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SWINE DAY 2002

Report of Progress 897

FOREWORD

It is with great pleasure that we present to you the 2002 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 the information will be of benefit as we attempt to meet the needs of the Kansas swine industry.

Editors, 2002 Swine Day Report of Progress,

Bob Goodband Mike Tokach Steve Dritz Joel DeRouchey

ABBREVIATIONS USED IN THIS REPORT

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

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

KSU VITAMIN AND TRACE MINERAL PREMIXES

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

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

Vitamin premix: each lb of premix contains vitamin A, 2,000,000 IU; vitamin D_3, 300,000 IU; vitamin E, 8,000 IU; menadione, 800 mg; riboflavin, 1,800 mg; pantothenic acid, 6,000 mg; niacin, 10,000 mg; and vitamin B_{12}, 8 mg.

Sow add pack: each lb of premix contains choline, 100,000 mg; biotin, 40 mg; folic acid, 300 mg; and pyridoxine, 2,750 mg.

NOTICE

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

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

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Growing-Finishing Management

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BIOLOGICAL VARIABILITY AND CHANCES OF ERROR

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

In some of the articles herein, you will see the notation "$P<0.05$." This means the probability of the differences resulting from chance is less than 5%. If two averages are said to be "significantly different," the probability is less than 5% that the difference is from chance or the probability exceeds 95% that the difference resulted from the treatments applied.

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

In other papers, you may see an average given as 2.5 ± 0.1. The 2.5 is the average; 0.1 is the "standard error." The standard error is calculated to be 68% certain that the real average (with unlimited number of animals) would fall within one standard error from the average, in this case between 2.4 and 2.6.

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

Swine Day 2002

EFFECTS OF WEANING AGE ON PIG PERFORMANCE IN THREE-SITE PRODUCTION

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

Summary

Two trials (n = 5,728 weaned pigs) were conducted to determine the effects of weaning age (12 to 21.5 days) on pig performance in a three-site production system. The second trial also examined the effects of modifying nursery feed budgets according to weaning age. In both studies, wean-to-finish ADG, mortality rate, average pig gain per days post-weaning, and pounds sold per pig weaned improved linearly as weaning age increased. The improvements in growth rate and mortality largely occurred in the initial 42-days post-weaning, with some ongoing growth improvement to slaughter. Modifying nursery feed budgets did not affect wean-to-finish growth performance. These studies indicate increasing weaning age up to 21.5 days predictably improves grow-finish throughput within a three-site production system.

(Key Words: Weaning Age, Throughput, Growth.)

Introduction

Previous research has demonstrated positive effects associated with segregated early weaning (SEW). Segregated early-weaning research has predominantly studied either pathogen elimination or growth performance benefits due to segregating production versus the on-site rearing of growing pigs. However, limited prospective research has been conducted to quantify the impact of weaning age within an applied SEW production scheme. Therefore, the objective of our first trial was to quantify the impact of weaning age on pig performance within a three-site production system. A second trial was completed to evaluate the effects of both weaning age and alternative nursery feed budget regimens on pig performance. Specifically, whether growth performance responses due to weaning age were significantly affected by altering nursery feed budgets.

Procedures

These experiments were completed with pigs originating from a 7,300-head sow farm with pigs flowing into single source, all-in all-out nursery and finishing sites. In Trial 1, treatments included weaning litters of pigs at 12, 15, 18, or 21 days of age. In Trial 2, litters were weaned at 15, 16, 18, 19, 21, or 22 days of age. This resulted in three wean age treatments (15.5, 18.5, and 21.5 days of age, i.e., 15.5 days = 50% 15 day pigs, and 50% 16 day pigs) Litters were ear notched at birth (18 to 20 litters/day of weaning age in each block), and all pigs were subsequently individually ear-tagged, weighed, and gender recorded three days prior to weaning. Each trial had four blocks. Each block consisted of all weaning age treatments weaned on the

[1]Food Animal Health and Management Center.

same day into the same nursery. Each block remained intact as pigs were transferred from nursery to finishing site. Pigs were only removed from trial pens due to either death or if a non-recoverable, moribund condition existed.

At weaning, pigs (PIC 280 × C22; Trial 1 n=2,272, Trial 2 n=3,456) of each age group were allotted using the individual pig weight and gender information. Each of the four blocks had four replicates (pens) per age (Trial 1) or age by feed budget combination (Trial 2). Each pen contained an equal number of barrows and gilts. Using the individual pig weight and gender information, each pen was allotted to replicate the normal weight distribution of barrows and gilts being weaned within each age group. Pens contained 36 pigs with the exception that the first block in Trial 1 had 34 pigs per pen. Nursery pens were 8 × 12 ft with wire flooring and two nipple waterers. Each pen contained a double-sided feeder with 5 holes on each side. In Trial 1, all pigs were fed a common three-phase nursery feed budget (Table 1). In Trial 2, each age group was fed a nursery feed budget that was classified as either being more or less complex. These nursery feed budget classifications were determined both on formulation complexity and the quantity of the complex diets fed (Table 2). Feed delivery was recorded on a pen basis throughout the nursery period. All pens were weighed at 42 days post-weaning, with individual pig weights being recorded. Growth and feed efficiency were calculated utilizing trial allotment weights attained 3 days prior to weaning. Weighing and tagging pigs prior to weaning was necessary due to labor availability.

Pigs (Trial 1 n=1,920; Trial 2 n=3,000) were re-allotted within treatment group and block to the finishing phase using the individual 42-day post-weaning weight and gender information. As described for the nursery allotment, finishing pens were allotted such that each pen was a replicate of the population of feeder pigs being placed for each specific treatment and block. All pigs were fed the same feed budget throughout finishing. Diet specifications and feed budget are outlined in Tables 1 and 2. These feed budgets were designed to ensure nutrient requirements were being exceeded for all wean age groups on feed. However, feed delivery information was not collected on a pen basis during the finishing period. In Trial 1, pigs (n=20 pigs/pen; 10 barrows, 10 gilts) were placed in 7.5 × 22 ft finishing pens. In Trial 2, pigs (n=25 pigs/pen; 13 gilts, 12 barrows) were placed in 9.5 × 22 ft finisher pens. Finishing pens had partially slatted concrete flooring (2/3 solid, 1/3 slatted), and curtain sided buildings were naturally ventilated. Each pen had 2 nipple waterers and a 4-hole feeder. Pens weighed off-test at 156 (Trial 1) and 153 (Trial 2) days post-weaning with individual weights being recorded. In Trial 1, each block was transferred to slaughter over a 28-day period after being weighed off-test (Table 3). In Trial 2, all pens in each block were marketed the day after being weighed off-test. Pen identity was maintained through the packing plant in both trials. Live performance and carcass data were analyzed for linear and quadratic effects, with pen serving as the experimental unit for all data analyses.

Results and Discussion

Trial 1. Allotment weight increased (linear, $P<0.0001$, Table 4) with increasing weaning age. Furthermore, the variation in allotment weight was reduced as weaning age increased (quadratic, $P<0.0001$). Allotment weight variation increased most noticeably in the pigs to be weaned at 12-days of age, with variation in older weaning ages similar. Nursery ADG, ADFI, mortality rate, and 42-day post-weaning weight improved (linear, $P<0.0001$) as weaning age increased from 12

to 21 days. Nursery F/G (quadratic, $P<0.03$) and variation in 42-day post-weaning weight (quadratic, $P<0.01$) also improved as weaning age increased. Feed efficiency and 42-day post-weaning weight variation were poorer in the 12-day weaned pigs, with F/G and weight variation among older weaning ages similar. However, step-wise improvements in 42-day post-weaning weight variation were observed as weaning age increased.

Finishing ADG, off-test weight, off-test weight variation, and average weight per day of age improved (linear, $P<0.0001$, Table 5) as weaning age was increased from 12 to 21 days. There were no differences ($P>0.17$) in finishing mortality or carcass yield. However, when adjusting carcass lean measures to a common carcass weight, improvements (quadratic, $P<.0001$) in 10th rib fat depth, loin depth, and percentage lean were observed as weaning age increased. The largest improvements in fat depth and lean percentage were observed as weaning age increased from 18 to 21 days. Loin depth was more quantitatively improved as weaning age increased from 15 to 18 days. Defining the mechanism driving the improvements in lean can only be hypothesized. The spread in body weight that continued to widen throughout the feeding period (Off-test weights: 12 d = 229, 15 d = 241, 18 d = 247, and 21 d = 258 lb) may have played a role in the observed differences in carcass lean at slaughter. Previous research has demonstrated that feeding amino acid densities above the nutrient requirements for optimizing growth and feed conversion yields incremental improvements in carcass lean. The older pigs were heavier at weaning and grew faster throughout the growing period. Therefore, the older pigs were incidentally fed a higher lysine:calorie (g lysine/Mcal ME) ratio relative to average body-weight throughout the feeding period. Previous research has also illustrated that feeding rather simple diets to pigs weaned at a younger age can negatively impact carcass lean. Either the complexity of the nursery diets in this study or the relative magnitude of over-feeding throughout the finishing period may be factors beyond the main effect of weaning age contributing to the differences in carcass lean observed at slaughter.

Wean-to-finish ADG, mortality, average pig gain per days post-weaning, and pounds sold per pig weaned improved (linear, $P<0.0001$, Table 6) as weaning age increased from 12 to 21 days. In these analyses, both ADG and average pig gain were determined. Average daily gain (ADG) was calculated to be a more holistic measure of throughput, as weight and days lost due to mortality were not accounted for in ADG calculations. Contrarily, average pig gain is simply a measure of growth rate that is not influenced by mortality. Similar to ADG, pounds sold per pig weaned more holistically evaluated the effects of weaning age on production system throughput. Expressing weight sold on a per pig weaned basis enables wean-to-finish throughput to be quantified in a manner that directly relates to value of the weaned pig. This removes mortality-induced bias in traditional closeout information.

Trial 2. There was no age by feed budget interactions ($P>0.26$) during the nursery phase. Allotment weight increased (quadratic, $P<0.001$,Table 7) with increasing weaning age. Although numerically similar, variation in allotment weight appeared to change (quadratic, $P<0.04$) as weaning age increased. The results of the allotment weights need to be interpreted with caution due to the allotment procedure, which made each pen within age group equivocal in average pig weight and pig weight variation. Therefore, the small within age group variation makes test statistics very sensitive on these allotment weight measures. Numerically speaking, allotment weights increased linearly (15.5 d = 9.0, 18.5 d = 10.5, 21.5 d =12.4 lb) with weaning age, but variation at weaning (15.5 d = 19.6, 18.5 d = 20.2, 21.5 d = 19.4 CV%) was similar

between age groups. Nursery ADG, ADFI, and 42-day post-weaning weight improved (linear, $P<0.0001$) as weaning age increased from 15.5 to 21.5 days. Weight variation at the end of the nursery phase also improved (linear, $P<0.003$) and removal rate tended to decrease ($P<0.09$) as weaning age increased. However, nursery F/G was poorer (linear, $P<0.0001$) as weaning age increased. Nursery feed budget complexity did not affect ($P>0.29$) growth rate, feed efficiency, or mortality. However, pigs fed the more complex nursery feed budgets tended ($P<0.06$) to have reduced variation in weight at 42-days post-weaning.

Similar to the nursery phase, there were no age by feed budget interactions ($P>0.14$) for the growth parameters measured during the finisher phase in Trial 2. Finishing ADG, off-test weight, and average pig weight per day of age improved (linear, $P<0.003$, Table 8) as weaning age increased from 15.5 to 21.5 days. In addition, there were no differences ($P>0.17$) in either off-test weight variation, or finishing mortality rate associated with weaning age. There was no effect ($P>0.10$) of weaning age on carcass yield. After adjusting lean measures to a common carcass weight, wean age by nursery feed budget interactions ($P<0.03$) for 10th rib fat depth, loin depth, and lean percentage were observed. Increasing nursery feed budget complexity improved ($P<0.002$) carcass yield and, as a result, tended ($P<0.08$) to increase average carcass weights. Only pigs weaned in the 15.5 day treatment had within age group differences in carcass yield (less complex = 74.72 vs. more complex = 75.96, SE 0.38%, $P<0.0004$), and carcass weight (less complex = 180.3 vs. more complex = 184.6, SE 2.4 lb, $P<0.003$). These within age group differences in carcass weight described for the pigs weaned at 15.5 days, coupled with similar within age group carcass weights in pigs weaned at 18.5 and 21.5 days, explains the nursery feed schedule by wean age interaction ($P<0.03$) on carcass weight observed. We have no explanation for the improvement in carcass yield by increasing nursery feed budget complexity in the youngest age group of wean pigs. In Trial 2, all pens were slaughtered the day after they were weighed off-test. Therefore, average carcass weight was confounded within weaning age. Confounding weaning age and average carcass weight, along with the magnitude of weight adjustment needed to bring carcass lean measures to a common carcass weight, may have played a role in the complicated interactions observed. In summary, the weaning age by nursery feed budget interactions limit the interpretation of either of these main effects on carcass lean.

Wean-to-finish ADG, average pig gain per days post-weaning, pounds sold per pig weaned (linear, $P<.00001$, Table 9), and wean to finish mortality (linear, $P<0.03$) improved as weaning age was increased from 15.5 to 21.5 days. Nursery feed budget complexity did not affect ($P>0.27$) wean-to-finish growth performance parameters measured.

Conclusions

The linear improvements in growth and throughput observed with increasing wean age are likely functions of both weight and physiological maturity at weaning. Weaning weight is directly confounded within weaning age in this study. Therefore, it is not appropriate to translate the weaning age effects directly back to weaning weight or other interim pig weights. Translating wean age performance improvements back to interim pig weight basis is only appropriate when the improved interim weights are due to an increased weaning age.

These trials indicate that weaning age has a significant and repeatable effect on growing pig performance within a given set of health and management conditions. These linear improvements in growth and livability largely occur in the 42-day post-weaning period, with some ongoing growth improvements in the

finishing phase. These studies suggest that the magnitude of growth rate improvement observed with increasing wean age is rather predictable within a given production system. However, the magnitude of the mortality improvement likely depends on baseline nursery mortality rates, as well as other pig-flow, site, or system specific challenges. Altering nursery feed budgets according to weaning age did not affect wean to finish growth performance. These trials did not conclusively demonstrate that either weaning age or nursery feed budgets affected carcass parameters measured. In summary, the linear improvements in throughput associated with increasing weaning age illustrate the importance for pork production systems to clearly rationalize weaning age targets. These studies indicate that population weaning age is a predictable input influencing the level of grow-finish throughput that is achieved within a given three-site production system.

Table 1. Feed Budget and Diet Composition (Trial 1)[a]

	Nursery			Finisher		
Item	Phase I	Phase II	Phase III	Phase IV	Phase V	Phase VI
Feed budget (lb/head)	3	6	remainder	110	150	remainder
Composition of diet %						
Spray-dried animal plasma, %	2.85	-	-	-	-	-
Lactose, %	20	12	-	-	-	-
TID lysine, %	1.37	1.21	1.14	1.05	0.97	0.86
Kcal of ME / lb	1580	1580	1570	1600	1609	1620

[a]All weaning age treatments (12, 15, 18, or 21 d) in trial 1 were fed a common feed budget.

Table 2. Feed Budget and Diet Composition (Trial 2)[a,b]

		Feed budget (lb/head)						
	Nursery budget complexity	Nursery				Finisher		
		Phase				Phase		
Wean age, d	classification	SEW	I	II	III	IV	V	VI
15.5	less	0	4	6	remainder	110	150	remainder
15.5	more	1.5	4	8.5	remainder	110	150	remainder
18.5	less	0	4	6	remainder	110	150	remainder
18.5	more	1	4	7	remainder	110	150	remainder
21.5	less	0	2	8	remainder	110	150	remainder
21.5	more	0	4	6	remainder	110	150	remainder
Composition of diet								
Spray-dried animal plasma, %		6.7	3.5	-	-	-	-	-
Lactose, %		22.5	20.0	11.0	-	-	-	-
TID lysine, %		1.40	1.56	1.37	1.26	1.05	0.90	0.78
Kcal of ME / lb		1595	1550	1550	1580	1575	1575	1575

[a]Each weaning age group (15.5, 18.5, or 21.5 d) was fed a nursery feed budget that was classified as either being more or less complex. The complexity classification was determined both on formulation complexity and the quantity of the more complex diets fed.
[b]Finishing feed budgets were common across treatments.

Table 3. Schedule for Transfer to Slaughter (Trial 1)[a]

	Weaning Age, days			
	12	15	18	21
Day after off-test weight	Number of pens tranferred[b]			
0	0	0	2	2
7	0	2	2	2
14	2	2	2	2
21	2	2	0	0
28	2	0	0	0

[a]All pens weighed off-test on a common day, with pens being sold in an all-out by pen basis over the next 28 days.

[b]Each pen placed with 20 pigs (10 barrows, 10 gilts).

Table 4. Influence of Weaning Age on Nursery Performance (Trial 1)[a]

	Weaning Age					Probability (*P*<)	
Item	12	15	18	21	SE	Linear	Quadratic
Allotment weight, lb[b]	7.6	9.4	10.8	12.7	0.12	0.0001	0.77
Allotment weight CV, %[c]	20.4	17.1	18.6	17.6	0.96	0.0001	0.0001
Regressed weaning weight, lb[d]	9.3	10.9	12.6	14.3	.	.	.
ADG, lb[e,f]	0.66	0.81	0.90	1.05	0.01	0.0001	0.66
ADFI, lb[e,f]	0.94	1.13	1.25	1.44	0.02	0.0001	0.64
Feed/gain[e,f]	1.42	1.39	1.38	1.38	0.01	0.0006	0.03
Mortality, %	5.25	2.82	2.11	0.54	0.76	0.0001	0.55
42-days post-weaning, lb	37.3	44.7	49.8	56.9	0.58	0.0001	0.60
42-days post-weaning CV,%[c]	20.0	15.6	14.4	12.9	0.68	0.0001	0.01

[a]2,272 pigs with 34 or 36 pigs per pen (50% barrows, 50% gilts), and 16 replications (pens) per treatment, or a total of 64 pens on test.

[b]Allotment weights were taken on all pigs 3 days prior to weaning.

[c]CV = Coefficient of Variation = (Standard Deviation of Weight / Mean Weight) * 100.

[d]Predicted treatment mean weaning weights were calculated by regressing the 3-day pre-weaning weights on a pen basis. (Weaning weight, lb = .5612Wean Age + 2.525; R^2=.97).

[e]Allottment weights were used for all growth and efficiency calculations.

[f]ADG, ADFI, and F:G are all calculated with alloted pen weight, 42-day pen weight, and pen space days post-weaning.

