ON WEANLING PIG PERFORMANCE

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Summary

Two hundred and ten weanling pigs were fed diets containing nonextruded corn (14.5% gelatinization; control) or corn that was extruded to provide 38.7%, 52.7%, 64.4%, or 89.3% starch gelatinization in the complete diet. With increasing gelatinization, ADG and ADFI decreased and then increased, but apparent digestibility of DM, CP, and energy increased then decreased. These results suggest that the degree of starch gelatinization has an inconsistent effect on weanling pig performance.

(Key Words: Weanling Pigs, Extrusion, Gelatinization.)

Introduction

Over the last several years, numerous experiments have been conducted to evaluate the effects of moist extrusion processing of cereal grains or the complete diet on weanling pig performance. Results of these studies have been variable, with some showing no beneficial response to extrusion processing but other showing improved pig performance. When carbohydrates are exposed to heat and moisture in extrusion processing, the starch may become gelatinized. We hypothesized that the variable responses to extrusion processing in previous experiments might have been the results of different degrees of starch gelatinization. Therefore, the objective of this experiment was to investigate the influence of degree of starch gelatinization on growth performance and nutrient digestibility of early-weaned pigs.

Procedures

Two hundred and ten weanling pigs (PIC L326 × C15) averaging 21 d of age and initially 15 ± 3 lb were used in an 18-d growth assay. Pigs were blocked by weight and allotted randomly to one of five treatments. The dietary treatments included nonextruded corn (control; 14.5% gelatinization) or extruded corn with 38.7%, 52.7% , 64.4%, or 89.3% gelatinization. In this study, only the corn was extruded through a Wenger X-20 single screw extruder (Wenger Inc., Sabetha, KS), The diets were mixed and then pelleted through a 5/32-inch die following conditioning at 140°F. Experimental diets were fed from d 0 to 18 after weaning. All diets were formulated to 1.4% total lysine, .39% methionine, .9% Ca, and .8% P and contained 10% dried whey and 2.5% spray-dried blood meal (Table 1). The extruder conditions were varied to create the various degrees of starch gelatinization (Table 2). The degree of starch gelatinization in the diet after pelleting was analyzed by a modified glucoamylase method.

Pigs were housed in 4 ft × 5 ft pens and allowed ad libitum access to feed and water. Each treatment included seven pigs per pen and six replications (pens). The pigs and feeders were weighed on d 7, 14, and 18 to calculate ADG, ADFI, and F/G. Chromic oxide (.20%) was included in the diets as an indigestible marker. On d 14, fecal samples were collected from at least three pigs per pen by rectal massage. Apparent nutrient digestibilities were determined for DM, CP, and DE. Linear and quadratic polynomials

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were evaluated using coefficients for unequally spaced treatments.

Table 1. Diet Composition[a]

Ingredient	Percentage
Corn	50.70
Dried whey	10.00
Soybean meal	28.59
Spray-dried blood meal	2.50
Soybean oil	3.00
Monocalcium phosphate	1.85
Limestone	1.01
Zinc oxide	.25
Vitamin premix	.25
L-Lysine·HCl[g]	.15
DL-Methionine	.10
Trace minerals	.15
Salt	.25
Antibiotic[b]	1.00
Chromic oxide	.20
Total	100.00

[a]Diets were formulated to contain 1.4% lysine, .39% methionine. Dietary treatments varied based on ground corn with 14.5%, 38.7%, 52.7%, 64.4%, 89.3% gelatinized starch.
[b]Provided 50 g/ton of carbadox.

Results and Discussion

From d 0 to 18, ADG and ADFI decreased and then increased with increasing starch gelatinization (quadratic, P = .05 and .01, respectively). Average daily gain and ADFI were maximized in pigs fed diets containing either 14.5 or 89.3% gelatinized corn. Feed efficiency was not affected by degree of starch gelatinization (P > .10).

Increasing the degree of starch gelatinization in corn increased apparent digestibility of all three variables (quadratic, P < .01). Although pigs fed the diet containing 64.4% gelatinized starch had the greatest apparent nutrient digestibilities, the greatest increase in nutrient digestibility occurred between pigs fed the control diet (14.5% gelatinized starch) and those fed 38.7% gelatinized starch.

Previous studies have reported both negative and positive effects of extrusion processing on growth performance of pigs fed corn- or grain sorghum-based diets. We hypothesized that a correlation exists between extruder conditions that result in different degrees of starch gelatinization and variations in growth performance. Under the ingredient processing conditions used in this experiment, increasing starch gelatinization in corn decreased and then increased ADG and ADFI. Apparent digestibility of DM, CP, and energy seemed to be correlated negatively with feed intake, increasing and then decreasing with increasing gelatinization. These results may be explained by changes in cereal chemistry. During extrusion processing, too much water and (or) too low a temperature can prevent full gelatinization of starch. After processing, because of ample moisture and rapidly decreasing temperature, the starch paste is cooled. This results in the starch chains becoming more stable and forming a firmer gel. As the gel ages, the starch chains interact and force water out of the system. Longer periods of storage give rise to more interaction between the starch chains and eventually can lead to formation of crystals. This process, called retrogradation, is the crystallization of starch chains in the gel. The retrogradation of starch (formation of beta-amylose and crystallized amylopectin) can decrease the ability of enzymes (amylases) to break down the linkages in starch and convert it into more soluble carbohydrates. Therefore, although gelatinization of starch can increase the digestibility of carbohydrates, retrogradation will decrease digestibility of starch in the small intestine. Under our processing conditions, we added high levels of water to produce corn with a low degree of gelatinized starch. Immediately drying the extruded corn may have allowed less opportunity for retrogradation and, therefore, increased the apparent nutrient digestibility. The diets with the highest degree of starch gelatinization may have contained damaged or burnt starch (Maillard reaction) as well as having a greater potential loss of available amino acids and(or) vitamins. Although an intermediate degree of gelatinization (38 to 64%) might be beneficial for digestibility, it did not affect pig growth performance. Additional research will be needed to determine the optimal extrusion processing conditions necessary to improve pig growth performance.

Table 2. Extrusion Processing Conditions[a]

	Starch Gelatinization			
Extruder Conditions	38.7%	52.7%	68.7%	89.3%
Barrel jacket temperature at the 8th head, °F	217	230	246	279
Barrel pressure, lb/in^2	200	300	600	500
Production rate, lb/min	4.40	5.00	6.25	5.50
Exit temperature, °F	190	202	212	221
Water flow, lb/min	1.22	1.00	.60	.40

[a]Corn was extruded through a Wenger X-20 extruder (Wenger Inc., Sabetha, KS) and dried at 250°F to 12 to 13% moisture, ingredients then were mixed, the complete feed was pelleted, and samples collected for starch gelatinization analysis.