Table 5. Influence of Weaning Age on Finishing Performance (Trial 1)[a]

	Weaning Age					Probability (*P*<)	
Item	12	15	18	21	SE	Linear	Quadratic
Allotment weight, lb	37.3	44.9	49.9	57.0	0.51	0.0001	0.14
Allotment weight CV, %[b]	19.5	14.8	13.7	12.4	0.55	0.0001	0.0001
ADG, lb[c]	1.59	1.60	1.62	1.69	0.02	0.002	0.19
Mortality, %	4.38	5.21	4.79	3.13	0.94	0.32	0.19
Off-test weight, lb	229.1	240.6	247	258.7	1.79	0.0001	0.94
Off-test weight CV, %[b]	12.4	10.4	10.4	9.0	0.64	0.0001	0.51
Off-test weight / day of age, lb[d]	1.36	1.40	1.42	1.46	0.01	0.0001	0.89
Carcass weight[e], lb	197.4	196.7	194.5	201.5	2.76	0.21	0.04
Yield, %	75.9	75.5	75.6	75.8	0.23	0.81	0.17
10th rib fat depth, in[f]	0.70	0.69	0.70	0.66	0.01	0.0001	0.0001
Loin depth, in[f]	2.53	2.52	2.57	2.55	0.02	0.0001	0.001
Lean, %[f]	54.55	54.58	54.73	54.90	0.11	0.0001	0.0001

[a]1,920 pigs with 20 pigs (10 barrows, 10 gilts) per pen and 24 replications (pens) per treatment, or 96 pens on test.

[b]CV = Coefficient of Variation = (Standard Deviation of Weight / Mean Weight) * 100.

[c]ADG = (Off-test pen weight - allotment pen weight) / (# of pigs spaces * # of days on-test).

[d]Off-test weight per day of age = Off-test weight / pig age.

[e]Due to extended transfer to slaughter strategy, comparing carcass weights between treatments was not of interest.

[f]10th rib backfat, loin depth, and lean percentage measures are all adjusted to a common carcass weight utilizing carcass weight as a covariate.

Table 6. Influence of Weaning Age on Wean-to-Finish Performance (Trial 1)[a]

	Weaning Age					Probability (*P*<)	
Item	12	15	18	21	SE	Linear	Quadratic
Allotment weight, lb	7.5	9.4	10.8	12.7	0.11	0.0001	0.68
Off-test weight, lb	229	240.6	247.0	259	1.79	0.0001	0.94
ADG, lb[b]	1.28	1.36	1.40	1.51	0.02	0.0001	0.36
Mortality, %[c]	9.39	7.88	6.80	3.68	0.95	0.0001	0.39
Average pig gain/ days post-weaning, lb[d]	1.42	1.48	1.51	1.57	0.01	0.0001	0.96
Pounds sold / pig weaned, lb[e]	207.5	221.6	230.3	249.3	2.89	0.0001	0.35

[a]Linking nursery allotment weights and nursery mortality data within treatment and block to respective finisher pen to quantify wean to finish performance.

[b]ADG = (Finisher pen weight sold - (nursery allotment weight * # of wean pigs required to place finishing pen)) / (# of wean pigs required to place finishing pen * # of days post-weaning).

[c]Mortality = (1 - (Finishing pen inventory weighed off-test / # of wean pigs to place finishing pen))*100.

[d]Average pig gain / days post-weaning = (Off-test weight - allotment weight) / # of days post-weaning.

[e]Pounds sold / pig weaned = Off-test pen weight / # of wean pigs required to place finishing pen.

Table 7. Influence of Weaning Age and Nursery Feed Budget Complexity on Nursery Performance (Trial 2)[a]

	Less Complex Nursery Budget			More Complex Nursery Budget							
	Wean Age, d							Probability (*P*<)			
Item	15.5	18.5	21.5	15.5	18.5	21.5	SE	Linear Age	Quadratic Age	Feed Budget	Age*Feed Budget
Allotment weight, lb[b]	9.0	10.5	12.4	9.0	10.5	12.5	0.21	0.0001	0.001	0.99	0.63
Allotment weight CV, %[c]	19.5	20.0	19.2	19.8	20.4	19.5	0.51	0.49	0.04	0.30	0.99
Regressed weaning weight, lb[d]	10.7	12.4	14.1	10.7	12.4	14.1	.	.	.	.	.
ADG, lb[e,f]	0.96	1.06	1.17	0.95	1.07	1.15	0.03	0.0001	0.70	0.51	0.30
ADFI, lb[e,f]	1.26	1.39	1.56	1.24	1.40	1.53	0.03	0.0001	0.79	0.29	0.26
Feed/gain[e,f]	1.30	1.31	1.33	1.30	1.31	1.34	0.01	0.0001	0.64	0.77	0.90
Mortality, %	1.91	1.91	1.22	2.43	1.22	1.39	0.50	0.09	0.69	0.99	0.46
42-days post-weaning, lb	50.5	55.9	62.2	50.2	56.0	61.6	1.41	0.0001	0.57	0.37	0.60
42-days post-weaning CV, %[c]	15.4	14.2	13.1	14.0	13.1	13.0	0.75	0.003	0.58	0.06	0.47

[a]3,456 pigs with 36 pigs per pen (18 barrows, 18 gilts), and 16 replications (pens) per treatment, or a total of 96 pens on test.

[b]Allotment weights were taken on all pigs 3 days prior to weaning.

[c]CV = Coefficient of Variation =(Standard Deviation / Mean) * 100.

[d]Predicted treatment mean weaning weights were calculated by regressing the 3-day pre-weaning weights on a pen basis (Weaning weight, lb = .5714Wean Age + 1.734; R^2=.92).

[e]Allotment weights were used for all growth and efficiency calculations.

[f]ADG, ADFI, and F:G are all calculated with allotted pen weight, 42 day pen weight, and pen space days post-weaning.

Table 8. Influence of Weaning Age and Nursery Feed Budget Complexity on Finishing Performance[a]

	Less Complex Nursery Budget			More Complex Nursery Budget							
	Wean Age, d							Probability (*P*<)			
Item	15.5	18.5	21.5	15.5	18.5	21.5	SE	Linear Age	Quadratic Age	Feed Budget	Age*Feed Budget
Allotment weight, lb	50.6	56.1	62.3	50.4	56.1	61.8	1.41	0.0001	0.33	0.10	0.22
Allotment weight CV, %[b]	14.2	12.7	12.0	13.0	12.2	12.1	0.61	0.0001	0.23	0.08	0.23
ADG, lb[c]	1.73	1.75	1.78	1.72	1.74	1.77	0.03	0.003	0.58	0.39	0.98
Mortality, %	1.00	2.00	1.00	2.61	1.80	1.40	0.62	0.30	0.42	0.20	0.29
Off-test weight, lb	245.9	255.4	263.2	248	254.1	262.4	2.95	0.0001	0.91	0.99	0.30
Off-test weight CV, %[b]	10.2	9.8	9.2	9.7	8.7	9.8	0.43	0.34	0.17	0.33	0.14
Off-test weight / day of age, lb[d]	1.46	1.49	1.51	1.47	1.48	1.50	0.01	0.0001	0.97	0.98	0.34
Carcass weight[e], lb	180.3	188.9	194.7	184.6	188.1	195.5	2.38	0.0001	0.73	0.08	0.03
Yield, %	74.72	74.83	75.21	75.95	75.19	75.52	0.38	0.89	0.10	0.002	0.10
10th rib fat depth, in[f]	0.66	0.64	0.66	0.66	0.67	0.67	0.02	0.13	0.001	0.0001	0.0001
Loin depth, in[f]	2.54	2.54	2.51	2.52	2.52	2.51	0.02	0.0001	0.0001	0.002	0.03
Lean, %[f]	54.86	54.95	54.74	54.81	54.75	54.66	0.10	0.0002	0.0001	0.0001	0.0004

[a]3,000 pigs with 25 pigs (12 barrows, 13 gilts) per pen and 20 replications (pens) per treatment, or a total of 120 pens on test.

[b]CV = Coefficient of Variation =(Standard Deviation / Mean) * 100.

[c]ADG = (Off-test pen weight - allotment pen weight) / (# of pigs spaces * # of days on-test).

[d]Off-test weight per day of age = Off-test weight / pig age.

[e]Due to extended tranfer to slaughter strategy, comparing carcass weights between treatments was not of interest.

[f]10th rib backfat, loin depth, and lean percentage measures are all adjusted to a common carcass weight.

Table 9. Influence of Weaning Age and Nursery Feed Budget Complexity on Wean-to-Finish Performance (Trial 2)[a]

	Less Complex Nursery Budget			More Complex Nursery Budget							
	Wean Age, d							Probability (*P*<)			
Item	15.5	18.5	21.5	15.5	18.5	21.5	SE	Linear Age	Quadratic Age	Feed Budget	Age*Feed Budget
Allotment weight, lb	9.0	10.5	12.4	9.0	10.5	12.5	0.21	0.0001	0.0001	1.00	0.52
Off-test weight, lb	245.9	255.4	263.2	248	254.1	262.4	2.95	0.0001	0.91	0.99	0.30
ADG, lb[b]	1.50	1.53	1.60	1.48	1.54	1.58	0.02	0.0001	0.78	0.37	0.53
Mortality, %[c]	2.89	3.86	2.20	4.95	2.99	2.77	0.69	0.03	0.69	0.27	0.08
Average pig gain/ days post-weaning, lb[d]	1.54	1.60	1.64	1.56	1.59	1.63	0.01	0.0001	0.76	0.85	0.27
Pounds sold / pig weaned, lb[e]	238.8	245.6	257.3	235.6	246.3	255.1	2.72	0.0001	0.70	0.35	0.53

[a]Linking nursery allotment weights and nursery mortality data within treatment and block to respective finisher pen to quantify wean to finish performance.

[b]ADG = ((Finisher pen weight sold - (nursery allotment weight * # of wean pigs required to place finishing pen)) / (# of wean pigs required to place finishing pen * # of days post-weaning).

[c]Mortality = (1 - (Finishing pen inventory weighed off-test / # of wean pigs required to place finishing pen))*100.

[d]Average pig gain / days post-weaning = (Off-test weight - allotment weight) / # of days post-weaning.

[e]Pounds sold / pig weaned = Off-test pen weight / # of wean pigs required to place finishing pen.

EFFECTS OF WEANING AGE ON COSTS AND REVENUE IN THREE-SITE PRODUCTION

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

Summary

Two trials were completed to determine the effects of weaning age on growing pig costs and revenue within a three-site production system. Cost and revenue were measured by applying operationally dependant information to trial data. Economic effects were determined assuming either limited or non-limited finishing capacity. In both trials and finishing capacity scenarios (limited or non-limited), income over costs and cost per hundredweight improved linearly as weaning age increased. In these studies, increasing weaning age up to 21.5 days resulted in linear increases in weaned pig value within a three-site production system. Assessing a common value to acceptable quality wean pigs regardless of weaning age or weight, may lead to false conclusions concerning a breeding herd's true financial performance.

(Key Words: Weaning age, Costs, Revenue, Economics.)

Introduction

Weaned pigs are commonly assigned an equal value within or between production operations, regardless of weaning age or weight. Although operations typically have individual pig quality criterion or discount programs, weaned pigs meeting the minimum standards are valued equally. Multi-site production has led sow farms to be independent financial entities. Depending on the scope of a production operation, the sow farm is either a cost or a profit center. Regardless of being a cost or profit center, sow farms typically value pigs or calculate cost information on a per weaned pig basis. Weaned pig production is the only segment of the production chain that does not have weight as the common denominator for cost information or in the matrix for revenue generation. These accepted standards for measuring cost and generating revenue operate under the premise that all wean pigs meeting a minimum standard are of equal value. These accepted means of accounting often encourage a reduction in weaning age. Sow farms can typically increase pigs weaned per week by increasing targets for litters farrowed. This weekly increase in litters subsequently causes weaning age to be reduced due to a fixed amount of lactation crates. Therefore, the objective of this research was to determine the effects of weaning age on growing pig costs and revenue. Two trials were completed to determine the effects of weaning age on pig performance within a three-site production system. The growth performance data from these trials was used to model economic implications of altering weaning age in applied three-site production.

[1]Food Animal Health and Management Center.

Procedures

Trial design, procedures and growth performance results are outlined in a preceding paper in this report. The paper is titled, "Effects of Weaning Age on Pig Performance in Three-Site Production." Cost and revenue information were applied to the growth performance data from these two prospective studies. The economic modeling is designed to allow for operationally specific cost and revenue information to be applied to trial data. The inputted cost and revenue information is being applied to trial data on a per finishing pen basis. (Trial 1 = 96 pens, 20 pigs per pen; Trial 2 = 120 pens, 25 pigs per pen). A standardized weaned pig cost and assumptions of an annualized $30 and $38 per pig space cost for nursery and finishing space were used (Table 1). Actual nursery-feed costs were used; however, since pen feed consumption was not measured in finishing, a common finishing feed cost per pound of gain was applied to all finishing weight gain. The miscellaneous per hundredweight cost is intended to allow for additional operationally specific costs, such as transport, supplies, vet-med, genetic royalties, and management fees. Additional assumptions were made for late-term finishing ADG, daily mortality rate, and a desired common market weight.

Cost and revenue information were calculated for both limited and non-limited finishing space scenarios. The limited finishing space analysis assumes restricted finishing capacity, and all age groups are sold after a fixed number of days post-weaning or in these analyses, off-test weigh day. Non-limiting finishing capacity allows all age groups to be grown to an equal average market weight. The information is presented on a per pig weaned and per head sold basis. Expressing performance and financial information on a per pig weaned basis enables all wean to finish throughput, cost, and revenue information to be brought back to a common denominator. This enables treatment differences in throughput and financial performance to be quantified in a manner that directly relates to value of the weaned pig and removes mortality-induced bias in traditional wean-to-finish close-out data analysis. In Trial 2, nursery feed budget complexity had no effect ($P>0.27$) on wean to finish growth performance. Therefore, only the main effects of weaning age are presented. Cost and revenue data were analyzed for linear and quadratic effects using finishing pen as the experimental unit in these analyses.

Results and Discussion

In Trial 1, feeder pig cost increased (quadratic, $P<0.01$, Table 2) as weaning age increased due to a linear increase in nursery feed intake with increasing weaning age. Only the 21-day weaned pigs had increased ($P<0.05$) feeder pig costs, as compared to other weaning age treatments. Quantitatively speaking, feeder pig costs were moderately flat as weaning age increased from 12 to 21 days due to the magnitude of mortality improvement observed with increasing weaning age. In both the limited and non-limited finishing capacity scenarios, revenue and income over costs per pig weaned increased (linear, $P<0.0001$, Tables 2 and 3.) and cost per hundred weight decreased (linear, $P<0.0001$) as weaning age increased from 12 to 21 days. Cost per head sold decreased (linear, $P<0.0001$) with weaning age, when all age groups can be marketed at an equal pig weight.

In Trial 2, feeder pig costs increased (linear, $P<0.0001$) as weaning age increased due to linearly improved nursery feed intake observed with increasing weaning age. In both the limited and non-limited finishing capacity scenarios, revenue and income over costs per pig weaned increased (linear, $P<0.0001$) and cost per hundred weight decreased (linear, $P<.0001$) as weaning age increased from 15.5 to 21.5 days. Cost per head sold decreased (linear, $P<0.0001$) with weaning age, when all age groups can be marketed at a equal pig weight.

In both studies, increasing weaning age increased (linear, $P<0.0001$) pounds sold per pig weaned due to improvements in growth and livability. Increasing pounds sold per pig weaned improved margins and production cost per hundredweight. These studies indicate that weaning age substantially affects the value of wean pigs within a given three-site production system.

Table 1. Assumptions Used to Model the Economic Effects of Weaning Age[a]

Input variable	Trial 1	Trial 2
Weaned pig cost, $	25	25
Nursery space ($ / space / day)	0.082	0.082
Nursery idle days / turn	5	5
SEW diet, $ / ton	0	450
Phase I diet, $ / ton	335	408
Phase II diet, $ / ton	237	263
Phase III diet, $/ton	172	194
Finisher space, $ / space / day	0.1041	0.1041
Miscellaneous costs (transport, meds & supplies, management fees, royalties, etc.), $ / CWT	5.00	5.00
Finisher idle days	7	7
Common finishing feed cost, $ / lb of gain	0.150	0.150
Net realized live price, $ / CWT	42.50	42.50
Late finishing (> 245 lbs) ADG, lb[b]	1.60	1.60
Late term finishing daily mortality[b], % per day	0.02%	0.02%
Non-limited grow-finish space, average market weight, lb[b]	265	265

[a]Operationally dependant cost and revenue assumptions were applied on two trials evaluating the effects of weaning age on growing pig costs and revenue.

[b]Assumptions of late-term finishing (>245 lb) ADG and daily mortality rate (Consistent with trial data, as trial groups were sold in June - August.), as well as desired average market weight are needed to model effects of weaning age in production operations non-limited in grow-finish capacity, enabling all treatments to be grown to a common average pig weight.

Table 2. Influence of Weaning Age on Cost and Revenue with Limited Finishing Space[a,b]

	Trial 1							Trial 2					
	Weaning Age					Probability (*P*<)		Weaning Age				Probability (*P*<)	
Item	12	15	18	21	SE	Linear	Quadratic	15.5	18.5	21.5	SE	Linear	Quadratic
Allottment weight, lb[c]	7.5	9.4	10.8	12.7	0.11	0.0001	0.68	8.98	10.54	12.44	0.21	0.0001	0.001
Off-test weight, lb[d]	229.0	240.6	247.0	258.7	1.79	0.0001	0.94	247.0	254.8	262.8	2.83	0.0001	0.91
Pounds sold / pig weaned, lb[e]	207.5	221.6	230.3	249.3	2.89	0.0001	0.35	237.2	246.1	256.2	2.36	0.0001	0.56
Feeder pig cost, $[f]	34.66	34.47	34.63	34.80	0.12	0.05	0.008	35.58	35.91	36.29	0.14	0.0001	0.65
Cost/CWT sold, $	39.10	37.76	36.96	35.54	0.21	0.0001	0.84	36.65	35.95	35.15	0.15	0.0001	0.66
Cost per head sold, $	89.52	90.82	91.27	91.94	0.56	0.003	0.57	90.5	91.55	92.34	0.72	0.0001	0.69
Revenue per pig weaned	88.17	94.19	97.86	105.94	1.23	0.0001	0.35	100.80	104.57	108.89	1.00	0.0001	0.70
Costs per pig weaned	80.98	83.54	84.98	88.52	0.65	0.0001	0.34	86.88	88.38	90.02	0.50	0.0001	0.85
Income over variable costs per pig weaned	7.19	10.65	12.88	17.42	0.60	0.0001	0.35	13.92	16.19	18.86	0.52	0.0001	0.56

[a]Wean-to-finish cost and revenue data from two trials (Trial 1 = 96 finishing pens with 20 pigs/pen, and Trial 2 = 120 finishing pens with 25 pigs/pen) evaluating effects of weaning age in production operations with limited finishing space.

[b]Limited finishing space is defined as having a fixed number of finishing spaces available. Therefore, analysis assumes all age groups have to be sold on a fixed number of days post-weaning, or off-test weight day in this analysis.

[c]Allottment weight is the average pig weight attained 3-days prior to weaning.

[d]Off-test weight is the average pig weight at 156 and 153 days post-weaning for Trials 1 and 2, respectively.

[e]Pounds sold/pig weaned = Off-test pen weight/number of weaned pigs required to place finishing pen.

[f]Feeder pig cost = Weaned pig cost + all nursery costs.

Table 3. Influence of Weaning Age on Cost and Revenue with Non-Limiting Finishing Space[a,b]

	Trial 1							Trial 2					
	Weaning Age					Probability (*P*<)		Weaning Age				Probability (*P*<)	
Item	12	15	18	21	SE	Linear	Quadratic	15.5	18.5	21.5	SE	Linear	Quadratic
Allottment weight, lb[c]	7.5	9.4	10.8	12.7	0.11	0.0001	0.68	8.98	10.54	12.44	0.21	0.0001	0.001
Sale weight, lb	265	265	265	265	.	.	.	265	265	265	.	.	.
Pounds sold / pig weaned, lb[d]	240.1	244.1	246.9	255.3	2.52	0.0001	0.39	254.59	255.90	258.41	1.37	0.0284	0.67
Wean-finish days to a common market weight, d	134	129	125	118	1.17	0.0001	0.94	123	118	113	1.33	0.0001	0.91
Cost per CWT sold, $	37.41	36.75	36.27	35.33	0.20	0.0001	0.43	35.96	35.58	35.07	0.08	0.0001	0.50
Cost / head sold, $	99.14	97.39	96.15	93.63	0.46	0.0001	0.43	95.30	94.29	92.93	0.21	0.0001	0.50
Revenue per pig weaned, $	102.03	103.73	104.95	108.52	1.07	0.0001	0.39	108.20	108.76	109.83	0.59	0.0284	0.67
Costs per pig weaned, $	89.72	89.57	89.46	90.14	0.54	0.63	0.44	91.51	91.01	90.61	0.42	0.0168	0.88
Income over costs per pig weaned, $	12.31	14.16	15.49	18.38	0.56	0.0001	0.35	16.69	17.75	19.22	0.26	0.0001	0.53

[a]Wean-to-finish cost and revenue data from two trials (Trial 1 = 96 finishing pens with 20 pigs/pen; Trial 2 = 120 finishing pens with 25 pigs/pen) evaluating effects of weaning age in production operations with non-limiting finishing space.

[b]Non-limiting finishing space is defined as having an unlimited number of finishing spaces available. Therefore, all age groups can be grown to an equal weight.

[c]Allottment weight is the average pig weight attained 3-days prior to weaning.

[d]Pounds sold/pig weaned = Off-test pen weight/number of wean pigs required to place finishing pen.

LINEAR EFFECTS OF INCREASING WEANING AGE IN THREE-SITE PRODUCTION

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

Summary

Two studies were conducted to measure the biologic and economic effects of weaning age in a three-site production system. Wean-to-finish growth and financial performance improved linearly as weaning age increased up to 21.5 days. Data from these trials were modeled to determine the linear rates of improvement observed as weaning age increased from 15 to 21.5 days. Each day increase in weaning age increased initial weight (taken prior to weaning) 0.565 ± 0.009 lb and weight sold to slaughter 3.71 ± 0.32 lb per pig weaned. In the financial analysis, income over cost increased $0.94 ± 0.07 per wean age d in the limited finishing space scenario and $0.53 ± 0.06 per wean age d in the non-limited space scenario. Therefore, if finishing space is limited, increasing weaning age from 16 to 19 d is predicted to improve income over cost by $2.82 per pig. These rates of improvement can be used to model the effects of weaning age on wean-to-finish throughput and financial performance in a three-site production system.

(Key Words: Weaning age, Throughput, Economics.)

Introduction

Pigs are commonly weaned in the United States at 15 to 21 days of age. Managers or farm owners typically regard pigs in this age range as being of equal in value, as long as minimum quality standards are met. Two studies in this report evaluated the effects of weaning age on growth and financial performance in a three-site production system. (i.e., Effects of Weaning Age on Pig Performance in Three-Site Production, and Effects of Weaning Age on Cost and Revenue in Three-Site Production). These studies observed linear improvements in wean-to-finish growth and economic performance as weaning age was increased from 12 to 21, and 15.5 to 21.5 days in Trials 1 and 2, respectively. The linear responses observed enable trial data to be readily modeled and applied to a variety of decision-making activities. The objective of this study is to model the linear rates of improvement observed as weaning age increased from 15 to 21.5 days.

Procedures

Two trials were completed to evaluate the effects of weaning age on biologic and financial response criteria. Further details of the trial design, procedures, and economic assumptions are described in the associated articles in this report. The range of weaning ages modeled included 15, 18, and 21 d from Trial 1 and 15.5, 18.5, and 21.5 d from Trial 2. Data from 12-d-old weaned pigs were collected in Trial 1. However, these data were not used to evaluate a similar range of ages in each trial. Data were analyzed in a single sta-

[1]Food Animal Health and Management Center.

tistical model to define the linear incremental rates of improvement observed as weaning age increased from 15 to 21.5 days. The analysis includes wean-to-finish growth and financial performance from 192 finishing pens (PIC C280 × C22, n = 4,518 weaned pigs). Results are presented as the rate of change per day increase in weaning age. These rates of change per day of weaning age also were translated to a per pound of weaning weight basis. However, these per pound of weaning weight improvements need to be interpreted with the understanding that the incremental pound increase in weaning weight is due to increasing lactation length. Due to the confounding nature of weaning age and weight in these trials, it is not possible to separate out the effects of weaning age and weight independently. Analyses were completed to quantify the effect of weaning age in operations either limited or non-limited in finishing capacity. Limited finishing capacity describes the effects of weaning age in terms of operations with a fixed or limited number of finishing spaces. Therefore, finishing barns need to be sold out on a common number of days post-weaning. Non-limited space describes effects of weaning age for operations with a non-limited number of finishing spaces. Thus, all age groups can be sold at a common average pig weight, regardless of growth rate.

Results and Discussion

The modeled rates of change per day increase in weaning age, as well as the translations of these values back to a per pound of weaning weight basis, are outlined in Table 1. The primary difference in the limited versus non-limited finishing capacity is that the value of growth rate is more fully recognized when finishing spaces are limited. In non-limiting finishing space scenarios, all pigs can be grown to common pig weight for slaughter. The linear improvements observed with increasing weaning age illustrate the magnitude of the measured response to increasing weaning age from 15 to 21.5 days in these studies. Understanding the effect of weaning age on weaned pig value demonstrates the need to identify lactation crate utilization inefficiencies or facility restrictions that may be constraining whole-system throughput. There was a $ 3.18 (unlimited G-F space) to $ 5.64 (limited G-F space) per weaned pig difference in realized margin observed as weaning age increased from 15 to 21.5 days. The data indicate that simply assessing a common value to wean pigs, regardless of age or weight, may lead to incorrect conclusions concerning sow herd productivity.

Understanding operationally dependent rates of biologic and economic improvement (characterized by the slopes of the regression lines in this study) due to increasing weaning age facilitates a series of strategic decision-making activities. Quantifying these slopes allows managers to understand cost-benefit relationships of altering weaning age within a production system. Improving lactation crate utilization, altering weekly farrowing targets, decreasing week-to-week variability in the number of sows farrowed, or increasing lactation capacity are the primary means of increasing and maintaining consistency in weaning age.

Table 1. Linear Rates of Change as Wean Age is Increased from 15 to 21.5 days[a]

Item	Rates of Linear Change per Day in Wean Age		Translating Linear Effects of Weaning Age to a Change per lb of Weaning Weight
	Change per day	SE	Change per lb at Weaning
Allotment weight, lb[b]	0.565	0.009	1.00
42-day post-weaning, lb	1.96	0.047	3.47
Growth & Economic Performance, Assuming Limited Grow-Finish Capacity[c]			
Off-test weight, lb	2.78	0.18	4.92
WF ADG, lb[d]	0.02	0.002	0.035
WF Mortality, %[e]	-0.42	0.11	-0.74
Pounds sold / pig weaned, lb[f]	3.71	0.32	6.57
Cost / CWT, $	-0.30	0.02	-0.53
Income over costs / pig weaned, $	0.94	0.07	1.66
Growth & Economic Performance, Assuming Non-Limited Grow-Finish Capacity[g]			
Post-weaning days to common market weight	-1.74	0.11	-3.08
Pounds sold / pig weaned, lb[f]	1.11	0.28	1.96
Cost / CWT at common market weight, $	-0.18	0.02	-0.32
Income over costs / pig weaned, $	0.53	0.06	0.93

[a]Modeling the rate of linear change (slopes) in wean-to-finish throughput and financial performance observed as wean age increased from 15 - 21.5 days (Trial 1 = 72 finishing pens with 20 pigs/pen, and Trial 2 = 120 finishing pens with 25 pigs/pen.).

[b]Allotment weights were taken on all pigs 3 days prior to weaning.

[c]Limited finishing space is defined as having a fixed number of finishing spaces available. Therefore, analysis assumes all age groups have to be sold on a fixed number of days post-weaning, or off-test weigh day in this analysis.

[d]WF ADG = ((Finisher pen weight sold - (nursery allotment weight * # of wean pigs required to place finishing pen)) / (# of wean pigs required to place finishing pen * # of days post-weaning)

[e]WFMortality = (1 - (Finishing pen inventory weighed off-test / # of wean pigs required to place finishing pen))*100.

[f]Pounds sold / pig weaned = Off-test pen weight / # of wean pigs required to place finishing pen.

[g]Non-limiting finishing space is defined as having an unlimited number of finishing spaces available. Therefore, all age groups can be grown to an equal weight.

EFFECT OF DEXAMETHASONE INJECTION AT BIRTH ON GROWTH PERFORMANCE OF PIGS FROM BIRTH TO WEANING

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

Summary

A total of 82 litters were used in a 21-day study to evaluate the effect of injecting litters of pigs with dexamethasone within 24 hours of birth on growth rate from birth to weaning. Experimental treatments consisted of an injection of 1 mg dexamethasone solution (2 mg/mL, Prolab Ltd, St. Joseph, MO) to all pigs within a litter, while pigs in control litters did not receive a dexamethasone injection. There was no difference in growth rate from birth to weaning between pigs injected with dexamethasone and control pigs. Number of pigs weaned per litter and preweaning mortality were not different. In this study no benefit was observed in growth rate from birth to weaning from injecting whole litters of pigs with 1 mg/pig of dexamethasone within 24 hours of birth.

(Key Words: Dexamethasone, Pigs, Growth Rate.)

Introduction

Researchers from the University of Missouri have found that the early neonatal period may be an opportune time to alter physiological factors that influence growth. In swine, there is an increase in maternal circulating cortisol, as well as a final fetal cortisol surge during labor. This elevation in fetal cortisol may trigger the adjustments to the endocrine system necessary for maintaining life and optimal growth in the extra uterine environment. The prepartum surges in glucocorticoids in swine have been shown to be an important mediator of intestinal maturation and function. They also suggested that the glucocorticoid role in intestinal maturation and function is most likely limited to the immediate perinatal period.

In previous research conducted by the USDA's Agricultural Research Service and the University of Missouri, pigs were injected intramuscularly with either sterile saline (Control; n=10 males and 10 females) or a dexamethasone solution (dexamethasone, Phoenix Pharmaceuticals, Inc., St. Joseph, MO, 0.5 mg/lb body weight; n=10 males and 10 females) within one hour of birth. Pigs injected with dexamethasone grew 12% (0.63 vs 0.56 lb/day) faster during the 18-day lactation period. Pig weights at weaning averaged 15.5 lb for the dexamethasone and 14.1 lb for the controls. Therefore, the objective of the present study was to determine if the benefits in growth performance obtained in the USDA study could be replicated in a more commercial production environment. This environment includes injecting whole litters of pigs at the time of processing within 24 hours of birth. Also, since pigs are rarely weighed at birth a more practical dosing scheme of 1 mg/pig was examined.

[1]Food Animal Health and Management Center.

Procedures

This study was conducted in the KSU Swine Teaching and Research Center's farrowing facilities. A total of 82 litters were used in the study, with approximately 41 litters per treatment. The sows used in the study were PIC Line 42 and were farrowed in three groups of approximately 30 sows per group. All sows were weighed entering the farrowing house and again at weaning. Sows were randomized to treatments based on parity and weight entering the farrowing house on day 110 of gestation. Sows were provided ad libitum access to feed and water and feed intake was recorded. All sows were fed a standard lactation diet formulated to contain 0.90% lysine, 0.90% calcium, and 0.80% P (Table 1). No sows were treated with dexamethasone during the trial.

Table 1. Lactation Diet[a]

Ingredient	%
Corn	68.55
Soybean meal, 46.5%	24.20
Soybean oil	3.00
Monocalcium phosphate, 21% P	2.15
Limestone	0.95
Salt	0.50
Sow vitamin premix	0.25
Vitamin premix	0.25
Trace mineral premix	0.15
Total	100.00

[a]Diets were formulated to contain 0.90% lysine, 0.90% calcium and 0.80% P.

There were two experimental treatments. In treatment one, all pigs within a litter were injected with 1 mg/pig of dexamethasone when the litter was processed, which was within the first 24 hours after birth. The dexamethasone used was a 2 mg/mL solution (Prolab Ltd, St. Joseph, MO). In the second treatment, pigs were processed according to standard practice and did not receive dexamethasone injection. The standard pig processing practice was that pigs had their needle teeth clipped, tails docked, ears notched and were injected with 1 ml/pig iron. All fostering that took place did so after processing and within the first 24 hours after birth. Pigs were only fostered across litters within treatment. At fostering, gilts and sows were standardized with 10 pigs. Pigs were weighed individually at birth and again at weaning. Any pigs removed from the trial were recorded along with their date of removal and weight. Data were analyzed using the mixed procedure of SAS.

Results and Discussion

As expected, pig birth weight was similar for the dexamethasone and control treatments (Table 2). From birth to weaning, neither ADG nor weaning weight differed between the two treatments. The number of pigs on day 1 of the trial, at weaning, and removed from the trial was also similar for the dexamethasone and control treatments. Preweaning mortality averaged 8.3% for the dexamethasone and 8.5% for the control treatments. Sow weight entering the farrowing house, at weaning, and weight loss in the farrowing house, lactation length and backfat at farrowing did not differ between treatments.

In conclusion, we observed no benefit in growth rate from birth to weaning for pigs injected with 1 mg/pig dexamethasone compared with the control pigs. The results do not agree with those of the recent USDA study where half the litter of pigs was injected with 0.5 mg/lb body weight within one hour of birth. In that study pigs injected with dexamethasone grew 12% (0.63 vs 0.56 lb/day) faster during the 18-day lactation period. Pig weights at weaning averaged 15.5 lb for the dexamethasone injected pigs and 14.1 lb for

the control pigs. There were a number of differences between the two studies. First, we injected whole litters of pigs with dexamethasone whereas in the USDA study, they injected half the litter with dexamethasone and the other half of the litter with sterile saline solution, which served as the control. Secondly, in the USDA study they injected pigs with 0.5 mg/lb of body weight of dexamethasone, whereas in our study we injected piglets with approximately 0.3 mg/lb of body weight. Thirdly, the source of dexamethasone used in the USDA study was supplied by Phoenix Pharmaceuticals, Inc., St. Joseph, MO, whereas the dexamethasone solution used in our study was supplied by Prolab Ltd, St. Joseph, MO. Finally, in the USDA study, they injected pigs within the first hour of birth whereas in our study we injected pigs within the first 24 hours of birth. In our study we attempted to simulate the growth performance obtained in the USDA study, but we modified some techniques in order to make our study more commercially applicable.

Other research by University of Missouri demonstrated that a 0.9 mg/lb body weight of dexamethasone given within 24 hours of birth significantly improved pre- and postweaning performance of barrows with no beneficial effect on gilts. Similar to our experiment, two other experiments carried out by the University of Missouri in commercial production conditions failed to detect improvements in preweaning performance. We failed to obtain a benefit in growth rate from birth to weaning by injecting litters of pigs with dexamethasone within the first 24 hours of birth. Therefore, it appears that the benefits of injecting pigs with dexamethasone within the first hour of birth are inconsistent, with no benefit observed in majority of the commercial trials.

Table 2. Effect of Dexamethazone Injection at Birth on Performance in the Farrowing House

	Treatment			
Item	Dexamethazone[1]	Control[2]	SEM	*P*<
Number of sows	42	40		
Parity	2.1	2.2	0.17	0.76
Lactation length, days	20.8	21.0	0.71	0.60
Sow weight, lb				
Entry farrowing	522	543	9.45	0.26
Weaning	501	509	9.03	0.55
Loss	21	34	5.88	0.28
Backfat at farrowing, mm	14.1	13.9	0.74	0.91
ADFI, lb lactation	12.77	13.19	0.40	0.46
Number of pigs				
Day 1	10.04	10.02	0.40	0.95
Weaning	9.16	9.14	0.31	0.97
Died	0.93	0.85	0.17	0.75
Preweaning mortality, %	8.70	8.28	1.56	0.85
Piglet weight, lb				
Birth	3.31	3.33	0.15	0.93
Weaning	14.69	14.72	0.48	0.95
Piglet ADG, lb	0.52	0.51	0.12	0.67

[1]All pigs within a litter were injected with 1 mg of Dexamethasone within 24 hours of birth.
[2]Pigs were not injected within Dexamethasone.