Table 3. Effects of Increasing Starch Gelatinization on Growth Performance of Early-Weaned Pigs[a]

	Starch Gelatinization, %[b]						Probability (P <)	
Item	14.5%	38.7%	52.7%	64.4%	89.3%	CV	Linear	Quadratic
Day 0 to 18								
ADG, lb	.78	.71	.70	.67	.75	11.86	.37	.05
ADFI, lb	1.05	.97	.98	.90	1.02	5.75	.10	.01
F/G	1.35	1.37	1.41	1.35	1.37	9.55	.89	.75
Apparent Digestibility (d 14), %								
DM	77.83	84.11	81.54	84.62	81.76	2.24	.01	.01
N	69.43	79.74	76.98	81.13	75.89	5.75	.01	.01
GE	76.63	84.39	81.75	85.35	82.12	2.57	.01	.01

[a]A total of 210 weanling pigs (initially 15 ± 3 lb and 21 d of age) was used with seven pigs/pen and six replicate pens/treatment.
[b]Ground corn was extruded to provide the different starch gelatinization treatments, then mixed and pelleted.

EFFECTS OF A HIGH PROTEIN, WHEY PROTEIN CONCENTRATE AND SPRAY-DRIED ANIMAL PLASMA ON GROWTH PERFORMANCE OF WEANLING PIGS [1]

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Summary

A 35-d experiment was conducted to compare the effects of increasing spray-dried animal plasma and a high protein whey concentrate (73% CP) on starter pig performance. Spray-dried animal plasma and whey protein concentrate replaced dried skim milk on an equal lysine basis. Pigs fed increasing spray-dried animal plasma protein had increased ADG and ADFI from d 0 to 7 after weaning, but not for any other period in the study. Increasing whey protein concentrate had no effect on growth performance in relation to the pigs fed dried skim milk.

(Key Words: Starter Pigs, Spray-Dried Animal Plasma, Whey Protein Concentrate.)

Introduction

Several different protein sources have been evaluated by Kansas State University for weanling pigs. These include spray-dried plasma protein, spray-dried blood meal, dried skim milk, and various soy protein concentrates. In this experiment, a special high protein whey protein concentrate was evaluated. This particular whey protein concentrate contains 73% protein and an amino acid profile that is comparable to that of animal plasma. The intent of this experiment was to determine if whey protein concentrate could be an alternative to animal plasma in starter diets.

Procedures

A total of 180 pigs (initially 12.5 lb and 21 d of age) was used in this 35 d growth trial. Pigs were blocked by weight, equalized for sex and ancestry, then allotted randomly to one of six dietary treatments with a total of six pigs/pen and six pens/treatment. Dietary treatments were based on a control diet containing dried skim milk with the treatments containing additional spray-dried animal plasma (2.5 or 5%) or whey protein concentrate (2.7 or 5.4%) substituted for dried skim milk on a lysine basis. Chemical compositions of the whey protein concentrate and spray-dried animal plasma protein are presented in Table 1.

The trial was divided into two phases with the pelleted, experimental diets fed from d 0 to 14 after weaning. All diets were formulated to contain 1.5% lysine, .9% Ca, .8% P. The control diet contained 1.0% spray-dried blood meal, 15.0% dried whey, and 13.4% dried skim milk. Spray-dried animal plasma, added at 2.5 and 5.0%, and lactose replaced skim milk in the control diet on an equal lysine and lactose basis. Experimental whey protein concentrate and lactose replaced dried skim milk, but at levels of 2.7 and 5.4% to provide identical lysine levels. We formulated diets using the calculated amino acid concentrations of high protein, whey protein concentrate provided by the supplier (analyzed values indicated slightly higher lysine concentrations).

Additional DL-methionine was used to maintain a constant level of methionine in all diets.

[1]The authors thank Formost Farms, USA, Sauk City, WI for providing the whey protein concentrate used in this experiment.

The amount of crystalline lactose was adjusted so that all diets contained the same amount of total lactose. From d 14 to 35, a common corn-soybean meal diet containing 10% dried whey and 2.5% spray-dried blood meal was fed in a meal form. The common diet was formulated to contain 1.35% lysine, .9% Ca, and .8% P (Table 2).

Pigs were housed in an environmentally controlled nursery in 5 × 5 ft pens. They were provided ad libitum access to feed and water. Average daily gain, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance on d 7, 14, 21, 28, and 35 after weaning.

Results and Discussion

From d 0 to 7 after weaning, ADG and ADFI increased with increasing animal plasma (linear, $P < .01$, Table 3). Feed efficiency was not affected by increasing animal plasma in the diet. Increasing whey protein concentrate did not affect ADG, ADFI, or F/G. From d 0 to 14 after weaning, no differences were observed for pigs fed either of the experimental protein sources.

From d 7 to 14 after weaning, whey protein concentrate resulted in slight improvement in ADG, but when all pigs were fed a common diet (d 14 to 35), the protein source fed from d 0 to 14 after weaning had no effect on ADG or F/G. However, ADFI from d 14 to 35 tended to increase then decrease (quadratic, $P < .10$) with increasing animal plasma fed from d 0 to 14 after weaning.

From d 0 to 35 after weaning, no differences occurred in the growth performance of pigs fed any of the experimental diets.

In conclusion, increasing animal plasma increased ADG and ADFI only from d 0 to 7 after weaning. This suggests that spray-dried animal plasma is an important ingredient in diets fed to pigs immediately after weaning; however, because of cost, animal plasma should be removed from the diet as soon as the responses in feed intake and growth disappear. Pigs fed increasing high protein whey protein concentrate had similar growth performance as those fed the control diet throughout the entire experiment. Based on this one experiment, high protein, whey protein concentrate is an excellent protein source resulting in performance similar to that of pigs fed dried skim milk. However, it cannot replace spray-dried animal plasma for the initial period after weaning.

Table 1. Compositions of High Protein, Whey Protein Concentrate and Spray-Dried Animal Plasma[a]

Item , %	Whey Protein Concentrate	Animal Plasma
Protein	73.18	70.00
Fat	6.00	2.00
Ash	6.50	13.00
Amino Acids		
Arginine	2.32 (1.4)	5.30
Cystine	1.68 (1.9)	2.50
Histidine	1.49 (1.2)	2.80
Isoleucine	4.15 (3.5)	1.96
Leucine	7.43 (7.7)	5.56
Lysine	6.81 (6.3)	6.80
Methionine	1.52 (1.57)	0.53
Phenylalanine	2.67 (2.5)	4.10
Threonine	4.64 (4.8)	4.13
Tryptophan	1.63 (1.7)	1.33
Tyrosine	2.34 (2.3)	3.90
Valine	4.42 (3.6)	4.12

[a]Analyzed values expressed on an as-fed basis; calculated values used in diet formulation are provided in parentheses.

Table 2. Compositions of Diets[a]

		Spray-Dried Animal Plasma, %		Whey Protein Concentrate, %		Day 14-35[b]
Ingredients, %	Control	2.5	5.0	2.7	5.4	Phase II
Corn	37.15	37.69	38.20	37.72	38.31	51.87
Soybean meal	24.17	24.17	24.17	24.17	24.17	26.85
Dried whey	15.00	15.00	15.00	15.00	15.00	10.00
Dried skim milk	13.40	6.70	--	6.70	--	--
Soybean oil	5.00	5.00	5.00	5.00	5.00	4.00
Lactose	--	3.35	6.70	3.08	6.16	--
Monocalcium phosphate	1.36	1.50	1.65	1.65	1.94	1.65
Whey protein concentrate	--	--	--	2.70	5.40	--
Spray-dried animal plasma	--	2.50	5.00	--	--	--
Spray-dried blood meal	1.00	1.00	1.00	1.00	1.00	2.50
Antibiotic[c]	1.00	1.00	1.00	1.00	1.00	1.00
Limestone	.72	.87	1.01	.77	.82	.98
Zinc oxide	.37	.36	.38	.38	.38	.25
Vitamin premix	.25	.25	.25	.25	.25	.25
Salt	.20	.20	.20	.20	.20	.25
Trace mineral premix	.15	.15	.15	.15	.15	.15
L-Lysine HCl	.15	.15	.15	.15	.15	.15
DL-Methionine	.08	.11	.14	.08	.07	.10
Total	100.00	100.00	100.00	100.00	100.00	100.00

[a]Diets were formulated to contain 1.5% lysine, .42% methionine, .9% Ca, and .8% P and fed from d 0 to 14 after weaning. [b]Diet was formulated to contain 1.35% lysine, .38% methionine, .9% Ca, and .8% P and fed to all pigs from d 14 to 35 after weaning. [c]Provided 50 g/ton carbadox.

Table 3. Effects of Increasing Whey Protein Concentrate and Animal Plasma Fed from d 0

		Spray-Dried Animal Plasma, %		Whey Protein Concentrate, %		
Item	Control	2.5	5.0	2.7	5.4	CV
D 0 to 7						
ADG, lb[b]	.42	.48	.53	.43	.43	13.5
ADFI, lb[b]	.38	.45	.49	.42	.41	12.0
F/G	.91	.92	.93	.96	.95	9.7
D 7 to 14						
ADG, lb	.80	.79	.70	.80	.84	17.2
ADFI, lb	.84	.79	.79	.80	.84	14.8
F/G	1.05	1.0	1.12	1.0	1.0	13.3
D 0 to 14						
ADG, lb	.61	.64	.61	.62	.64	13.4
ADFI, lb	.61	.62	.64	.61	.62	11.8
F/G	1.01	.97	1.04	.99	.97	8.7
D 14 to 35[c]						
ADG, lb	1.26	1.27	1.27	1.22	1.32	7.0
ADFI, lb[d]	1.89	2.01	1.92	1.91	1.93	4.2
F/G	1.50	1.56	1.52	1.58	1.46	6.7
D 0 to 35						
ADG, lb	1.00	1.03	1.00	.98	1.05	6.2
ADFI, lb	1.38	1.46	1.41	1.39	1.41	4.7
F/G	1.38	1.42	1.40	1.43	1.34	4.7

[a]A total of 180 weanling pigs (initially 12.5 lb and 17 to 21 d of age) with six pigs per pen and six replications per treatment. [b]Linear effect of animal plasma ($P < .01$) . [c]Common diet was fed from d 14 to 35 after weaning. [d]Quadratic effect of animal plasma ($P < .10$).

EFFECTS OF LOW-PROTEIN, AMINO ACID-FORTIFIED DIETS, FORMULATED ON A NET ENERGY BASIS, ON THE GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF FINISHING PIGS [1]

J. W. Smith, II, P. R. O'Quinn, M. D. Tokach, R. D. Goodband, and J. L. Nelssen

Summary

Two hundred eighty-eight gilts were used to determine the effects of corn-soybean meal or low-protein, amino acid-fortified diets, formulated on a net energy (NE) basis on growth performance and carcass characteristics. Pigs fed high NE grew faster from 105 to 165 lb. However, pigs fed diets with intact protein grew faster and more efficiently during the finishing period and for the entire trial than those fed low protein, amino acid-fortified diets. Carcass data revealed that pigs consuming high NE were fatter and had lower percentage lean than pigs consuming low NE. Additionally, longissimus muscle area tended to be greater in pigs fed diets containing intact protein than pigs fed low protein, amino acid-supplemented diets. Based on these results, pigs fed low protein, amino acid-fortified diets had poorer ADG, feed efficiency, and carcass leanness than those fed diets with intact protein, regardless of NE.

(Key Words: Growing-Finishing Pigs, Net Energy.)

Introduction

Recent decreases in prices have increased the interest in replacing soybean meal with synthetic amino acids. However, research has shown that pigs fed low protein, amino acid-fortified diets generally have poorer carcass characteristics than those fed intact protein (soybean meal). None of the previous research has examined the role of energy, specifically net energy (NE), in low protein, amino acid-fortified diets. Soybeanmeal has a lower NE value than synthetic amino acids and corn. Therefore, replacing soybean meal with synthetic amino acids and corn would result in diets with a greater NE content. With this in mind, the objective of this experiment was to determine the effects of low protein, amino acid-fortified diets, formulated on an NE basis, on growth performance and carcass characteristics of growing-finishing pigs.

Procedures

Two-hundred eighty-eight crossbred gilts (PIC L326 × C22, initially 106 lb) were used. Diets were fed in two phases: growing (105 to 165 lb) and finishing (165 to 245). Both were formulated to contain .75 and .55 % apparent digestible lysine, respectively (Table 1). All diets were corn-soybean meal based and were fed in the meal form. Treatments were arranged in a 2 × 2 factorial. Main effects included NE level and protein source. The low NE growing and finishing diets contained 1.14 and 1.17 Mcal NE/lb, respectively; and the high NE grower and finisher diets contained 1.17 and 1.20 Mcal NE/lb, respectively. Protein was provided from soybean meal in the intact protein diets, and crystalline amino acids were used in the amino acid-fortified diets. Low protein, amino acid-fortified diets were formulated to meet true and apparent digestible amino acid requirements using the Illinois ideal amino acid ratio. Soybean oil (1.20 to 2.6%) was added to the corn-soybean meal diets to provide identical NE concentrations as the low

[1]The authors thank Nutri-Quest Inc. and BioKyowe Inc., Chesterfield, MO for providing the amino acids used for this project.

protein, amino acid-fortified diets. Pigs were blocked by weight and ancestry and allotted to one of the four dietary treatments.