INFLUENCE OF DIETARY CARNITINE AND/OR CHROMIUM ON BLOOD PARAMETERS OF GESTATING SOWS[1]

J. C. Woodworth, M. D. Tokach, J. L. Nelssen, R. D. Goodband, S. S. Dritz[2], S. I. Koo, J. E. Minton, and K. Q. Owen[3]

Summary

Gestating sows (n=44; parity=2.0; BW=458 lb) were used to determine the effects of dietary Carnitine and/or chromium picolinate on daily blood parameter profiles. Diets were formulated as a 2 × 2 factorial with carnitine (0 or 50 ppm) and chromium (0 or 200 ppb) and were fed from breeding, through gestation, lactation, and 30 d into the next gestation at which time blood was collected. Sows were fed one meal per day during gestation (2.1 kg) and ad libitum during lactation. Sows were fitted with indwelling venous catheters and blood (plasma) was collected at feeding, once every 15 min for the first 3 h after feeding, and at 6, 9, 15, 20, and 24 h after feeding. Chromium picolinate elicited its greatest effect immediately after feeding (0-3 h) by decreasing (P<0.05) insulin and c-peptide, whereas Carnitine decreased (P<0.05) NEFA and urea N (PUN) in the fasting state (6-24 h post-feeding). Sows fed both carnitine and chromium exhibited intermediate responses. Post-feeding glucose peak was lower (P<0.05) for diets with carnitine and/or chromium versus the control and mean glucose concentration was lower (P<0.01) for sows fed diets with chromium. Mean insulin and c-peptide concentration was lowest (P<0.01) for sows fed the diet with chromium and highest for sows fed the control, with sows fed diets with carnitine or carnitine and chromium having intermediate responses (Carnitine × chromium, P<0.01). Mean NEFA was lower (P<0.01) for sows fed diets with carnitine. Mean NEFA and glycerol were higher (P<0.03) for sows fed the diets with chromium. Sows fed the diet with only carnitine had the lowest PUN, but no differences were observed between the other three diets (carnitine × chromium, P<0.01). Dietary carnitine increased (P<0.05) the circulating leptin concentration, specifically in the fasting portion of the day. Both carnitine and chromium were observed to influence (P<0.05) the concentrations of some amino acids. No differences were observed for IGF-1, IGFBP-3, glucagon, or triglyceride (P>0.10); however, sows fed carnitine had numerically higher (P=0.11) IGF-1 and IGFBP-3 (P=0.06). In summary, the changes in metabolites and metabolic hormones indicate that both carnitine and chromium influence energy metabolism of gestating sows; however, their effects on blood parameters are different. Thus, the improvement in energy status from adding both carnitine and chromium may have an additive effect on reproductive performance of sows.

(Key Words: Sows, Carnitine, Chromium, Blood Parameters.)

[1]Appreciation is expresed to Lonza, Inc., Fair Lawn, NJ for financial support of this experiment.
[2]Food Animal Health and Management Center.
[3]Lonza, Inc., Fair Lawn, NJ.

Introduction

Carnitine is a vitamin-like compound that is essential in the transport of long- and medium-chain fatty acids across the mitochondrial membrane for beta-oxidation. Carnitine also enhances pyruvate carboxylase activity and decreases the activity of branch-chain ketoacid dehydrogenase, resulting in less muscle degradation. Research has shown that dietary carnitine fed to sows will increase the number of pigs born live per litter, improve farrowing rate, and increase the muscle development of offspring. The past improvements in sow and litter performance have been attributed to improved nutrient utilization by the sow.

Chromium is a trace mineral that is essential for activating specific enzymes and stabilizing proteins and nucleic acid. Its primary role in metabolism, however, is to increase the effectiveness of insulin through its presence on a molecule known as glucose tolerance factor. Dietary chromium has been shown to improve insulin sensitivity, and consequently glucose uptake, in swine. Chromium has also been shown to increase farrowing rate and number of pigs born live per litter.

Carnitine and chromium are both essential for proper energy metabolism in swine. Researchers at Kansas State University observed that when carnitine and chromium are added to diets of gestating sows, farrowing rate improved with the greatest improvement observed from the diet containing both carnitine and chromium. However, few trials have evaluated the effects of these two dietary additives on blood parameters in the gestating sow that is fed one meal per day, similar to commercial production. The objective of this experiment was to determine the influence of dietary carnitine and(or) chromium on the daily blood parameter profiles of the limit-fed gestating sow.

Procedures

The Kansas State University Animal Care and Use Committee approved all procedures used in this experiment. Sows (n=44; parity=2.0; BW=458 lb; PIC C-22) were randomly allotted to one of four dietary treatments based on parity and weight at initial breeding. At allotment, each sow was eartagged with one of four different colors corresponding to the treatment she received so that identification throughout the experiment could easily be maintained. Sows were housed in individual gestation crates in the KSU gestation barn from breeding until approximately d 30 of gestation, at which time they were moved to outside pens and fed in individual feeding stalls. At approximately d 110 of gestation, sows were placed in the farrowing house and remained there until weaning. At weaning sows were returned to the gestation barn and placed in the individual crates and remained there until the end of the experiment.

Dietary treatments (Table 1) were corn-soybean meal-based and were formulated to meet or exceed NRC nutrient requirement estimates. Sows were fed 4.5 lb of gestation diet from breeding until d 100 of gestation, then 6.5 lb until they farrowed. Lactation diet was fed ad libitum from farrowing until weaning. Treatments were arranged in a 2 × 2 factorial design with main effects of carnitine (0 or 50 ppm) and chromium (0 or 200 ppb). Carnitine and(or) chromium replaced cornstarch in the basal diet to form the experimental treatments. Both the carnitine (Carniking) and chromium (chromium picolinate) were obtained from Lonza Inc., Fair Lawn, NJ. Sows were fed the experimental treatments starting at the initial breeding, through gestation, the following lactation and wean-to-breeding interval, and approximately 28-d into the subsequent gestation at which time blood was collected.

Table 1. Diet Composition (As-Fed Basis)

Item, %	Gestation	Lactation
Corn	79.47	64.60
Soybean meal, 46.5%	14.50	27.60
Monocalcium phosphate	2.28	2.05
Limestone	1.10	1.10
Soy oil	1.00	3.00
Cornstarch[a]	0.50	0.50
Salt	0.50	0.50
Vitamin premix	0.25	0.25
Sow add pack	0.25	0.25
Trace mineral premix	0.15	0.15
Calculated analysis, %		
Lysine	.65	1.00
Ca	.90	.90
P	.80	.80

[a]Cornstarch was replaced with 50 ppm carnitine and(or) 200 ppb chromium to form the experimental treatments.

Approximately 5-d prior to blood collection, the sows were removed from the gestation barn and transported to a nearby surgery room. Sows were surgically fitted with indwelling cephalic vein catheters to minimize stress during blood collection. The catheters were exteriorized approximately 2 inches anterior to the point of the left shoulder and the loose end of the catheter stored in a pouch that was secured between the shoulder blades of the sow. After recovery from surgery, the sows were returned to the gestation barn and allowed four days of acclimation to the catheter prior to blood collection. Catheters were removed after blood collection on d 28 after breeding.

Blood (10 ml) from each sow was collected in tubes containing EDTA at approximately d 28 after the second breeding, or approximately 167 d after dietary treatments began. Blood was collected from each sow at feeding, once every 15 min for the first 3 h after feeding, and at 6, 9, 15, 20, and 24 h after feeding for a total of 18 collections from each sow. Samples collected from 0 to 3 h after feeding would represent the fed-state, and samples collected 6 h or later after feeding would represent the fasted state. After collection, blood samples were centrifuged and 12 separate aliquots of plasma were frozen (-40°C) for each sow at each bleeding time. Samples were then analyzed to determine insulin, connecting peptide of insulin, glucagon, glucose, IGF-1, non-esterfied fatty acids, urea nitrogen, leptin, glycerol, triglyceride, IGFBP-3, and amino acids.

Data were analyzed as a randomized complete block design with repeated measures over time with sow as the experimental unit. The experimental model included all two-way interactions and main effects of carnitine and chromium. Covariates of weight and parity at bleeding were used. Least square means was used to compare treatment means within time. Area under the response curve (AUC) was calculated using trapezoidal geometry.

Results and Discussion

Proinsulin is the peptide that is released from the beta-cells of the pancreas in response to rising concentrations of glucose and fatty acids in the blood. Proinsulin is comprised of one molecule of insulin and one molecule of the connecting peptide of insulin (c-peptide). For insulin to become active, the c-peptide must be cleaved off of the proinsulin molecule. Because the c-peptide has a greater half-life than insulin, determining the c-peptide concentration in blood will more accurately reflect the amount of activated insulin released. In our experiment, a carnitine × chromium interaction was observed ($P<0.0001$; Table 2) for mean c-peptide concentration. Sows fed the diet containing only chromium had decreased c-peptide concentrations com-

pared to sows fed the control diet; however, when carnitine was also fed in the diet the reduction was not as dramatic. A carnitine × chromium interaction was also observed ($P<0.0001$; Table 3) for the AUC of c-peptide for the first three hours after feeding (fed-state). Sows fed diets containing either carnitine or chromium had decreased c-peptide concentrations, but the decrease was not as great when both carnitine and chromium were added in the diet. The concentration of c-peptide was influenced the greatest in the first three hours after feeding (Figure 2). Sows fed diets containing neither carnitine nor chromium had greater ($P<0.05$) c-peptide concentrations compared to sows fed the other treatments at 0.5 and 0.75 hours after feeding; sows fed the diet containing chromium at 1, 1.5, 2.25, and 2.5 hours after feeding; and sows fed the diet containing carnitine at 2.75 hours after feeding. Sows fed the diet containing both carnitine and chromium had greater ($P<0.05$) c-peptide concentration compared to sows fed the diet containing chromium at one hour after feeding. Thus, diets containing chromium had the greatest influence on c-peptide concentration, primarily in the first three hours after feeding.

Insulin is the main anabolic hormone released in the body. Insulin is released in times of energy abundance. Rising concentrations of insulin in the blood would signal energy storage strategies, such as lipogenesis or muscle synthesis, whereas low concentrations of insulin are associated with energy mobilization from body tissues such as lipolysis or glycogenolysis. In our experiment, carnitine and chromium influenced insulin concentration similarly to their effects on c-peptide. A carnitine × chromium interaction was observed ($P<0.0004$) for mean insulin concentration (Table 2) and AUC for the first three hours after feeding (Table 3). Feeding diets containing either carnitine or chromium lowered insulin concentrations in the blood; however, when both carnitine and chromium were added to the diet, an intermediate response was observed (Figure 3). Area under the curve was lowest ($P<0.05$) for the total 24-hr period and the fasting period (3 to 24 hr after feeding) when sows were fed diets containing chromium. Similar to c-peptide, the greatest treatment effect on insulin concentration was observed in the first three hours after feeding (Figure 4). Sows fed the control diet had higher ($P<0.05$) insulin concentrations than sows fed diets containing chromium at .5, 1, 2.25, and 2.5 hours after feeding; sows fed all other diets at 0.75 and 1.25 hours after feeding; and sows fed the diet containing carnitine at 2.5 hours after feeding. Sows fed the diet containing carnitine and chromium had higher ($P<0.05$) insulin concentration compared to sows fed the diet containing carnitine at 0.75 hours after feeding and compared to sows fed the diet containing chromium at 1 hour after feeding. Therefore, the greatest effect on insulin concentration was observed from sows fed diets containing chromium, especially from 0 to 3 hours after the meal. Because, insulin and c-peptide were influenced similarly it would suggest that added dietary chromium resulted in less insulin secretion in response to the meal.

Glucose is the main energy substrate of the body. Blood glucose concentrations will rise after a meal, then decline as insulin initiates their clearance from the blood. Blood glucose concentration is regulated by hormones such as insulin and glucagon. Mean glucose concentration was lowered ($P<0.0006$) when chromium was added to the diets; however, AUC was not influenced by carnitine, chromium, or a combination of both. Again the greatest effect of carnitine or chromium on glucose concentrations was observed in the fed state (Figure 6). Sows fed the control diet had greater ($P<0.05$) glucose concentrations compared to sows fed the other treatments at 0.5 hours after feeding; sows fed the diet con-

taining both carnitine and chromium at 0.25 and 0.75 hours after feeding; and sows fed the diet containing chromium at 0.75, 1.5, and 2.25 hours after feeding. Sows fed the diet containing carnitine and chromium had lower (P<0.05) glucose concentrations compared to the other treatments at 0.5 hours after feeding; and sows fed diets containing only carnitine at 1 and 1.25 hours after feeding. The ability of carnitine and(or) chromium to lower glucose concentrations immediately after the meal would signify more rapid clearance of glucose from the blood since all sows were fed the same amount of feed, thus dietary glucose would be constant across treatments. In agreement with other research, dietary chromium decreased glucose concentration in the presence of lower concentrations of insulin. Therefore, the action of insulin was potentiated when chromium was included in the diet. Interestingly, carnitine also improved glucose tolerance immediately after the meal.

Non-esterfied fatty acids (NEFAs) or free-fatty acids (FFAs) are fatty acids that are present in the blood in a form not bound to glycerol or other substrates. Glycerol is the carbon back bone that lipids are bound to to form triglycerides, the storage form of lipid. Blood NEFA concentrations will increase after the meal reflective of dietary NEFA supply, but are most important in the fasted state when they are the main energy source for the body. Blood NEFA and glycerol concentrations will rise in response to greater lipolytic activity, or catabolism of adipose tissue. Sows fed diets containing carnitine had lower (P<0.002) mean NEFA concentrations compared to sows fed diets without carnitine. Sows fed diets with chromium had higher (P<0.03) mean NEFA concentrations compared to sows fed diets without chromium. Sows fed diets containing carnitine had lower (P<0.0006) AUC for NEFA for the total 24-hr period as well as the fasting period (3 to 24 hours after feeding). Carnitine also tended to decrease (P<0.053) AUC for NEFA during the fed state, while sows fed diets containing chromium tended to have higher (P<0.053) NEFA AUC during the fed state compared to sows fed diets without chromium. Sows fed diets containing chromium had greater (P<0.05; Figure 7) NEFA concentrations compared to sows fed diets with carnitine at 6, 20, and 24 hours after the meal, and greater (P<0.05) NEFA concentrations compared to sows fed diets with both carnitine and chromium at 20 and 24 hours after the meal. Sows fed the control diet had elevated (P<0.05) NEFA concentrations compared to sows fed diets with carnitine or carnitine and chromium at 24 hours after the meal. Sows fed diets with carnitine or carnitine and chromium had lower (P<0.05; Figure 8) NEFA concentrations compared to sows fed diets without carnitine or chromium at feeding (0 hours after the meal), and lower (P<0.05) NEFA concentrations than sows fed the diet containing chromium at 0.25 hours after the meal. Sows fed the diet containing chromium had elevated (P<0.05) NEFA concentrations compared to sows fed diets containing carnitine at 1.5 hours after the meal. Sows fed diets containing chromium had greater (P<0.05) NEFA concentrations compared to sows fed the control diet or the diet containing carnitine at 2.5 and 2.75 hours after the meal, and greater (P<0.05) NEFA concentrations compared to sows fed the diet containing both carnitine and chromium at 2.75 hours after the meal. Sows fed the control diet had lower (P<0.05) NEFA concentrations at 2.5 hours after the meal compared to sows fed the diet containing both carnitine and chromium. Sows fed diets containing chromium had higher (P<0.05) mean glycerol concentrations and greater (P<0.05) AUC from 0 to 20, 0 to 2, and 2 to 20 h after feeding. Sows fed the diet containing chromium had greater (P<0.05; Figure 15) plasma glycerol compared to sows fed the control diet at 0.5 h after feeding. Sows fed the diets containing chromium or carnitine and chromium had greater

(P<0.05) plasma glycerol compared to sows fed the diet containing only carnitine 6 h after the meal. These results agree with past research showing that dietary carnitine will improve utilization of fatty acids, resulting in more extraction or less breakdown (lower concentrations) of NEFA from the blood without altering the concentration of glycerol. The rise in NEFA and glycerol concentration observed from adding chromium to the diet could be a reflection of the lower insulin concentrations observed from these sows because low blood insulin would act as a signal for lipolysis.

Triglyceride is the main storage form of lipids in the body. Dietary carnitine and/or chromium had no effect (P>0.10) on mean triglyceride concentration or AUC. Pigs fed the diets containing either carnitine or carnitine and chromium had elevated (P<0.05; Figure 16) plasma triglycerides compared to sows fed the control diet or the diet containing chromium at 0.5 h after feeding. At 6 h after the meal, sows fed the diet containing chromium had greater (P<0.05) plasma triglyceride compared to the sows fed the diet containing carnitine.

Insulin-like growth factor 1 (IGF-1) is an important anabolic hormone. Higher concentrations of IGF-1 would be associated with protein deposition as well as initiate the release of other growth hormones important for proper fetal growth and development. Insulin-like growth factor binding protein-3 is the main carrier of IGF-1 in the blood and acts to stabilize the IGF-1 molecule and extend its half-life. Because of high variability in IGF-1, no significant treatment differences were observed for mean IGF-1 concentration, AUC, or treatment differences within time; however, the sows fed the diet containing carnitine had numerically the greatest IGF-1 concentration. Similarly, there was a tendency for carnitine to increase (P<0.06) the circulating concentrations of IGFBP-3, which may have indirectly increased the circulating IGF-1 by increasing its half-life. This would support past research conducted at Kansas State University showing that dietary carnitine enhanced plasma IGF-1 concentrations of gestating sows and increased the muscle development of offspring.

Glucagon is an important hormone that is released in times of greater energy demand. It acts as a signal to mobilize energy substrates from body stores. Thus, it has opposing effects to insulin. Carnitine and(or) chromium did not influence mean glucagon concentration or AUC. The only treatment difference within time occurred 1.5 hours after feeding when sows fed the diet containing chromium had greater (P<0.05; Figure 12) glucagon concentration compared to sows fed the diet containing carnitine. These results would suggest that carnitine and(or) chromium do not have a major effect on glucagon concentrations in the blood.

Plasma urea nitrogen (PUN) represents the nitrogenous waste present in the blood from catabolism of amino acids. A carnitine × chromium interaction was observed (P<0.005) for mean PUN concentration and a tendency for a carnitine × chromium interaction (P<0.08) was observed for PUN AUC for the total 24-hour period as well as from 3 to 24 hours after the meal. Sows fed the diet containing only carnitine had lower PUN concentration and AUC; however, there was no difference in PUN or AUC when both carnitine and chromium were added to the diet. Carnitine decreased (P<0.05; Figure 13) PUN concentration at 6 and 24 hours after the meal compared to the control diet, and decreased (P<0.05) PUN at 24 hours after the meal compared to the diet containing both carnitine and chromium. Sows fed diets containing carnitine had lower (P<0.05; Figure 14) PUN concentrations compared to sows fed diets containing chromium at 0.75 and 1 hours after

feeding, had lower (P<0.05) PUN compared to diets containing carnitine and chromium at 2 and 2.25 hours after feeding, and had lower (P<0.05) PUN compared to sows fed the control diet at 2.25, 2.5, 2.75, and 3 hours after feeding. Sows fed the control diet had higher (P<0.05) PUN compared to sows fed the diet containing chromium at 2.25 hours after feeding. Sows fed the diet containing carnitine had numerically the lowest PUN concentrations at all bleeding times, suggesting that less muscle catabolism occurred when carnitine was fed. This would agree with previous research in finishing pigs showing that carnitine decreased the activity of branch-chain keto-acid dehydrogenase, an important enzyme necessary for branch-chain amino acid catabolism.