The pigs were housed in a modified open-front finishing barn with 6 ft × 16 ft partially slatted pens. Each pen had nine pigs and contained a single two-hole feeder and a nipple waterer to allow ad libitum access to feed and water. Drip coolers were activated when temperatures exceeded 80°F, cycling on 3 out of every 15 min. This trial was conducted in two stages of four replicates. The first four replicates were fed from May to July, and the second four from June to August. Pigs and feeders were weighed every 14 d to calculate ADG, ADFI, and F/G. Pigs were scanned ultrasonically to determine body composition when their mean pen weight reached 250 lb. Additionally, 184 pigs were slaughtered at a commercial packing facility to collect carcass data.

The data from this trial were analyzed with the GLM procedure of SAS. The statistical model included main and interactive effects of NE and protein source. Live weight, at the time of ultrasound scanning was used as a covariate in the statistical analysis of tenth rib fat depth, longissimus muscle area, and lean percentage. Additionally, hot carcass weight was used as a covariate in the analysis of skinned fat depth, loin depth, lean percentage, and carcass yield.

Results and Discussion

No protein source by NE concentration interactions were detected for any of the criteria evaluated in this trial. During the growing phase (105 to 165 lb), pigs fed diets containing 1.17 Mcal NE/lb grew faster than pigs provided the diets containing 1.14 Mcal NE/lb ($P < .10$). The increase in ADG was primarily due to increased energy intake, both NE and metobolizable energy (ME), of those pigs ($P < .05$). Pigs fed low protein, amino acid-fortified diets consumed more feed and were less efficient than pigs consuming the intact protein diets ($P < .10$ and .05, respectively).

From 165 to 245 lb, pigs fed intact protein diets had increased ADG and ME intakes, and improved F/G ($P < .01$). The NE concentration did not affect growth or feed intake. However, as expected, pigs fed high NE diets consumed more NE and ME ($P < .01$ and 06, respectively) from 165 to 235 lb.

Over the entire experiment, pigs fed diets containing intact protein grew faster and more efficiently than pigs fed low protein, amino acid-fortified diets ($P < .001$). This was primarily due to the improved performance during the finishing period. Pigs fed the diets formulated to contain high NE consumed more feed during the entire feeding trial than pigs fed the low NE diet ($P < .05$).

Real-time ultrasound revealed that pigs fed low protein, amino acid-fortified diets had greater 10th rib fat depths and, therefore, had lower lean percentage ($P < .10$) than pig fed diets with intact protein. When pigs were slaughtered, pigs fed diets with intact protein had less 10th rib, skinned fat depth and percentage lean than pigs fed the low protein, amino acid-fortified diets ($P < .05$ and .10, respectively).

Based upon the results of this experiment, providing more energy in diets for growing-finishing pigs can improve growth during the growing period and increase fat depth of the carcass. More importantly, providing protein from synthetic sources impairs growth and decreases feed utilization, especially in the finishing phase of production. The marked decrease in feed utilization needs to be evaluated against any savings in diet cost that may be achieved by adding synthetic amino acids to growing-finishing swine diets.

Table 1. Compositions of Growing Diets

	Net Energy			
	Low Protein Source		High Protein Source	
Item	Intact	Synthetic	Intact	Synthetic
Corn	71.32	82.73	69.90	81.20
SBM, 46.5% CP	24.57	13.82	24.67	14.02
Soybean oil	1.32	—	2.63	1.32
Monocalcium phosphate, 21% P	.91	1.09	.92	1.10
Limestone	1.04	1.02	1.04	1.01
Salt	.35	.35	.35	.35
Vitamin premix	.20	.20	.20	.20
Trace mineral premix	.15	.15	.15	.15
Antibiotic	.13	.13	.13	.13
L-Lysine	—	.32	—	.32
DL-Methionine	.02	.10	.02	.10
L-Threonine	—	.08	—	.08
L-Tryptophan	—	.02	—	.02
Calculated Analysis				
ME, Mcal/lb	1.53	1.50	1.55	1.53
NE, Mcal/lb	1.14	1.14	1.17	1.17
CP, %	17.64	13.72	17.57	13.68
Ca, %	.65	.65	.65	.65
P, %	.55	.55	.55	.55
Calculated Total Amino Acids, %				
Lysine	.93	.88	.92	.88
Threonine	.68	.60	.68	.60
Tryptophan	.20	.17	.20	.17
Isoleucine	.76	.56	.76	.56
Methionine	.31	.34	.61	.34
Methionine + cystine	.62	.60	.62	.60
Calculated Digestible Amino Acids, %				
Lysine	.75	.75	.75	.75
Threonine	.52	.47	.51	.47
Tryptophan	.15	.13	.15	.13
Isoleucine	.62	.45	.62	.45
Methionine	.27	.31	.27	.31
Methionine + cystine	.49	.49	.49	.49

Table 2. Compositions of Finishing Diets

	Net Energy			
	Low Protein Source		High Protein Source	
Item	Intact	Synthetic	Intact	Synthetic
Corn	80.36	90.90	79.09	89.52
SBM, 46.5% CP	16.02	6.15	16.11	6.33
Soybean oil	1.20	—	2.37	1.20
Monocalcium phosphate, 21% P	.81	.98	.83	.99
Limestone	.88	.86	.87	.85
Salt	.35	.35	.35	.35
Vitamin premix	.15	.15	.15	.15
Trace mineral premix	.10	.10	.10	.10
Antibiotic	.13	.13	.13	.13
L-Lysine	—	.29	—	.29
DL-Methionine	—	.03	—	.03
L-Threonine	—	.05	—	.05
L-Tryptophan	—	.02	—	.02
Calculated Analysis				
ME, Mcal/lb	1.53	1.51	1.55	1.53
NE, Mcal/lb	1.17	1.17	1.20	1.20
CP, %	14.44	10.79	14.37	10.76
Ca, %	.55	.55	.55	.55
P, %	.50	.50	.50	.50
Calculated Total Amino Acids, %				
Lysine	.69	.65	.69	.65
Threonine	.55	.45	.55	.45
Tryptophan	.16	.13	.16	.13
Isoleucine	.60	.42	.60	.42
Methionine	.25	.23	.25	.23
Methionine + cystine	.52	.46	.52	.45
Calculated Digestible Amino Acids, %				
Lysine	.55	.55	.55	.55
Threonine	.41	.34	.41	.34
Tryptophan	.11	.09	.11	.09
Isoleucine	.48	.33	.48	.33
Methionine	.22	.21	.22	.21
Methionine + cystine	.41	.36	.41	.36

Table 3. Effects of Net Energy and Protein Source on Finishing Pig Growth Performance and Carcass Characteristics[a]

	Net Energy							
	Low Protein Source		High Protein Source		Net	Effects		
Item	Intact	Synthetic	Intact	Synthetic	Energy	Protein	Interaction	CV
Growing (1-5 to 165 lb)								
ADG, lb	1.96	1.90	2.03	1.98	.0482	.1537	.8631	5.3
ADFI, lb	4.84	5.01	4.97	5.11	.1420	.0530	.8876	4.4
F/G	2.47	2.64	2.45	2.58	.1465	.0001	.4540	2.8
ME intake, Mcal/d	7.39	7.53	7.70	7.81	.0221	.2954	.8917	4.5
NE intake, Mcal/d	5.52	5.73	5.83	6.01	.0043	.0553	.9097	4.5
Total lysine intake, g/d	20.32	20.07	20.85	20.49	.1547	.3567	.8719	4.5
Digestible lysine intake, g/d	16.48	17.09	16.92	17.42	.1420	.0533	.8876	4.4
Finishing (165 to 245 lb)								
ADG, lb	1.84	1.57	1.89	1.58	.3270	.0001	.6223	5.3
ADFI, lb	5.40	5.18	5.37	5.34	.3440	.0721	.1660	3.5
F/G	2.96	3.40	2.86	3.42	.6083	.0001	.4214	6.7
ME intake, Mcal/d	8.27	7.83	8.32	8.18	.0584	.0093	.1698	3.6
NE intake, Mcal/d	6.31	6.05	6.42	6.39	.0108	.0768	.1759	3.6
Total lysine intake, g/d	16.93	15.32	16.82	15.79	.4110	.0001	.1861	3.7
Digestible lysine intake, g/d	13.48	12.92	13.39	13.32	.3440	.0721	.1660	3.5
Overall								
ADG, lb	1.89	1.71	1.94	1.75	.0444	.0001	.7920	3.7
ADFI, lb	5.15	5.11	5.19	5.24	.0311	.9481	.2433	2.1
F/G	2.73	3.01	2.66	3.00	.3797	.0001	.6444	4.1
Ultrasound Data[b]								
Live weight, lb	248.7	235.5	254.5	240.3	.0121	.0001	.7896	2.2
10th rib fat depth, in	.75	.80	.78	.87	.0577	.0931	.4477	7.7
Loin muscle area, in^2	6.10	6.01	5.89	5.99	.4169	.9967	.4614	5.8
Lean percentage	52.97	52.22	52.06	51.51	.0547	.3068	.7769	1.8
Packing Plant Data[c]								
Live weight, lb	248.2	236.7	255.1	241.0	.0215	.0001	.5847	2.6
Hot carcass weight, lb	159.9	151.4	165.2	156.0	.0053	.0001	.8019	2.8
Skinned fat depth, in	.56	.59	.56	.62	.3300	.0263	.2049	5.6
Loin depth, in	2.12	2.08	2.06	2.10	.6174	.9386	.2999	4.9
Lean percentage	56.66	56.14	56.56	55.72	.3727	.0829	.5010	1.2
Carcass yield, %	64.30	64.27	64.30	64.83	.2342	.4126	.1554	.8

[a]Means derived from 288 gilts (PIC 326 × C22, initially 105 lb) housed at 9 pigs per pen with eight replicate pens per treatment.
[b]Live weight was used as a covariate to analyze 10th rib fat depth, loin muscle area, and lean percentage.
[c]One-hundred eighty-four gilts were slaughtered at a commercial packing plant to collect commercial carcass data. Hot carcass weight was used as a covariate to analyze skinned fat depth, loin depth, lean percentage, and carcass yield.

EFFECT OF DIETARY ENERGY DENSITY AND LYSINE:CALORIE RATIO ON THE GROWTH PERFORMANCE OF GROWING PIGS AND SUBSEQUENT FINISHING PERFORMANCE

J. W. Smith, II, P. R. O'Quinn, M. D. Tokach, R. D. Goodband, and J. L. Nelssen

Summary

One hundred twenty crossbred gilts were used in a growth trial to evaluate the effects of increasing dietary energy density and lysine:calorie ratio on growing pig growth performance and subsequent finishing performance. Feeding 3% choice white grease and 3.45 g lysine:Mcal ME maximized growth performance of growing gilts. Choice white grease additions and increasing lysine:calorie ratio during growing (65 to 160 lb) did not affect carcass backfat or loin depth at 235 lb.

(Key Words: Feed:Gain Ratio, Energy Density, Lysine:Calorie Ratio, Growing-Finishing Pigs.)

Introduction

Research reported in the 1996 KSU Swine Day showed that increasing choice white grease and lysine:calorie ratio improved the growth performance of pigs fed from 20 to 55 lb. Additional research from our laboratory indicated that increasing fat additions to diets fed to pigs from 100 to 160 lb improved feed utilization. However, this research did not examine the effects of lysine:calorie ratio on growth performance of growing pigs. With this in mind, the objective of this research trial was to examine the effects of increasing energy density and lysine:calorie ratio on growing pig growth and subsequent finishing growth performance.

Procedures

One hundred twenty crossbred gilts (PIC L326 × C22, initially 65 lb) were used in a growth assay. Pigs were blocked by weight and ancestry and allotted to one of the seven dietary treatments. During the growing phase (65 to 160 lb), pigs were fed increasing levels of choice white grease (CWG; 0, 3, and 6%) and lysine: calorie ratio (2.75, 3.10, 3.45, and 3.80 g lysine:Mcal ME; Table 1). Growing diets were formulated to contain .70% Ca and .60 %P. The lysine:calorie ratio of the experimental diets was achieved by adjusting the corn:soybean meal ratio. When mean block weight reached 160 lb, pigs were switched to a common finishing diet until mean block weight reached 200, then a second common finishing diet was fed. The common diet fed during early finishing (160 to 200 lb) was formulated to contain .90% lysine, .65% Ca, .55% P, and 2.72 g lysine:Mcal ME. The diet fed from 200 to 235 lb was formulated to contain .70% lysine, .55% P, .50% Ca, and 2.10 g lysine:Mcal ME.

The pigs were housed in an environmentally controlled finishing barn with 4 ft × 4 ft totally slatted pens. Each pen had two pigs and contained a single-hole feeder and a nipple waterer to allow ad libitum access to feed and water. Pigs and feeders were weighed every 14 days to calculate ADG, ADFI, and F/G. When mean block weight reached 235 lb, pigs were slaughtered in a commercial packing facility to collect carcass data.

The data from this trial were analyzed with the GLM procedure of SAS. The statistical model included main and interactive effects of CWG and lysine:calorie ratio. Linear and quadratic polynomials also were used to determine the effects of increasing additions of CWG and lysine:calorie ratio.