Amino acids are the main building blocks of protein. Circulating concentrations of individual amino acids will increase after the meal but may also increase during fasting as a reflection of muscle catabolism for energy. Both carnitine and chromium influenced the circulating concentrations of some amino acids. A carnitine × chromium interaction (P<0.05) was observed for alanine, tyrosine, ornithine, lysine, and arginine, with all amino acids being lower when either carnitine or chromium were added to the diet. But no difference was observed when both carnitine and chromium were added to the diet compared to sows fed the control diet. Sows fed the diets containing carnitine exhibited higher (P<0.05) circulating concentrations of taurine, glutamine, glycine, methionine, and histidine and sows fed the diets containing chromium had higher (P<0.05) glutamate and lower (P<0.05) tryptophan concentrations. Thus, both carnitine and chromium will influence protein metabolism.

In summary, this trial illustrates that both carnitine and chromium are important modifiers of energy status of sows fed one meal per day. Carnitine's greatest effect was during the fasted state (3 h or more after the meal) when it was associated with lower PUN and NEFA concentrations, the body's main energy substrate under these conditions. However, chromium elicited its greatest effect during the fed state (0 to 3 h after the meal) by decreasing the concentrations of both plasma insulin and glucose, suggesting a greater efficiency of glucose uptake. When both carnitine and chromium were added to the diets, similar and additive responses were observed; however, the change in blood parameter profile was not as dramatic. Therefore, both carnitine and chromium may act in concert to influence carbohydrate, lipid, and protein metabolism. The additive effects on energy status that were observed in this trial may explain the additive effects on reproductive performance that were observed in a previous experiment.

Table 2. Influence of Carnitine and(or) Chromium on Mean Blood Parameter Concentration[a]

	Carnitine, ppm	0	50	0	50		Probability, *P*<		
Item	Chromium, ppb	0	0	200	200	SEM	Carn.	Chrom.	C × C
C-peptide of insulin, nmol/L[b]		0.485	0.417	0.391	0.430	0.018	0.31	0.004	0.0001
Insulin, pmol/L[b]		190.5	148.3	135.0	158.5	15.6	0.32	0.02	0.0004
Glucose, mmol/L[b]		4.42	4.41	4.30	4.22	0.07	0.25	0.0006	0.42
NEFA, mmol/L[b]		0.145	0.135	0.167	0.138	0.008	0.002	0.03	0.10
IGF-1, nmol/L[b]		14.34	17.91	14.08	15.12	1.97	0.11	0.28	0.37
Glucagon, pmol/L[b]		30.95	30.84	32.85	30.81	1.24	0.33	0.39	0.37
Urea nitrogen, mmol/L[b]		4.61	3.64	4.32	4.46	0.21	0.04	0.18	0.005
Glycerol, mmol/L[c]		0.043	0.042	0.051	0.049	0.005	0.73	0.008	0.70
Triglyceride, mmol/L[c]		0.263	0.277	0.276	0.276	0.026	0.60	0.69	0.61
IGFBP-3, nmol/L[c]		4.70	4.86	4.72	5.40	0.23	0.06	0.19	0.22
Leptin, μg/L[b]		0.80	1.84	1.12	1.22	0.38	0.02	0.56	0.06

[a]Values represent a total of 44 sows (BW = 458 lb; parity = 2.0) with 10 or 12 sows per treatment.

[b]Values represent the mean of samples collected at feeding, once every 15 min for the first 3 h after feeding, and at 6, 9, 15, 20, and 24 h after feeding.

[c]Values represent the mean of samples collected at feeding, 30 min, 1, 2, 6, and 20 h after feeding.

Table 3. Influence of Carnitine and(or) Chromium on AUC of Blood Parameters[a]

	Carnitine, ppm	0	50	0	50		Probability, *P*<		
Item	Chromium, ppb	0	0	200	200	SEM	Carn.	Chrom.	C × C
C-peptide of Insulin, min•nmol/L[b]									
0 to 24 hr after feeding		367.4	383.8	337.5	359.5	19.6	0.28	0.12	0.87
0 to 3 hr after feeding		108.5	82.6	83.9	89.9	6.0	0.10	0.14	0.008
3 to 24 hr after feeding		259.3	301.6	255.1	268.6	16.7	0.08	0.23	0.35
Insulin, min•pmol/L[b]									
0 to 24 hr after feeding		130,010	125,437	101,449	113,510	13,590	0.70	0.04	0.38
0 to 3 hr after feeding		44,557	30,321	30,900	35,290	4,892	0.22	0.27	0.02
3 to 24 hr after feeding		85.594	95,325	71,107	77,717	10,538	0.32	0.05	0.84
Glucose, min•mmol.L[b]									
0 to 24 hr after feeding		5,154	5,143	5,154	4,954	117	0.23	0.27	0.26
0 to 3 hr after feeding		778	733	740	723	35	0.16	0.25	0.50
3 to 24 hr after feeding		4,376	4,411	4,413	4,229	97	0.31	0.31	0.13
NEFA, min•mmol/L[b]									
0 to 24 hr after feeding		175.2	148.9	187.8	142.0	10.8	0.0006	0.76	0.30
0 to 3 hr after feeding		24.3	23.6	29.5	24.3	3.4	0.053	0.053	0.13
3 to 24 hr after feeding		151.2	126.0	158.3	116.5	9.7	0.0006	0.89	0.34
IGF-1, min•nmol/L[b]									
0 to 24 hr after feeding		14,578	18,757	13,433	14,324	2,745	0.35	0.29	0.53
0 to 3 hr after feeding		2,744	3,092	2,666	2,727	496	0.68	0.64	0.76
3 to 24 hr after feeding		11,817	15,625	10,783	11,658	2,287	0.29	0.25	0.49
Glucagon, min•pmol/L[b]									
0 to 24 hr after feeding		34,678	33,738	35,081	34,044	2,293	0.74	0.90	0.99
0 to 3 hr after feeding		5,501	5,100	5,953	5,451	393	0.25	0.28	0.89
3 to 24 hr after feeding		29,176	28,638	29,128	28,593	1,927	0.82	0.98	0.99
Urea nitrogen, min•mmol/L[b]									
0 to 24 hr after feeding		5,345	4,185	5,027	5,204	400	0.22	0.36	0.08
0 to 3 hr after feeding		814	611	766	786	76	0.23	0.38	0.13
3 to 24 hr after feeding		4,532	3,574	4,262	4,419	327	0.22	0.36	0.08
Glycerol, min•mmol/L[c]									
0 to 20 hr after feeding		54.69	48.38	63.55	62.61	7.33	0.45	0.02	0.57
0 to 2 hr after feeding		4.56	5.07	6.08	5.38	0.58	0.81	0.02	0.12
2 to 20 hr after feeding		50.14	43.32	57.48	57.21	6.96	0.44	0.03	0.46

Table 3. Continued

Triglyceride, min•mmol/L[c]								
0 to 20 hr after feeding	346.2	340.5	362.8	332.6	29.3	0.41	0.84	0.56
0 to 2 hr after feeding	28.4	31.6	30.8	32.1	3.3	0.27	0.48	0.63
2 to 20 hr after feeding	317.8	332.2	308.8	300.6	26.4	0.33	0.87	0.57
IGFBP-3, min•nmol/L[c]								
0 to 20 hr after feeding	3862.8	3885.5	4010.9	4582.6	344.9	0.34	0.16	0.36
0 to 2 hr after feeding	636.3	686.6	657.1	748.1	43.8	0.11	0.33	0.62
2 to 20 hr after feeding	3227.4	3200.8	3354.6	3831.1	324.3	0.43	0.18	0.37

[a]Values represent the mean of 44 sows (BW = 208; parity = 2.0), with 10 or 12 sows per treatment. AUC = area under the curve.
[b]Values represent the mean of samples collected at feeding, once every 15 min for the first 3 h after feeding, and at 6, 9, 15, 20, and 24 h after feeding.
[c]Values represent the mean of samples collected at feeding, 30 min, 1, 2, 6, and 20 h after feeding.

Table 4. Influence of Carnitine and/or Chromium on Circulating Amino Acid Concentrations[a]

		Carnitine, ppm	0	50	0	50				
Item	Hours after feeding	Chromium, ppb	0	0	200	200	Time	Carn	Chrom.	C × C
Taurine							0.0001	0.024	0.14	0.72
	0		70.0	70.1	63.2	72.0				
	0.5		67.7	73.8	80.2	81.8				
	1.0		75.3[a]	113.1[b]	81.7[a]	81.4[a]				
	2.0		111.6[a]	102.2[ab]	102.5[ab]	85.0[b]				
	6.0		114.9[a]	143.7[b]	93.4[c]	146.5[b]				
	20.0		87.1	89.9	74.0	79.1				
Aspartate							0.0001	0.42	0.68	0.10
	0		22.6	25.2	20.8	22.9				
	0.5		41.7	35.1	33.2	32.9				
	1.0		41.0[ca]	48.8[ab]	37.6[c]	56.7[b]				
	2.0		44.6	37.7	40.3	46.3				
	6.0		37.4	31.8	31.6	33.7				
	20.0		17.5	16.9	17.1	17.5				
Threonine							0.0001	0.40	0.83	0.57
	0		128.5	134.0	138.5	133.6				
	0.5		163.7	149.3	160.2	157.6				
	1.0		186.9	187.8	181.1	203.0				
	2.0		218.4[a]	168.8[b]	208.8[c]	187.5[cb]				
	6.0		188.0	188.4	165.5	175.2				
	20.0		120.3	122.5	138.1	123.7				
Serine							0.0001	0.43	0.71	0.12
	0		127.3	125.8	122.1	131.8				
	0.5		150.7	138.8	141.6	154.0				
	1.0		165.7[ab]	166.9[ab]	150.4[a]	182.3[b]				
	2.0		174.8[a]	151.8[b]	166.3[ab]	159.1[ab]				
	6.0		150.4[ab]	158.9[a]	134.3[b]	145.2[ab]				
	20.0		110.5	115.7	109.9	119.3				

Table 4. Continued

Asparagine						0.0001	0.41	0.68	0.10
	0	22.6	25.2	20.8	22.9				
	0.5	41.7	35.1	33.2	32.9				
	1.0	41.0^{ca}	48.8^{ab}	37.6^{c}	56.7^{b}				
	2.0	44.6	37.7	40.3	46.3				
	6.0	37.4	31.8	31.6	33.7				
	20.0	17.5	16.9	17.1	17.5				
Glutamate						0.0001	0.24	0.03	0.39
	0	297.7^{a}	284.9^{ab}	283.0^{ab}	231.0^{b}				
	0.5	350.5^{a}	285.9^{b}	336.3^{ab}	375.2^{a}				
	1.0	419.2^{a}	386.6^{ab}	356.5^{b}	348.2^{b}				
	2.0	475.9^{a}	364.4^{b}	420.5^{ab}	377.5^{b}				
	6.0	335.9^{a}	412.9^{b}	276.1^{c}	306.1^{c}				
	20.0	290.1	286.3	273.8	282.6				
Glutamine						0.0001	0.0001	0.66	0.12
	0	255.6^{a}	332.1^{bc}	294.2^{ab}	357.7^{c}				
	0.5	241.1^{a}	336.6^{b}	243.3^{a}	249.1^{a}				
	1.0	174.0^{a}	272.6^{b}	202.4^{a}	307.5^{b}				
	2.0	121.8^{a}	170.6^{b}	154.8^{ab}	153.9^{ab}				
	6.0	178.1	166.3	170.9	159.6				
	20.0	194.4	196.6	205.4	187.6				
Glycine						0.21	0.02	0.10	0.20
	0	847.9^{a}	816.8^{a}	894.3^{a}	1083.5^{b}				
	0.5	840.0^{a}	869.8^{a}	918.8^{a}	1101.5^{b}				
	1.0	846.9^{a}	1088.3^{b}	861.5^{a}	1125.2^{b}				
	2.0	965.7	840.2	939.9	955.0				
	6.0	854.6^{ab}	1031.4^{b}	828.3^{a}	1010.8^{ab}				
	20.0	901.7	941.6	948.3	1043.3				
Alanine						0.0001	0.46	0.11	0.05
	0	347.2	335.4	323.0	317.3				
	0.5	441.4	373.6	383.0	384.5				
	1.0	531.2^{a}	467.0^{ab}	456.5^{b}	529.4^{a}				
	2.0	532.2^{a}	453.6^{b}	495.7^{ab}	458.9^{b}				
	6.0	405.6^{a}	401.3^{a}	301.9^{b}	359.7^{ab}				
	20.0	330.1	294.3	281.3	310.8				

Table 4. Continued

Valine						0.0001	0.40	0.17	0.82
	0	272.8	280.9	280.7	272.6				
	0.5	310.0	306.2	317.1	299.4				
	1.0	362.7	335.0	333.2	349.6				
	2.0	377.3^{aa}	323.9^{b}	362.9^{a}	328.2^{b}				
	6.0	327.0^{ac}	352.4^{c}	283.2^{b}	312.6^{ab}				
	20.0	249.3^{ab}	271.4^{a}	270.7^{a}	235.9^{b}				
Methionine						0.0001	0.018	0.29	0.77
	0	39.9	44.2	42.8	46.2				
	0.5	46.8	46.9	47.7	53.8				
	1.0	53.4^{a}	53.4^{a}	52.1^{a}	63.6^{b}				
	2.0	50.6	50.5	53.2	56.0				
	6.0	46.5^{a}	56.5^{b}	45.6^{a}	49.7^{ab}				
	20.0	38.5	46.5	42.1	42.3				
Isoleucine						0.0001	0.35	0.15	0.78
	0	108.6^{ab}	120.4^{a}	111.5^{ab}	100.3^{b}				
	0.5	141.5	126.8	135.7	131.9				
	1.0	168.5	153.1	153.6	159.8				
	2.0	166.6	151.9	158.3	155.0				
	6.0	147.4^{a}	142.8^{ab}	126.4^{b}	136.5^{ab}				
	20.0	103.0	111.7	110.1	96.5				
Leucine						0.0001	0.75	0.08	0.29
	0	213.8	237.1	222.9	214.7				
	0.5	266.9	250.4	257.3	251.7				
	1.0	313.9^{a}	281.7^{b}	279.9^{b}	297.7^{ab}				
	2.0	316.9	297.9	300.4	297.4				
	6.0	328.4^{a}	294.9^{b}	262.2^{c}	291.9^{b}				
	20.0	208.7	233.4	216.6	214.8				
Tyrosine						0.0001	0.80	0.26	0.002
	0	72.4	73.6	70.5	74.5				
	0.5	90.1^{a}	74.8^{b}	84.2^{ab}	94.5^{a}				
	1.0	109.6^{ac}	94.6^{bc}	100.9^{c}	115.4^{a}				
	2.0	116.3	111.0	117.7	117.0				
	6.0	112.7^{a}	94.3^{b}	93.1^{b}	110.8^{a}				
	20.0	72.4	81.6	76.4	82.1				

Table 4. Continued

Phenylalanine						0.0001	0.21	0.17	0.65
	0	79.1[a]	92.2[b]	81.0[ab]	69.7[a]				
	0.5	91.1	80.8	86.3	84.1				
	1.0	111.8	100.7	110.1	106.3				
	2.0	113.5	113.7	118.1	110.0				
	6.0	109.5[a]	99.1[ab]	92.3[b]	98.5[ab]				
	20.0	72.3	79.0	76.1	70.0				
Tryptophan						0.0001	0.59	0.02	0.64
	0	33.3[a]	43.6[ab]	48.1[b]	46.0[b]				
	0.5	53.3[ab]	48.2[a]	59.2[b]	52.5[ab]				
	1.0	55.5	63.1	56.8	65.8				
	2.0	56.8[a]	44.4[b]	57.7[a]	60.9[a]				
	6.0	44.8[a]	53.5[ab]	46.4[a]	62.4[b]				
	20.0	43.3	35.2	41.7	34.5				
Ornithine						0.0001	0.37	0.87	0.006
	0	83.2	72.3	77.5	95.2				
	0.5	91.8	76.3	85.6	100.4				
	1.0	104.8[bc]	130.9[a]	90.4[c]	128.7[ab]				
	2.0	148.0[a]	112.0[b]	126.1[ab]	125.9[ab]				
	6.0	140.0[a]	132.3[ab]	114.6[b]	135.8[ab]				
	20.0	81.9	75.6	75.9	84.3				
Lysine						0.0001	0.43	0.88	0.03
	0	246.5[ab]	209.6[a]	237.1[ab]	261.5[b]				
	0.5	295.5[a]	234.7[b]	276.3[ab]	298.2[a]				
	1.0	321.4[ab]	363.7[b]	288.7[a]	362.6[b]				
	2.0	343.1[a]	254.3[c]	306.1[ab]	299.3[bc]				
	6.0	247.9	234.2	212.9	211.0				
	20.0	224.1	212.5	224.3	193.5				
Histidine						0.0001	0.02	0.47	0.20
	0	74.1[a]	80.2[ab]	78.9[ab]	88.0[b]				
	0.5	86.9[a]	83.4[b]	85.2[b]	101.7[b]				
	1.0	94.0[a]	109.4[b]	94.1[a]	114.6[b]				
	2.0	98.8	92.3	99.6	98.8				
	6.0	90.7	91.7	80.8	84.5				
	20.0	76.2	81.6	74.3	79.9				

Table 4. Continued

Arginine					0.0001	0.87	0.13	0.002
	0	124.6[a]	114.7[b]	131.5[b]	197.8[b]			
	0.5	179.2[ab]	146.1[a]	163.1[ab]	183.2[b]			
	1.0	201.8[a]	220.8[ab]	191.4[a]	237.3[b]			
	2.0	227.0[a]	170.4[b]	208.5[a]	217.1[a]			
	6.0	198.7[a]	160.7[b]	166.0[ab]	162.4[b]			
	20.0	123.7	124.9	129.3	122.2			

[a]Values represent the mean of 44 sows (BW = 208; parity = 2.0), with 10 or 12 sows per treatment.
[a,b,c]Means within the same row with different superscripts differ, $P<0.05$.

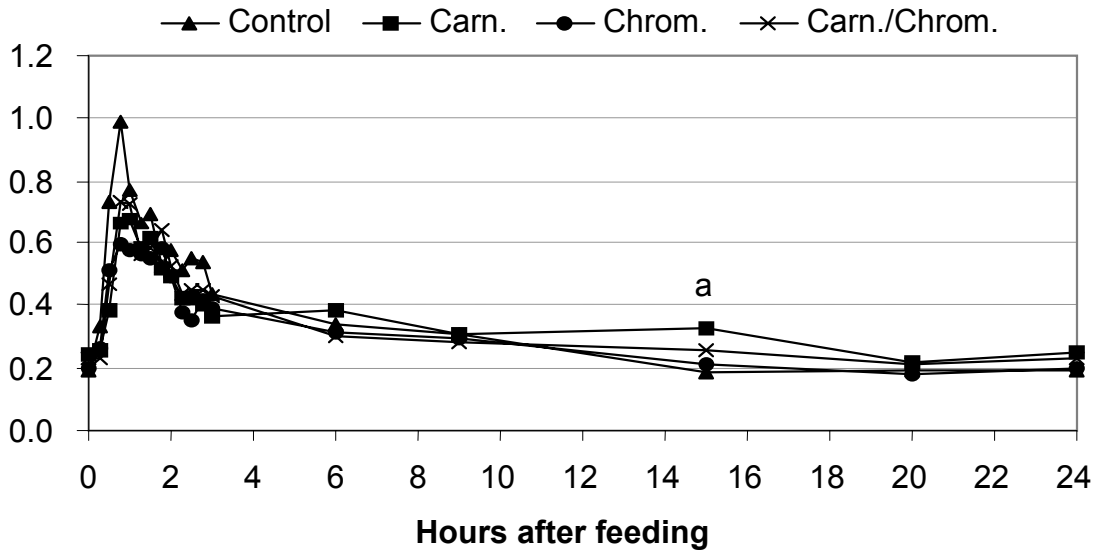

Figure 1. Influence of Carnitine and(or) Chromium on the Connecting-Peptide of Insulin (nmol/L).

[a]Carn. > Control; P<0.05.

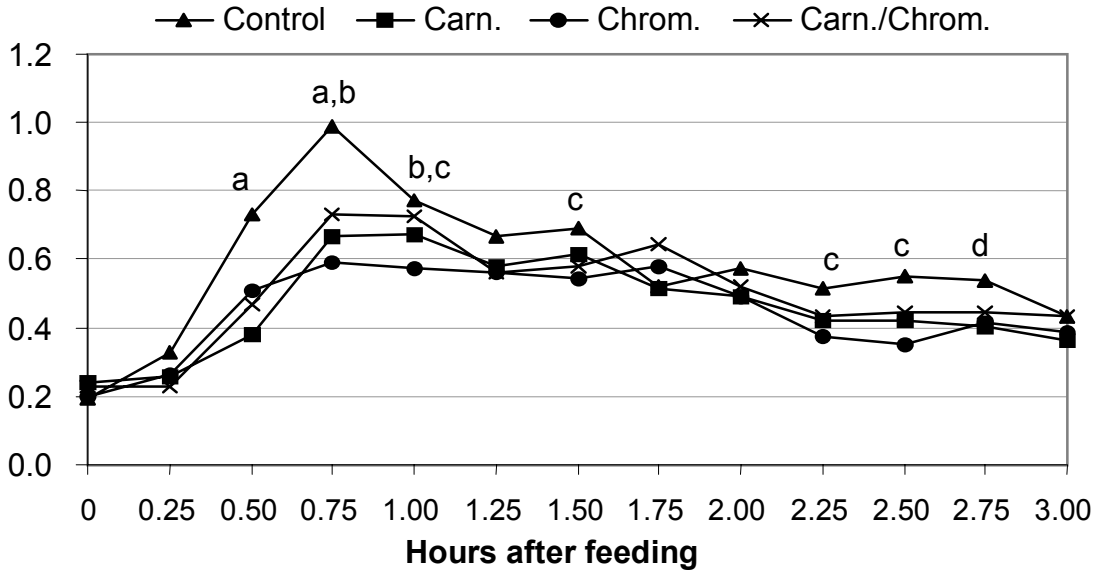

Figure 2. Influence of Carnitine and(or) Chromium on the Connecting-Peptide of Insulin (nmol/L).

[a]Control > others; P<0.05. [b]Carn./Chro. > Chrom.; P<0.05. [c]Control > Chrom.; P<0.05. [d]Control > Carn.; P<0.05.

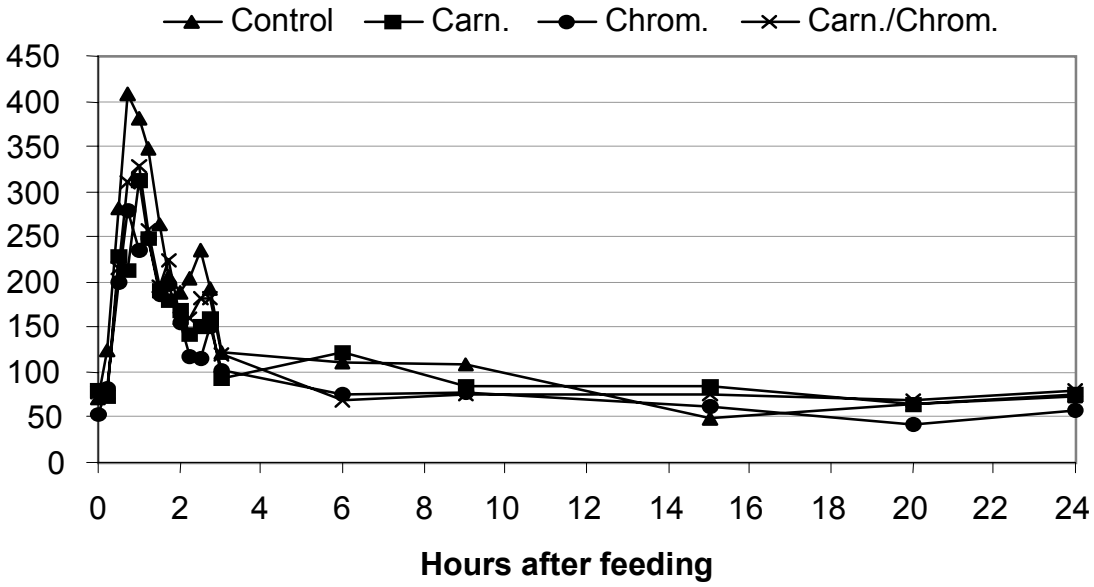

Figure 3. Influence of Carnitine and(or) Chromium on Insulin (pmol/L).

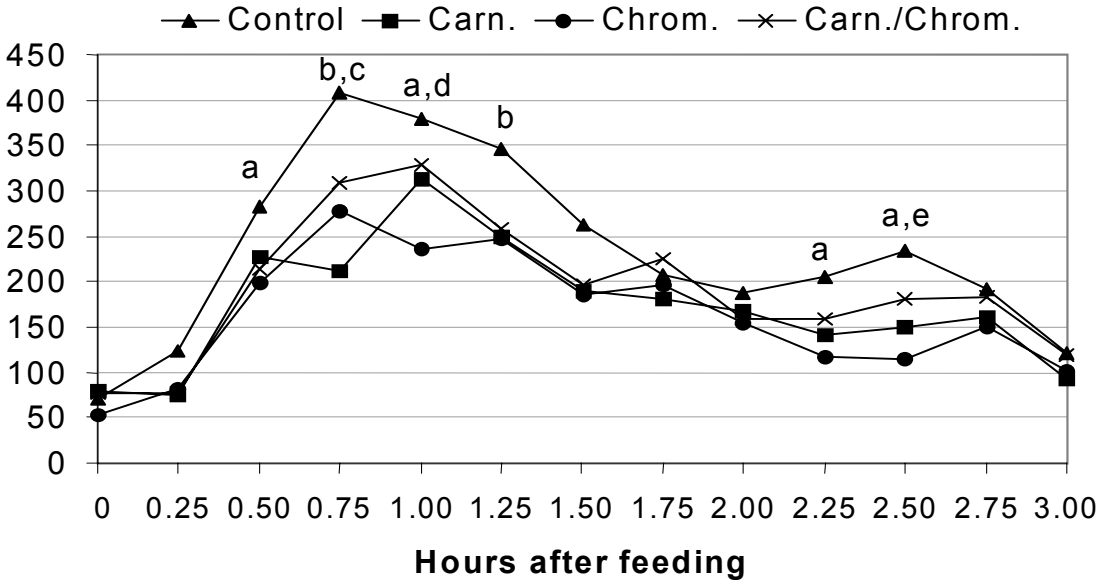

Figure 4. Influence of Carnitine and(or) Chromium on Insulin (pmol/L).

[a]Control > Chrom.; P<0.05. [b]Control > others; P<0.05. [c]Carn./Chrom. > Carn.; P<0.05. [d]Carn./Chrom > Chrom.; P<0.05. [e]Control > Carn.; P<0.05.

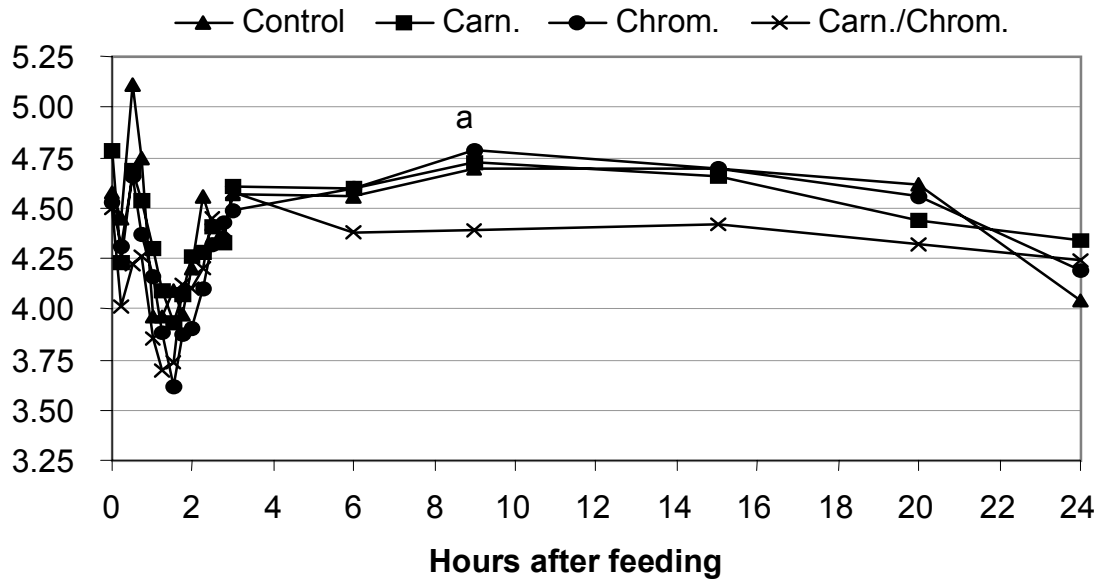

Figure 5. Influence of Carnitine and(or) Chromium on Glucose (mmol/L).

[a]Chrom. > Carn./Chrom.; P<0.05.

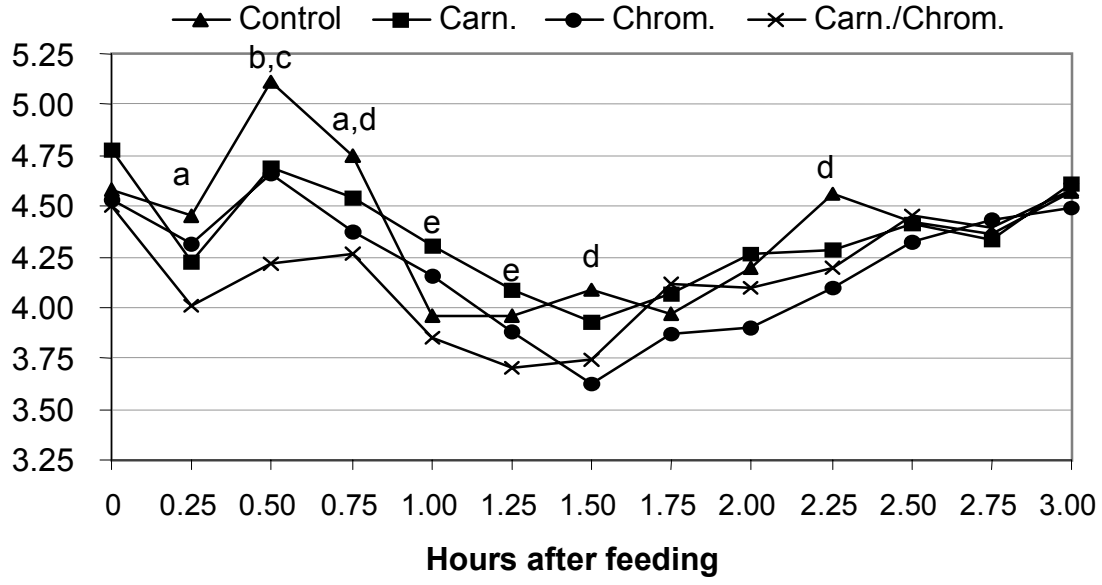

Figure 6. Influence of Carnitine and(or) Chromium on Glucose (mmol/L).

[a]Control > Carn./Chrom.; P<0.05. [b]Control > others; P<0.05. [c]Carn./Chrom. < others; P<0.05. [d]Control > Chrom.; P<0.05. [e]Carn. > Carn./Chrom.; P<0.05.

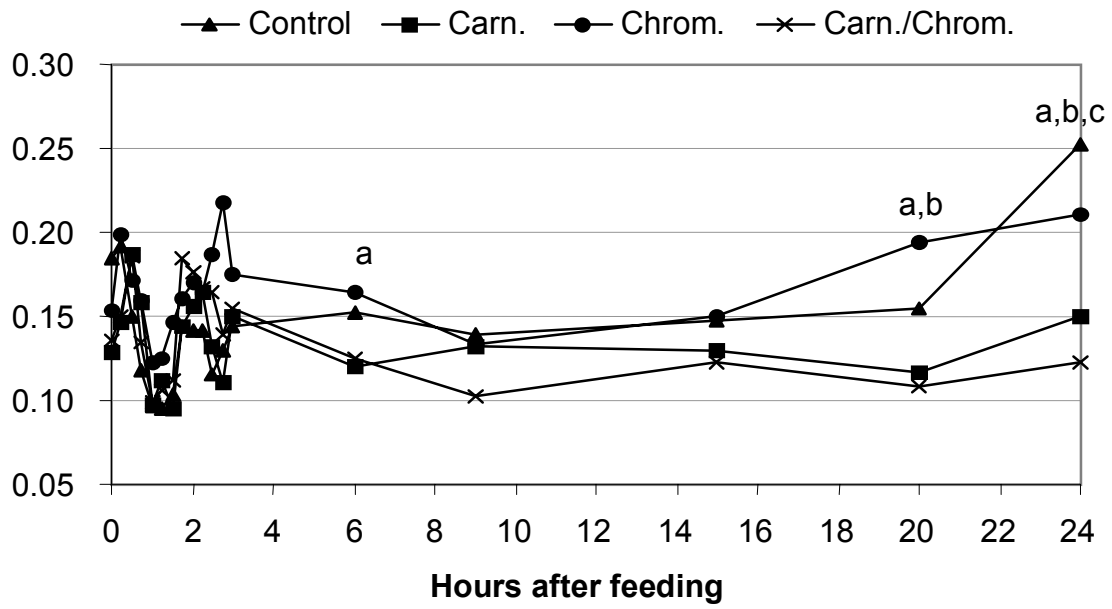

Figure 7. Influence of Carnitine and(or) Chromium on NEFA (mmol/L).

[a]Chrom. > Carn.; P<0.05. [b]Chrom. > Carn./Chrom.; P<0.05. [c]Control > Carn. and Carn./Chro.; P<0.05.

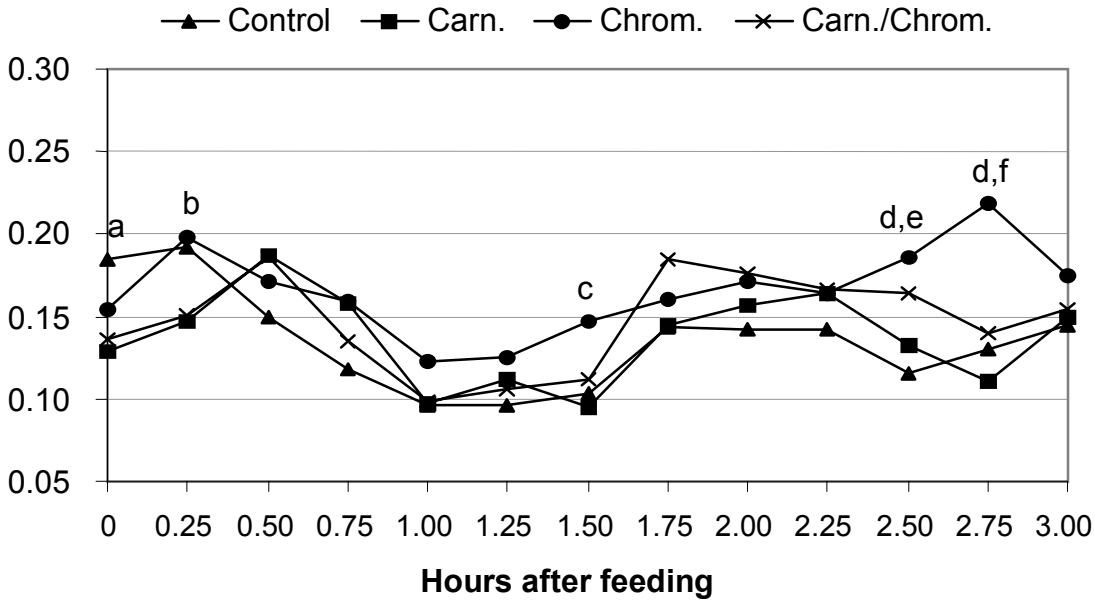

Figure 8. Influence of Carnitine and(or) Chromium on NEFA (mmol/L).

[a]Control > Carn. and Carn./Chrom.; P<0.05. [b]Chrom. > Carn. and Carn./Chrom.; P<0.05. [c]Chrom. > Carn.; P<0.05. [d]Chrom. > Control and Carn.; P<0.05. [e]Carn./Chrom. > Control.; P<0.05. [f]Chrom. > Carn./Chro.; P<0.05.