Results and Discussion

During the growing phase, increasing CWG and lysine:calorie ratio improved ADG (linear, $P < .05$ and .01, respectively). Additionally, increasing CWG decreased ADFI and improved F/G (linear, $P < .01$). Lysine and ME intakes increased as lysine:calorie ratio increased (linear, $P < .01$, and .10, respectively). This was due to increased ADFI as the lysine:calorie ratio increased (linear, $P < .10$).

When a common diet was fed from 160 to 200 lb, increasing CWG and lysine:calorie during the grower period had a detrimental effect on ADG (linear, $P < .05$). This was due to decreased ADFI, lysine intake, and ME intake for pigs that previously were fed diets containing increased CWG during the growing phase (linear, $P < .05$). Additionally, pigs previously fed increasing lysine: calorie ratio during the growing period had poorer F/G (linear, $P < .01$). This response appears to be the result of compensatory gain by pigs fed diets with lower lysine:calorie ratios during the growing phase.

The level of CWG or lysine:calorie ratio fed during the grower phase did not affect ADG, ADFI, and F/G during late finishing (200 to 236). However, for the entire growing-finishing period, pigs fed increasing CWG during the growing phase consumed less feed (linear, $P < .05$) and tended (linear, $P < .10$) to convert feed more efficiently.

The level of CWG and lysine:calorie fed from 65 to 160 lb did not affect fat depth, loin depth, or carcass yield of pigs fed common diets during early and late finishing.

The results of this experiment indicate that feeding 3% CWG and a lysine:calorie ratio of 3.45 g lysine:Mcal ME from 65 to 160 lb maximizes growth of crossbred gilts during the growing phase of production. However, for the entire trial, growth rate and feed efficiency were not affected by the lysine: calorie ratio fed from 65 to 160 lb. Increasing fat additions from 65 to 160 lb improved feed efficiency for the entire growth trial.

Table 1. Compositions of Diets[a]

Item, %	Basal Growing[b]	Finishing I[c]	Finishing II[d]
Corn	72.77	73.52	81.07
Soybean meal, 46.5%	24.19	23.80	16.52
Monocalcium phosphate	1.14	.90	.79
Limestone	1.07	1.05	.89
Salt	.35	.35	.35
Vitamin premix	.20	.15	.15
Trace mineral premix	.15	.10	.10
Antibiotic[e]	.13	.13	.13
Choice white grease	—	—	—

[a]Diets were formulated to 2.26 g lysine/Mcal ME, .60% Ca, and .50% P. Dietary lysine levels ranged from .75 to .81%.
[b]The experimental growing diets were formulated to contain .70% P and .60% Ca.
[c]The common finishing I diet was formulated to contain .65% P, .55% Ca, and 2.72 g lysine:Mcal ME.
[d]The common finishing II diet was formulated to contain .55% P, .50% Ca, and 2.10 g lysine:Mcal ME.
[e]Provided 50 mg tylosin/lb.

Table 2. Effects of Increasing Energy Density and Lysine:Caloie Ratio in the Diet on Pig Performance

	CWG, %			g Lysine/Mcal ME					Main Effects			Fat		Lysine	
Item	0	3	6	2.75	3.10	3.45	3.80	CV	Fat	Lysine	Fat × Lysine	Lin.	Quad	Lin.	Quad
Growing (66 to 160 lb)															
ADG, lb	2.00	2.07	2.08	1.99	2.00	2.11	2.11	6.4	.0917	.0164	.1665	.0486	.3390	.0042	.9150
ADFI, lb	4.91	4.75	4.56	4.65	4.61	4.89	4.82	7.5	.0124	.1153	.4683	.0062	.8944	.0666	.9002
F/G	2.47	2.29	2.19	2.34	2.32	2.32	2.29	5.1	.0001	.6812	.4240	.0001	.2207	.2529	.9322
Lysine intake, g/d	24.19	24.31	24.31	19.95	22.28	26.30	28.57	7.5	.9717	.0001	.4276	.8444	.8925	.0001	.9531
ME intake, Mcal/d	7.37	7.41	7.39	7.25	7.18	7.63	7.51	7.5	.9719	.1091	.4277	.8991	.8410	.0655	.8782
Finishing I (160 to 200 lb)															
ADG, lb	2.38	2.23	2.15	2.30	2.41	2.14	2.16	13.1	.0639	.0429	.7605	.0213	.6930	.0435	.5113
ADFI, lb	6.59	6.36	6.14	6.25	6.48	6.32	6.41	8.6	.0422	.6738	.9390	.0124	.9526	.5843	.6298
F/G	2.82	2.90	2.90	2.77	2.73	3.00	3.01	10.4	.6412	.0184	.6227	.4235	.6243	.0063	.7350
Lysine intake, g/d	26.93	25.68	25.10	25.52	26.46	25.83	26.21	8.6	.0422	.6738	.9390	.0124	.9526	.5843	.6298
ME intake, Mcal/d	9.89	9.54	9.21	9.37	9.71	9.48	9.62	8.6	.0422	.6738	.9390	.0124	.9526	.5843	.6298
Finishing II (200 to 236 lb)															
ADG, lb	2.02	2.12	2.03	2.08	2.01	1.97	2.18	19.2	.6783	.5243	.2987	.9326	.3832	.5586	.7989
ADFI, lb	7.38	7.27	7.79	7.58	7.47	7.48	7.38	13.4	.2457	.9583	.2272	.2062	.2691	.6085	.9844
F/G	3.57	3.44	4.22	3.69	3.56	4.23	3.45	35.1	.1432	.3439	.1943	.1260	.2083	.9909	.3130
Lysine intake, g/d	23.45	23.12	24.74	24.10	23.75	23.78	23.46	13.4	.2457	.9583	.2272	.2062	.2691	.6085	.9844
ME intake, Mcal/d	11.14	10.98	11.76	11.45	11.28	11.30	11.15	13.4	.2457	.9583	.2272	.2062	.2691	.6085	.9844
Overall															
ADG, lb	2.09	2.12	2.09	2.08	2.10	2.08	2.13	6.0	.6545	.6517	.8119	.9259	.3623	.3361	.6652
ADFI, lb	5.81	5.64	5.59	5.62	5.65	5.74	5.72	5.9	.1046	.7631	.3849	.0423	.5406	.3498	.7676
F/G	2.78	2.66	2.69	2.71	2.70	2.76	2.68	6.1	.0612	.5392	.2952	.0784	.1069	.9480	.3913
Carcass (236 lb)															
Skinned fat depth, in	.57	.59	.59	.59	.58	.56	.60	13.9	.7383	.4087	.9089	.5108	.6807	.9884	.1336
Loin depth, in	2.25	2.61	2.21	2.23	2.23	2.28	2.28	7.1	.1800	.6586	.8397	.4776	.0875	.2442	.9665
Carcass yield	64.42	64.58	64.20	64.60	63.92	64.52	64.56	1.8	.6021	.3442	.1253	.5708	.4072	.7386	.2381

[a]Means derived from 84 pigs housed at two per pen with six replicate pens per treatment.