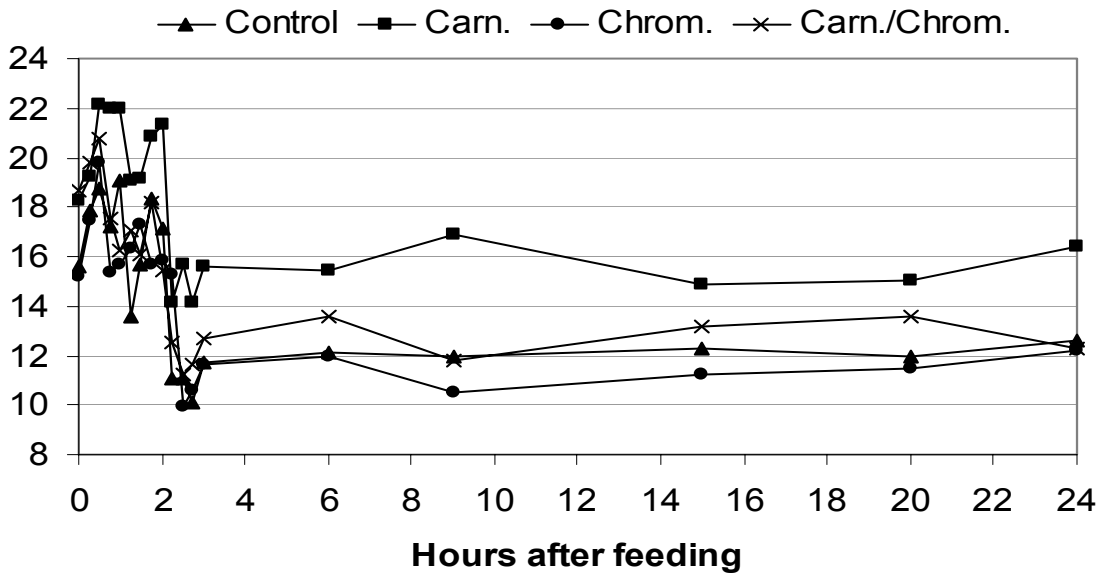

Figure 9. Influence of Carnitine and(or) Chromium on IGF-1 (nmol/L).

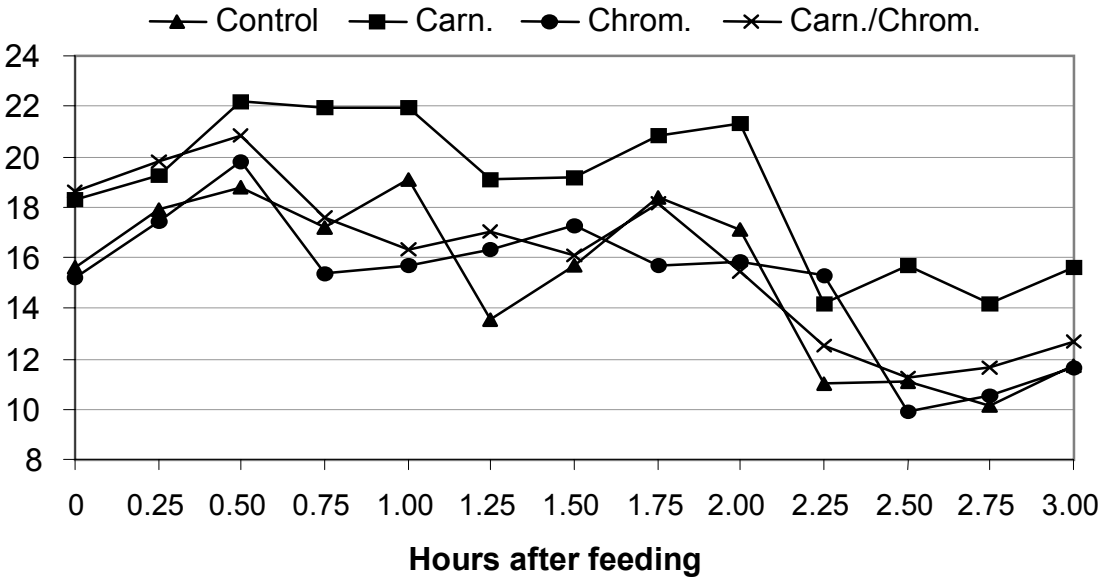

Figure 10. Influence of Carnitine and(or) Chromium on IGF-1 (nmol/L).

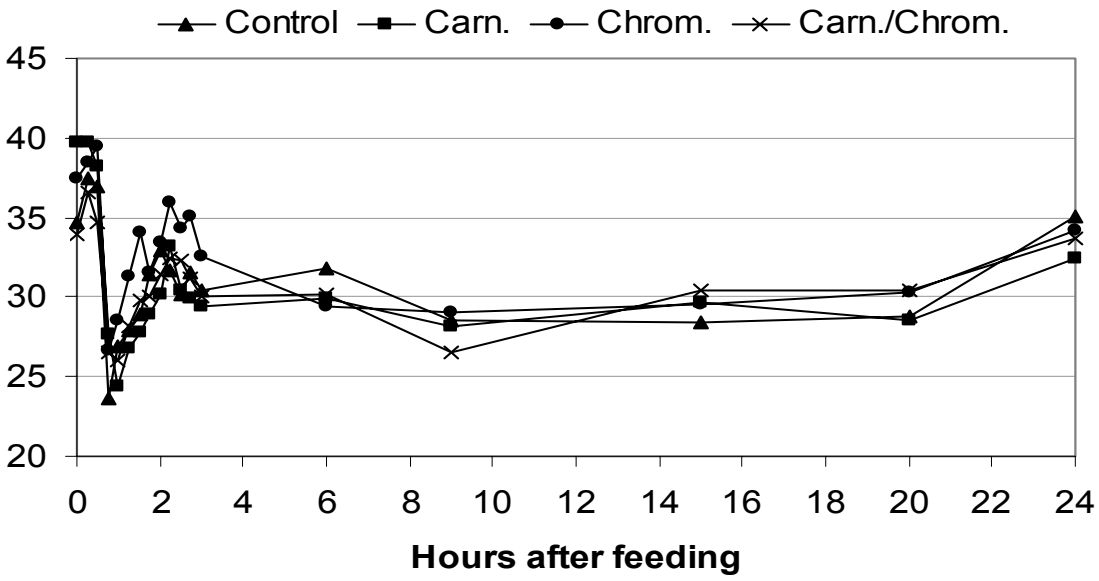

Figure 11. Influence of Carnitine and(or) Chromium on Glucagon (pmol/L).

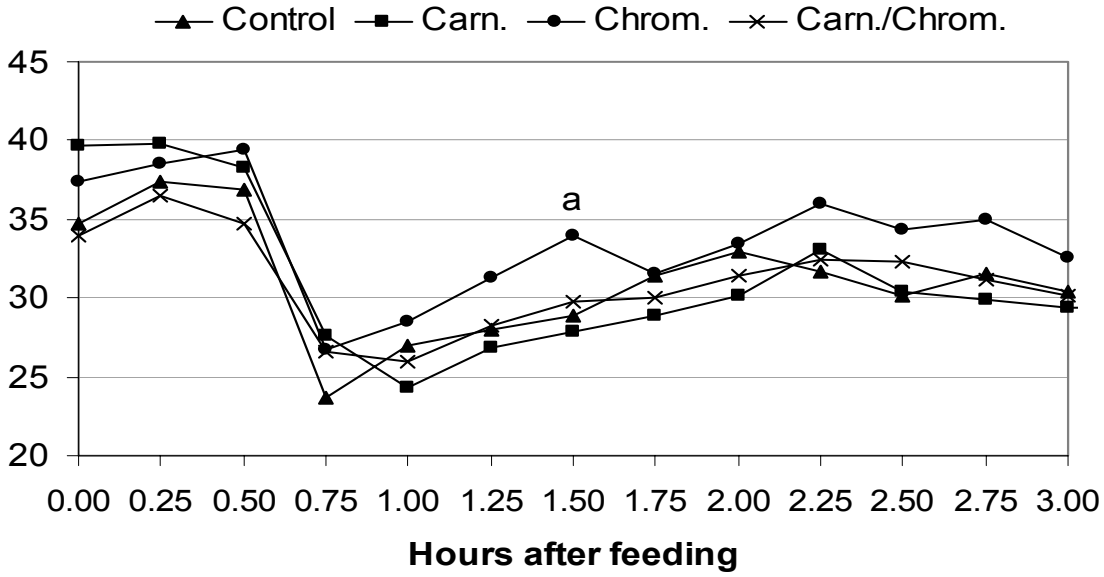

Figure 12. Influence of Carnitine and(or) Chromium on Glucagon (pmol/L).

[a]Chrom. > Carn.; $P<0.05$.

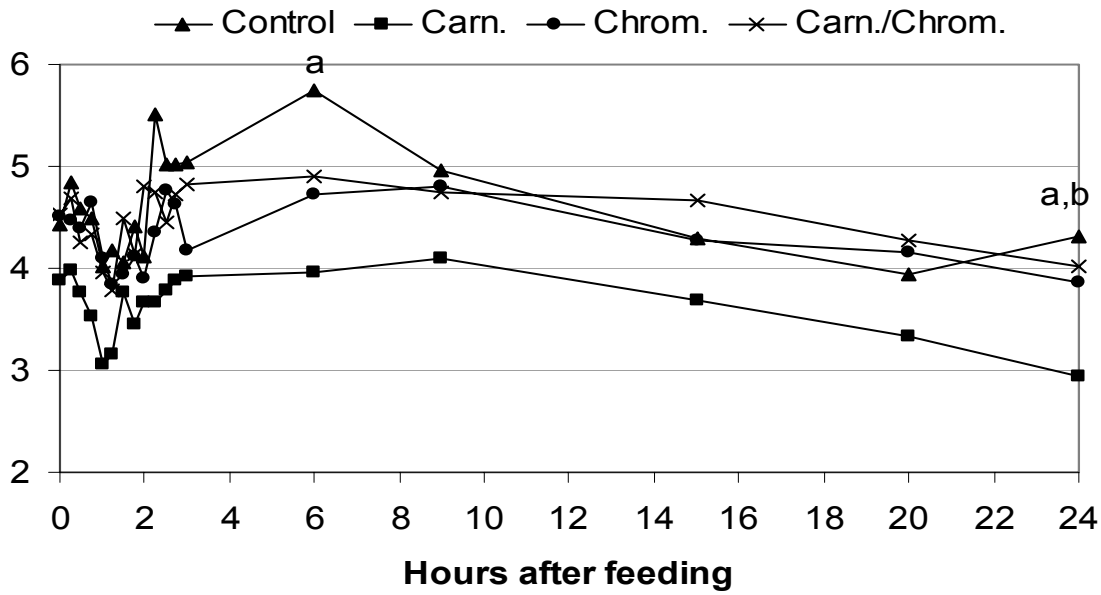

Figure 13. Influence of Carnitine and(or) Chromium on Plasma Urea Nitrogen (mmol/L).

[a]Control > Carn.; P<0.05. [b]Carn./Chrom. > Carn.; P<0.05.

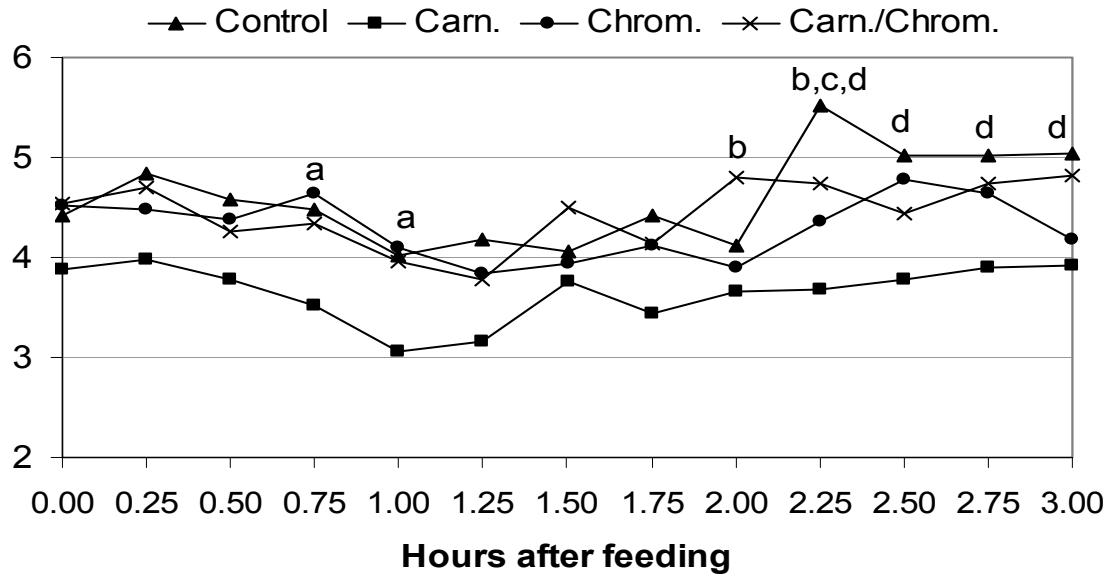

Figure 14. Influence of Carnitine and(or) Chromium on Plasma Urea Nitrogen (mmol/L).

[a]Chrom. > Carn.; P<0.05. [b]Carn./Chrom. > Carn.; P<0.05. [c]Control > Chrom.; P<0.05. [d]Control > Carn.; P<0.05.

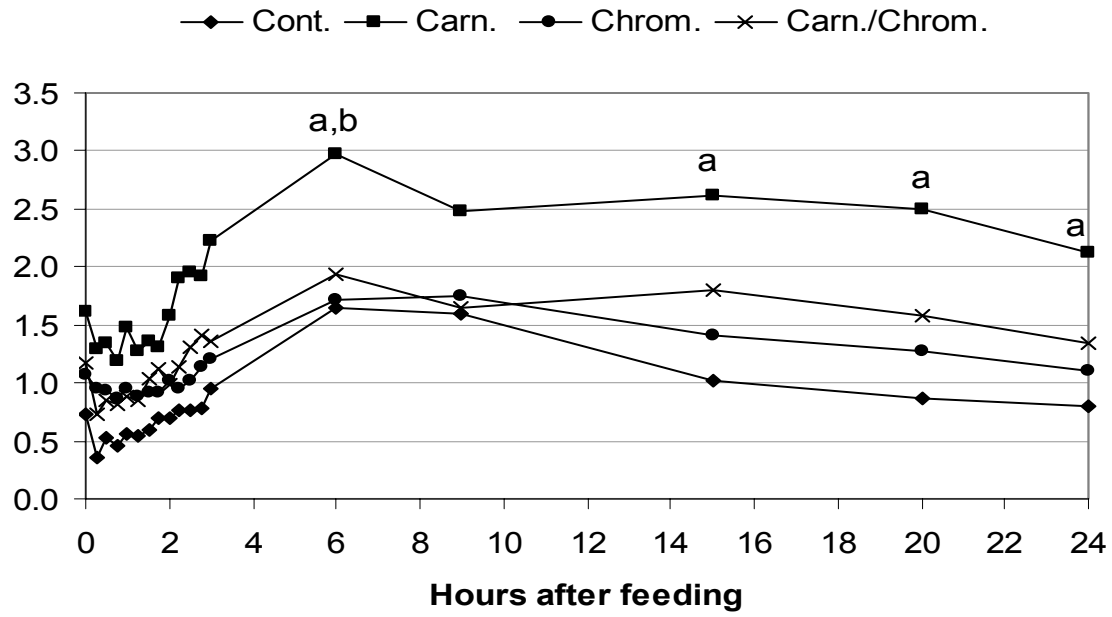

Figure 15. Influence of Carnitine and(or) Chromium on Plasma Leptin (μg/L).

[a]Carn. > Control or Chrom.; P<0.05. [b]Carn. > Carn./Chrom.; P<0.05.

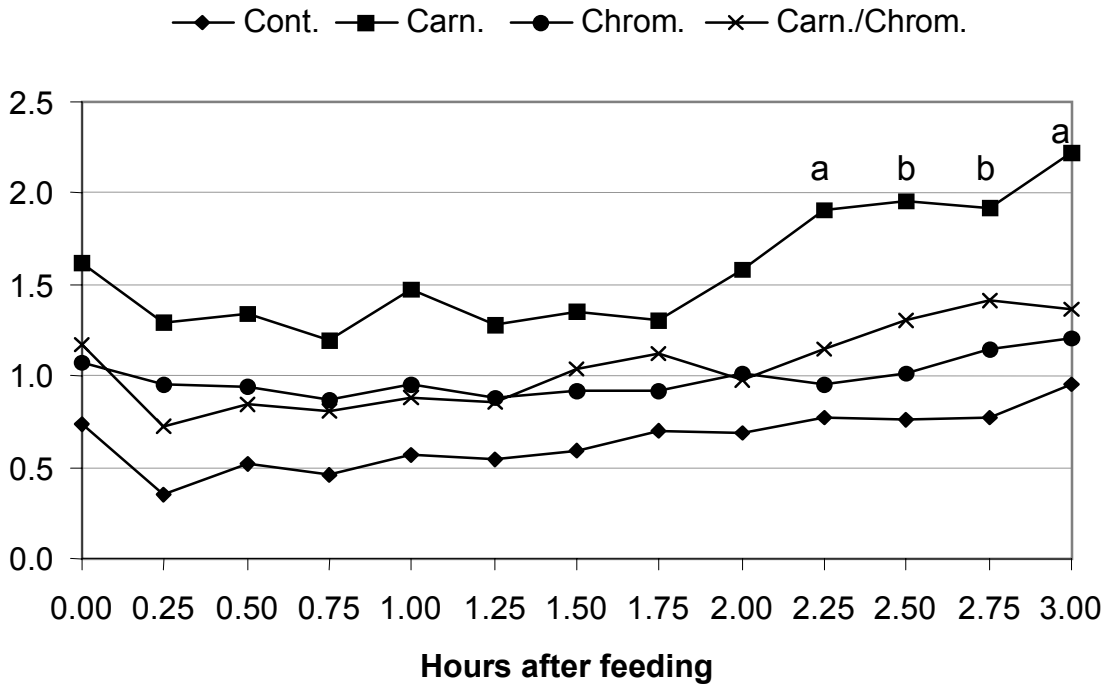

Figure 16. Influence of Carnitine and(or) Chromium on Plasma Leptin (μg/L).

[a]Carn > Control or Chrom.; P<0.05. [b]Carn. > Control; P<0.05.

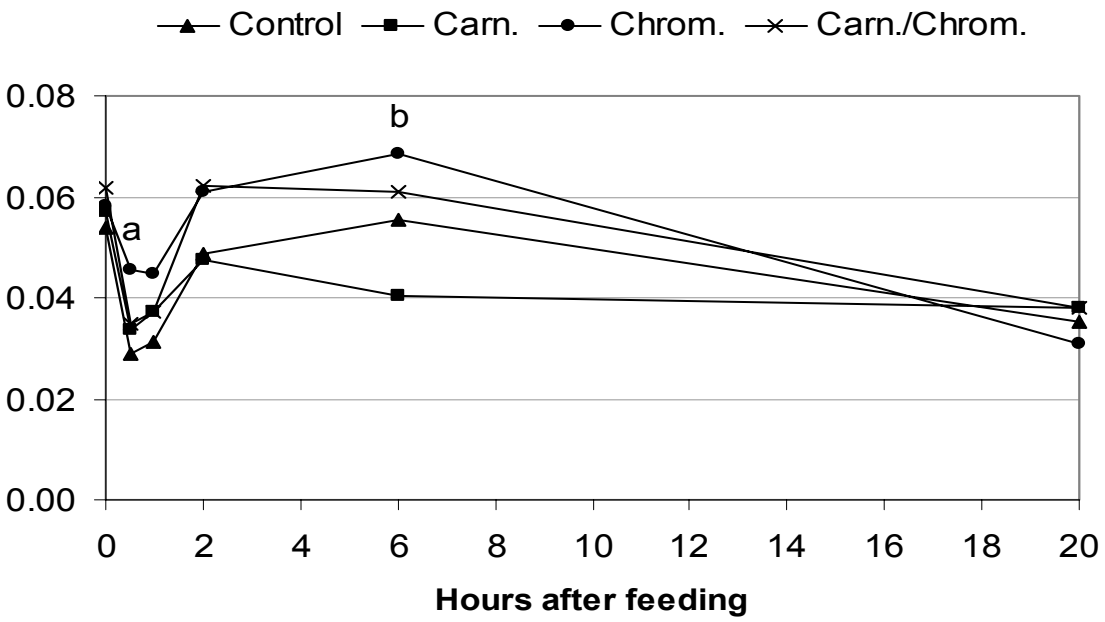

Figure 17. Influence of Carnitine and(or) Chromium on Glycerol (mmol/L).