EFFECTS OF POULTRY FAT AND CHOICE WHITE GREASE ON FINISHING PIG GROWTH PERFORMANCE, GENERAL CARCASS CHARACTERISTICS, AND PORK LONGISSIMUS MUSCLE QUALITY [1]

J. J. Engel, J. W. Smith, II, R. D. Goodband, J. A. Unruh, M. D. Tokach, and J. L. Nelssen

Summary

Eighty-four crossbred gilts were used to examine the effects of increasing dietary additions of poultry fat (PF) or choice white grease (CWG) on finishing pig growth performance, standard carcass characteristics, and longissimus muscle quality. Increasing CWG or PF improved feed efficiency. Increasing CWG tended to increase then decrease longissimus muscle visual color compared with longissimus muscles from those animals fed PF. Pigs fed CWG had firmer, less exudative, and more purplish-red (measured by a Minolta chronometer) longissimus muscles compared with pigs fed PF. Feeding CWG or PF did not affect standard carcass traits and had minimal effects on longissimus muscle quality.

(Key Words: Finishing Pigs, Choice White Grease, Poultry Fat, Performance, Longissimus Muscle Quality.)

Introduction

Much research has been conducted to investigate the effects of dietary fat additions on finishing pig growth performance and carcass characteristics. Research from Kansas State University indicated that increasing CWG to as much as 6% of the diet did not affect growth performance or standard carcass characteristics of finishing pigs. However, the effects of alternative energy sources on the growth performance, standard carcass characteristics, and longissimus muscle quality of finishing pigs has not been examined. We know that differences in saturated and unsaturated fat depositions in pork carcasses can result from the source of dietary fat added to the finishing pig diet. Adding unsaturated poultry fat (PF) to finishing pig diets at high levels might have an influence on pork quality.

Therefore, the objective of this study was to compare the effects of dietary additions of increasing PF or CWG on finishing pig growth performance, standard carcass traits, and longissimus muscle quality.

Procedures

Eighty four crossbred gilts, PIC L326 × C15 at an initial weight of 133 lb were used in this experiment. Choice white grease and PF were added at 2, 4, or 6% to a corn-soybean meal-based control diet (Table 1). Pigs were blocked by ancestry and allotted to one of seven dietary treatments.

The experimental control diet contained 0% added fat and was formulated to .75% lysine, .55% Ca, .50% P, and 2.26 g lysine/Mcal ME. This lysine-calorie ratio was maintained in all of the diets containing PF or CWG additions. The lysine levels in the diets with the added fat varied from .75 to .81%. The corn-soybean meal-based experimental diets were fed in a meal form. The pigs were housed with two pigs per pen in an environmentally controlled finishing barn with 4 ft × 4 ft slatted pens. Each treatment included two pigs per pen and six replicate pens. The pens provided ad libitum access to feed and water.

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Table 1. Basal Diet Composition[a]

Item	%
Corn	83.33
Soybean meal, 46.5%	14.07
Monocalcium phosphate	1.01
Limestone	.83
Salt	.35
L-Lysine HCl	.15
Vitamin premix	.15
Trace mineral premix	.10
Ethoxyquin	.01
Choice white grease[b]	—
Poultry fat[b]	—
Total	100.00

[a]Diets were formulated to 2.26 g lysine/Mcal ME, .60% Ca, and .50% P. Dietary lysine levels ranged from .75 to .81%.
[b]Choice white grease and poultry fat were added at 2, 4, or 6% to provide the experimental diets.

Pigs and feeders were weighed every 14 days to calculate ADG, ADFI, and F/G.

Individual fat sources were analyzed for their fatty acid profile (Table 2). This profile indicated that the percentages of palmitic fatty acids were very similar between the two fat sources. Palmitic and linoleic acid levels were almost double in PF as compared to CWG. Stearic acid levels were nearly double in CWG. Oleic acid levels were slightly higher in CWG than in PF.

Table 2. Fatty Acid Profile of Choice

Fatty Acid, %	PF	CWG
Palmitic (16:0)	22.2	23.3
Palmitoleic (16:1)	8.4	3.5
Stearic (18:0)	5.1	11.0
Oleic (18:1)	42.3	47.1
Linoleic (18:2)	19.3	11.0

Both fat sources were analyzed using several key quality indicators (Table 3). These indicators included total fatty acid percentage; free fatty acid percentage; moisture, impurities, and unsaponifiables; and peroxide values. CWG tended to have a higher peroxide value. Nonetheless, this analysis revealed that both fat sources were of high quality.

Table 3. Fat Quality Indicators of Choice White Grease and Poultry Fat

Item	PF	CWG
Total fatty acids, %	98.7	97.9
Free fatty acids, %	3.2	3.2
M.I.U., %	1.3	.8
Peroxide value	.2	7.3

Pigs were slaughtered at the Kansas State University Meats Laboratory when the mean weight of pigs in a pen reached 240 lb. At 24hours postmortem, standard carcass measurements were taken. The carcasses were then ribbed at the tenth rib and allowed to bloom for 30 minutes. At this time, the longissimus muscle was evaluated by a three-person panel for visual quality characteristics including visual marbling, visual color, and visual firmness and wetness. Longissimus muscle color was evaluated on a 1 to 5 scale with 1 representing a muscle that was pale-pinkish-gray, and 5 being a muscle that was dark-purplish red in color. Longissimus muscle visual firmness and wetness were evaluated on a 1 to 5 scale, with 1 being very soft and watery and 5 being very firm and dry. Visual marbling was evaluated on a 1 to 5 scale with 1 being practically devoid and 5 being moderately abundant or greater.

Following the visual evaluations, the longissimus muscle and the subcutaneous fat surrounding the longissimus muscle were evaluated with a Minolta chronometer to obtain CIE L* a* b* values. The L* a* b* values then were used to calculate saturation index, hue angle, and A:B ratio. Minolta L* values represent the lightness of a sample. Longissimus muscles with a higher L* value would have a lighter color, whereas those with a lower L* value would appear darker.

Minolta a* values are chromatic coordinates representing a change from a green to a red color. A higher a* value represents a sample with more red color. Minolta b* values are also chromatic coordinates, representing a change in color from blue to yellow. The higher the b* value, the more yellow the color of the sample. Saturation indexes, hue angles, and A:B ratios can be calculated from Minolta L* a* b* values. Saturation index tells the chroma, or the total color of the sample. The greater the value of the saturation index, the more intensely colored the sample is. Saturation index also can be referred to as the vividness of a sample. The hue angle represents the change from a red toward an orange color. The higher the hue angle, the less red the sample. The A:B ratio indicates a change in redness. The higher the value, the redder the color.

Longissimus muscle samples were removed, and drip loss after 24 and 48 hours of suspension was evaluated. This evaluation was conducted by suspending the sample on a fish hook inside a sealed Tupperware container. The weight loss of each sample then was collected and reported as a percent of the original weight.

The data from this experiment were analyzed with the GLM procedure of SAS. The experimental design was a two by three factorial arrangement. The statistical model included linear and quadratic effects of increasing additions of PF and CWG added at levels of 2, 4 or 6%.

Results and Discussion

Neither energy source nor level (Table 4) affected ADG. Increasing CWG tended to increase then decrease ADFI (quadratic, $P < .10$). Feed efficiency improved as pigs were fed increasing CWG or PF (linear, $P < .01$ and .10 respectively). Similar to ADFI, lysine and energy intakes increased then decreased as additions of dietary CWG increased (quadratic, $P < .10$). Additions of CWG or PF did not affect standard carcass characteristics of pigs in this experiment (Table 5).

Increasing CWG tended to increase and then decrease longissimus muscle visual color (quadratic, $P < .10$; Table 6). Visual color score of longissimus muscles increased for pigs fed 4% CWG compared to longissimus muscles from pigs fed 2% CWG. This represents a progression toward a darker color. As the level of CWG in the diet increased to 6%, the color score decreased, indicating a paler color. Pigs fed CWG tended ($P = .10$) to have increased longissimus muscle firmness compared with pigs fed PF. The firmness and wetness scores of pigs fed PF and CWG showed a quadratic effect. As PF or CWG levels were increased to 4%, their firmness and wetness scores increased. This indicates a firmer, less exudative sample. The scores decreased at 6% indicating a wetter, less firm sample. Increasing CWG decreased and then increased longissimus muscle Minolta L* (quadratic, $P < .10$). Longissimus muscle A:B ratio increased and then decreased with increasing CWG (quadratic, $P < .05$). These results suggest that CWG or PF can be added to finishing pig diets to improve feed efficiency with minimal effects on standard carcass characteristics and longissimus muscle quality.

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Table 4. Effects of Choice White Grease and Poultry Fat on Finishing Pig Growth

		Choice White Grease, %			Poultry Fat, %			
Item	Control	2	4	6	2	4	6	CV
ADG, lb	2.02	2.11	2.15	2.08	2.05	2.05	2.07	5.6
ADFI, lb[bc]	6.77	7.11	6.73	6.33	6.70	6.77	6.36	7.4
F/G[cd]	3.32	3.36	3.13	3.04	3.26	3.32	3.08	6.3
Lysine intake, g[be]	23.04	24.20	22.97	21.55	23.43	24.27	23.40	7.3
Energy intake, Mcal[be]	10.21	10.72	10.15	9.54	10.37	10.75	10.37	7.3

[a]Means derived from 84 pigs housed at two per pen with six replicate pens per treatment.
[b,c]Linear effect of choice white grease ($P < .10$ and .01, respectively).
[d]Linear effect of poultry fat ($P < .10$).
[e]Quadratic effect of choice white grease ($P < .10$).

Table 5. Effects of Choice White Grease and Poultry Fat on Finishing Pig Carcass

		Choice White Grease, %			Poultry Fat, %			
Item	Control	2	4	6	2	4	6	CV
Backfat								
First rib, in	1.54	1.47	1.51	1.47	1.53	1.51	1.51	9.5
Tenth rib, in	.79	.74	.81	.78	.80	.78	.76	18.6
Last rib, in	.94	.89	.93	.93	.90	.90	.94	14.3
Last lumbar, in	.77	.67	.80	.75	.78	.77	.81	18.6
Average, in[b]	1.08	1.01	1.08	1.05	1.07	1.06	1.09	9.7
LMA, in^2	6.64	6.87	6.51	6.72	6.57	6.17	6.69	11.4
Lean, %[c]	54.47	54.87	53.50	54.73	53.75	53.95	54.35	2.1
Muscle, %[d]	56.59	57.39	56.42	56.81	56.49	56.17	57.03	3.0
Dressing percentage	76.49	75.36	75.29	75.95	75.95	75.77	74.94	3.2

[a] Means derived from 84 pigs slaughtered at 240 lb with 12 pigs per treatment. Hot carcass weight was used covariant in the statistical analysis.

[b] AVGBF calculated as the average of first rib, last rib, and last lumbar fat depths.

[c] Lean percent was derived from NPPC equations for carcasses with 5% fat.

[d] Muscle percent was derived from NPPC equations for carcasses with 10% fat.

Table 6. Effects of Choice White Grease and Poultry Fat on Longissimus Muscle and

		Choice White Grease, %			Poultry Fat, %			
Item	Control	2	4	6	2	4	6	CV
Drip Loss								
24 hour, %[b]	2.26	3.19	2.34	2.88	2.94	2.41	3.6	64.2
48 hour, %[b]	3.91	4.98	3.94	4.57	4.58	3.67	4.81	54.6
Visual color[c]	2.50	2.57	2.67	2.34	2.46	2.46	2.45	16.1
Visual marbling[d]	2.61	2.44	2.56	2.33	2.40	2.53	2.20	26.4
Visual	2.86	2.83	3.02	2.80	2.66	2.81	2.66	16.2
Longissimus Fat								
Minolta L*[fi]	77.76	77.70	77.28	77.16	77.74	77.52	76.54	1.7
Minolta a*[f]	5.20	4.94	4.99	4.86	4.76	4.68	4.80	18.8
Minolta b*[f]	5.88	5.86	5.88	5.79	5.76	5.92	5.87	11.3
Longissimus Muscle								
Minolta L*[gh]	51.54	50.56	49.50	52.24	51.58	50.64	52.06	5.8
Minolta a*[g]	11.45	12.10	11.00	11.19	11.52	11.85	13.00	18.4
Minolta b*[g]	7.99	8.02	7.30	7.92	8.09	7.95	8.94	22.8
Saturation index[g]	13.99	14.56	13.24	13.73	14.10	14.29	15.80	19.2
Hue angle[g]	48.77	46.05	45.16	50.59	49.42	45.27	47.90	16.2
A:B ratio[gh]	1.46	1.35	1.59	1.42	1.44	1.53	1.46	13.4

[a] Means derived from 84 pigs slaughtered at 240 lb with 12 pigs per treatment.

[b] Expressed as a percentage loss of the original sample weight.

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

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

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

[f] Means derived from two readings of the fat surrounding the loin eye.

[g] Means derived from two readings per loin. Measure of dark to light (Minolta L*), redness, (Minolta a*), yellowness (Minolta b*), vividness or intensity (saturation index), or red to orange (Hue angle).

[h] Quadratic choice white grease effect ($P < .05$).

[i] Linear poultry fat effect ($P < .05$).

LIST OF KEY WORDS

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