[a]Chrom. > Control; P<0.05. [b]Chrom. and Carn./Chrom. > Carn.; P<0.05.

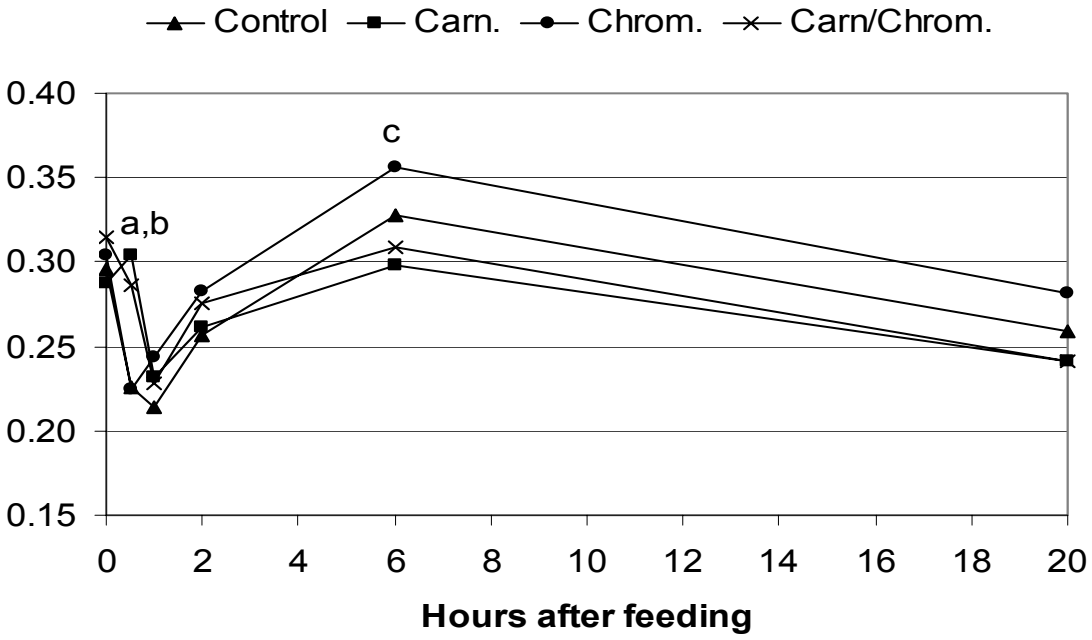

Figure 18. Influence of Carnitine and(or) Chromium on Triglyceride (mmol/L).

[a]Carn. and Carn./Chrom > Control.; P<0.05. [b]Carn. and Carn./Chrom. > Chrom.; P<0.05. [c]Chrom. > Carn.; P<0.05.

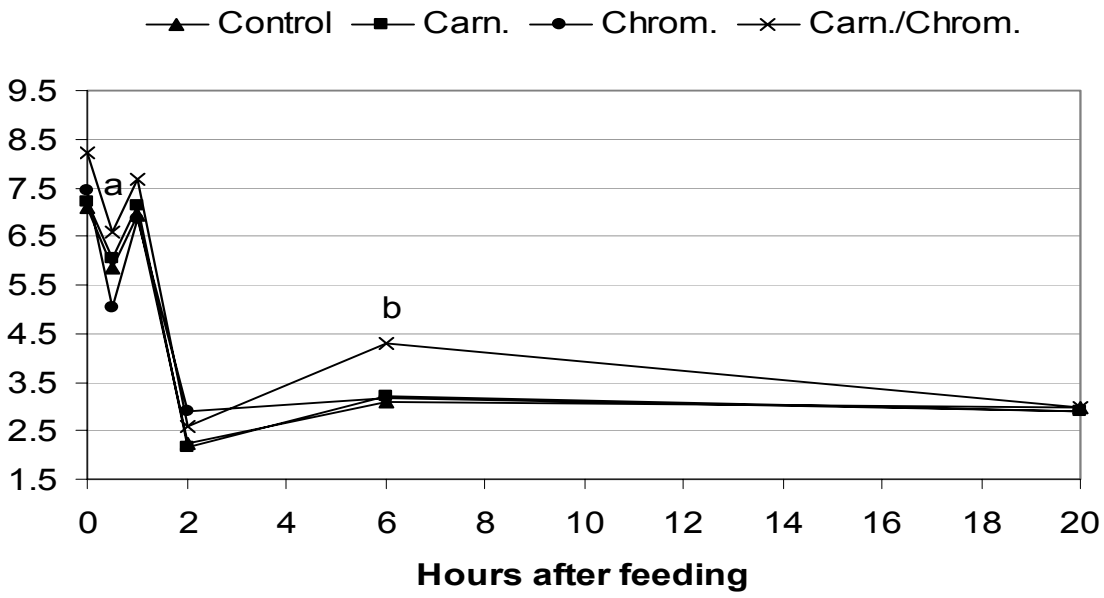

Figure 19. Influence of Carnitine and(or) Chromium on IGF Binding Protein-3 (nmol/L).

[a]Carn. and Carn./Chrom. > Chrom.; P<0.05. [b]Carn./Chrom. > Control and Chrom.; P<0.05.

EFFECTS OF AN ACUTE ENTERIC DISEASE CHALLENGE ON IGF-1 AND IGFBP-3 GENE EXPRESSION IN PORCINE SKELETAL MUSCLE

B. J. Johnson, J. P. Kayser, J. D. Dunn, A. T. Waylan, S. S. Dritz[1], J. C. Nietfeld[2], and J. E. Minton

Summary

Eighteen pigs (initial weight 25 lb and approximately 5 wk of age) were used in a 14-d trial to determine the effects of an acute *Salmonella enterica* serotype typhimurium (ST) disease challenge on both circulating insulin-like growth factor-1 (IGF-1) and insulin-like growth factor binding protein-3 (IGFBP-3) and steady-state IGF-1 and IGFBP-3 mRNA levels in skeletal muscle. Muscle biopsies and blood samples were obtained from all pigs on d 0, 3, 7, and 14 relative to ST-challenge. Results suggest that an acute ST-challenge decreased circulating IGF-1 levels on d 3 and 7 but did not affect circulating IGFBP-3 concentrations. Additionally, ST-challenge had no effect on steady-state IGF-1 and IGFBP-3 mRNA levels in skeletal muscle following the onset of disease. These data suggest that an acute enteric disease insult can lower circulating IGF-1 but more chronic conditions may be necessary to affect local IGF-1 levels in skeletal muscle. Additionally, the increased muscle IGF-1 mRNA without increased IGFBP-3 levels on d 14 most likely results in increased IGF-1 synthesis that contributes to circulating IGF-1 concentrations.

(Key Words: Pigs, *Salmonella*, Muscle, IGF-1, IGFBP-3.)

Introduction

Our previous data with an acute enteric disease (*Salmonella enterica* serotype typhimurium, ST) challenge showed a precipitous decrease in circulating IGF-1 and IGFBP-3 concentrations 48 h after challenge. These data suggest that alterations in IGF/IGFBP levels during a diseased-state may contribute to the reduced skeletal muscle protein accretion. To our knowledge no one has ascertained the effect of an acute enteric disease challenge on local IGF-1 and IGFBP-3 synthesis in skeletal muscle tissue. A more thorough understanding of alterations in local IGF-1 and IGFBP-3 mRNA levels in skeletal muscles of pigs during an acute disease challenge will increase our understanding of the effect of disease on these important growth mediators and, ultimately, protein synthesis and degradation in skeletal muscle. The objective of the current study was to determine the effect of an infectious dose of ST on changes in steady-state IGF-1 and IGFBP-3 mRNA of porcine skeletal muscle.

Procedures

The experimental protocol used in this study was approved by the KSU Institutional Animal Care and Use Committee. A total of 18 pigs (initial weight 25 lb and approxi-

[1]Food Animal Health and Management Center.
[2]Diagnostic Medicine/Pathobiology.

mately 5 wk of age) were randomly allotted to one of two treatments (n=9 pigs per treatment) with weight balanced across the treatments in a 14-d experiment. The two treatments were control or *Salmonella*-challenged (ST). Preceding the study fecal samples were obtained and cultured using standard microbiological direct plating and enrichment techniques at the Kansas State University Veterinary Diagnostic Laboratory to ensure that pigs were not shedding ST prior to challenge.

On d 0, nine pigs were challenged with ST using a challenge model described previously. Pigs were challenged orally with 11×10^9 cfu of ST. The control pigs received sterile medium orally.

Pigs were weighed and feed disappearance was measured on d 0, 7, and 14. On d 7 after challenge, fecal samples were obtained from all pigs and cultured for ST at the Kansas State University Veterinary Diagnostic Laboratory. Rectal temperature was measured on pigs daily from d 0 to 7. Blood samples were obtained via venipuncture on d 0 (prior to challenge), 3, 7, and 14.

Muscle samples (0.5 g) were obtained from the gluteus medius of pigs on d 0, 3, 7, and 14, relative to disease challenge using a biopsy technique. Briefly, pigs were administered general anesthesia. Once pigs reached a surgical plane of anesthesia (approximately 10 min.) the biopsy site was scrubbed thoroughly and a 1-cm incision was performed. A Bergstrom biopsy needle was inserted to obtain approximately 0.5 g of muscle tissue. The incision site was closed with tissue adhesive. Pigs fully recovered within 1.5 hr of the procedure. Muscle samples were immediately homogenized in 10 mL of a preservative solution, followed by rapid freezing in liquid nitrogen and stored at -80°C for subsequent analysis.

Total RNA was isolated according to established procedures. RNA integrity was determined by electrophoresis of total RNA through a 1% agarose formaldehyde gel followed by ethidium bromide staining to visualize 28 and 18S ribosomal RNA (rRNA). Once RNA integrity was assessed, any contaminating DNA was removed. The RNA (1 ug) was reverse transcribed to synthesize the first-strand of cDNA.

All real-time quantitative (RTQ-PCR) reactions were performed on a ABI Prism 7000 sequence detection system, (Applied Biosystems, Foster City, CA). Specific cDNA sequence, forward and reverse primer sequences, and Taq Man detection probe sequences were:

IGF-1: Genbank Accession # M31175, forward primer (38) TCTTCTACTTGGCCCTGTGCTT, reverse primer (110) GCCCCACAGAGGGTCTCA, and TaqMan probe (65) CCTTCAC-CAGCTCTGCCACGGC

IGFBP-3: Genbank Accession #AF085482, forward primer (692) AGCACG-GACACCCAGAACTT, reverse primer (753) CGGCAAGGCCCGTATTC, and TaqMan probe (713) TCCTCTGAGTCCAAGCGCGAGA

Relative expression of IGF-1 and IGFBP-3 were normalized to 18S rRNA with the eukaryotic 18S rRNA endogenous control (ABI Cat. # 4319413E; Genbank Accession # X03205) and were reported as arbitrary units.

Blood collected on d 0, 3, 7, and 14 was allowed to clot at 4°C for 48 h and serum harvested by centrifugation. Serum IGF-1 was determined via immunoradiometric assay as described previously for use in pigs. Circulating concentrations of IGFBP-3 were also determined with a commercially available im-

munoradiometric assay (Diagnostic Systems Laboratories, Inc., Webster, TX, Cat. # DSL 6600).

All data were analyzed with the PROC MIXED procedure of SAS as a completely randomized design with repeated measures over time. The model included terms for the fixed effects of treatment, day, and treatment × day interaction. Unless noted on figures, comparisons of treatment or time were conducted only when a significant main effect or interaction was found.

Results and Discussion

None of the pigs were shedding ST prior to challenge. On d 7 following challenge, 77.8 % (7/9) of pigs orally-challenged with ST were shedding ST in their feces as compared to 0 % (0/9) in the control group. Rectal temperature in ST-challenged pigs did not differ from control pigs during the 14-d trial (data not shown). However, daily feed intake was dramatically reduced in pigs challenged with ST the first week following challenge as compared to control pigs (0.84 lb/d ± .15 vs. 1.61 lb/d ± .11).

Circulating IGF-1 levels did not differ (P>0.10) between control and ST-challenged pigs prior to challenge (Figure 1). Following the oral ST-challenge, infected pigs exhibited a precipitous drop in circulating IGF-1 levels on d 3 as compared to the d 0 value (33 vs. 97 ng/mL). Sera from pigs challenged with ST had reduced (P<0.05) IGF-1 on d 3 and 7 as compared to sera from control pigs (Figure 1). However, by d 14 following challenge, sera from ST-infected pigs had similar circulating IGF-1 as compared to sera from control pigs, suggesting the pigs were recovering from the acute disease challenge (Figure 1). The circulating IGF-1 results need to be viewed with some caution. While the treatment × day interaction tended to be significant (P=0.09) in this study, we believe the treatment comparisons within day are representative. First, the changes reported here mirror results published previously which were obtained from the same ST- disease challenge model. Furthermore, due to the precipitous drop in feed intake the first week following ST-challenge, we would fully expect circulating IGF-1 concentrations to be reduced during this period.

Serum concentrations of IGFBP-3 are illustrated in Figure 2. No significant (P>0.10) treatment × day interaction was observed for circulating IGFBP-3. We did observe a significant day effect (P<0.001). Circulating IGFBP-3 in sera from pigs on d 7 and 14 were elevated (P<0.01) as compared to samples obtained on d 0 and 3.

The effects of ST-challenge on steady-state IGF-1 mRNA levels in muscle are illustrated in Figure 3a. No significant treatment × day interaction was observed for steady-state IGF-1 mRNA levels in muscle of pigs. However, we did detect a significant day effect. Steady-state IGF-1 mRNA in muscle samples obtained on d 14 were significantly greater (P<0.001) than d 0, 3, and 7. In this study, skeletal muscle IGF-1 mRNA levels were unaffected by ST-challenge even though circulating IGF-1 levels were reduced following the acute ST-challenge. These data suggest that an acute disease challenge may not be sufficient to alter local IGF-1 levels in skeletal muscle. However, a more chronic disease challenge could lower IGF-1 levels in skeletal muscle which would affect protein synthesis and degradation rates.

No treatment effect was observed for steady-state IGFBP-3 mRNA levels in muscle samples obtained by biopsy (Figure 3b). It is noteworthy that during the period of increasing muscle IGF-1 mRNA concentrations (d 14) local muscle IGFBP-3 mRNA levels were unaffected. This difference between responses

between muscle IGF-1 and IGFBP-3 gene expression on d 14 may contribute to increased skeletal muscle protein synthesis during periods of rapid muscle accretion in the growing pig. The increased muscle IGF-1 mRNA without increased IGFBP-3 levels on d 14 most likely results in increased IGF-1 synthesis. It is likely that this IFG-1 production exits the muscle and contributes to the increased circulating IGF-1 levels.

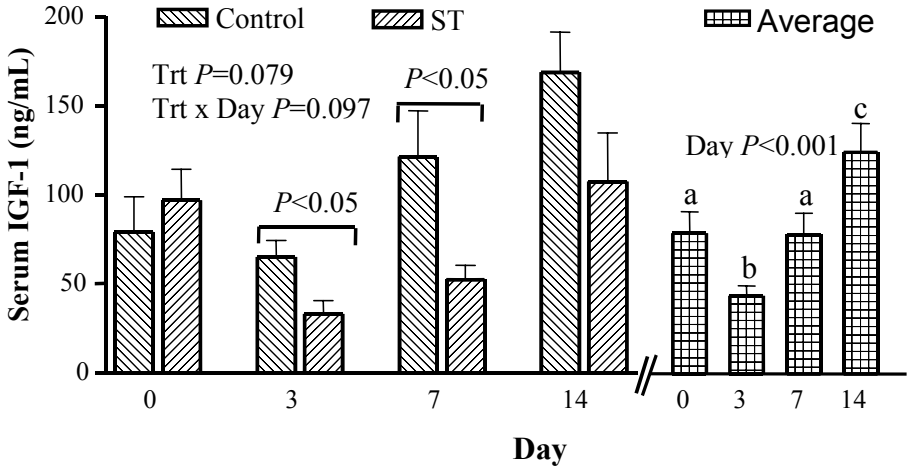

Figure 1. Serum Insulin-Like Growth Factor 1 (IGF-1) Concentrations in ST-Challenged and Control Pigs (n=9). Sera were obtained on d 0, 3, 7, and 14 following challenge.

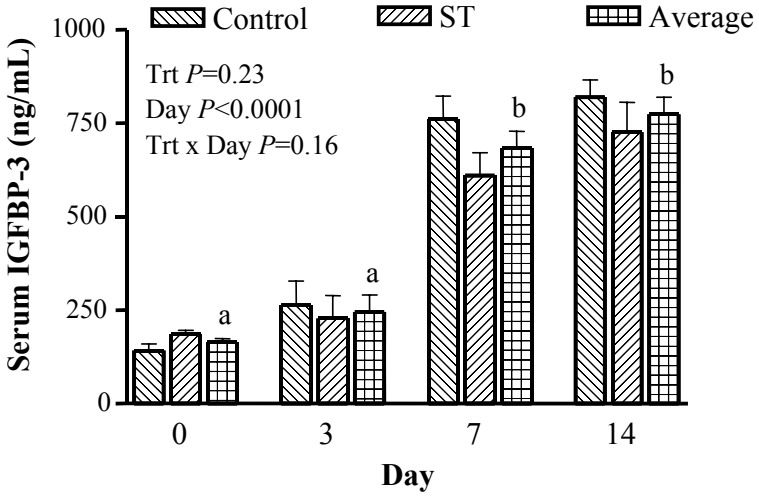

Figure 2. Serum Insulin-Like Growth Factor Binding Protein 3 (IGFBP-3) Concentrations in ST-Challenged and Control Pigs (n=9). Sera were obtained on d 0, 3, 7, and 14 following challenge. Average (day) values with different superscripts differ *P*<0.05.

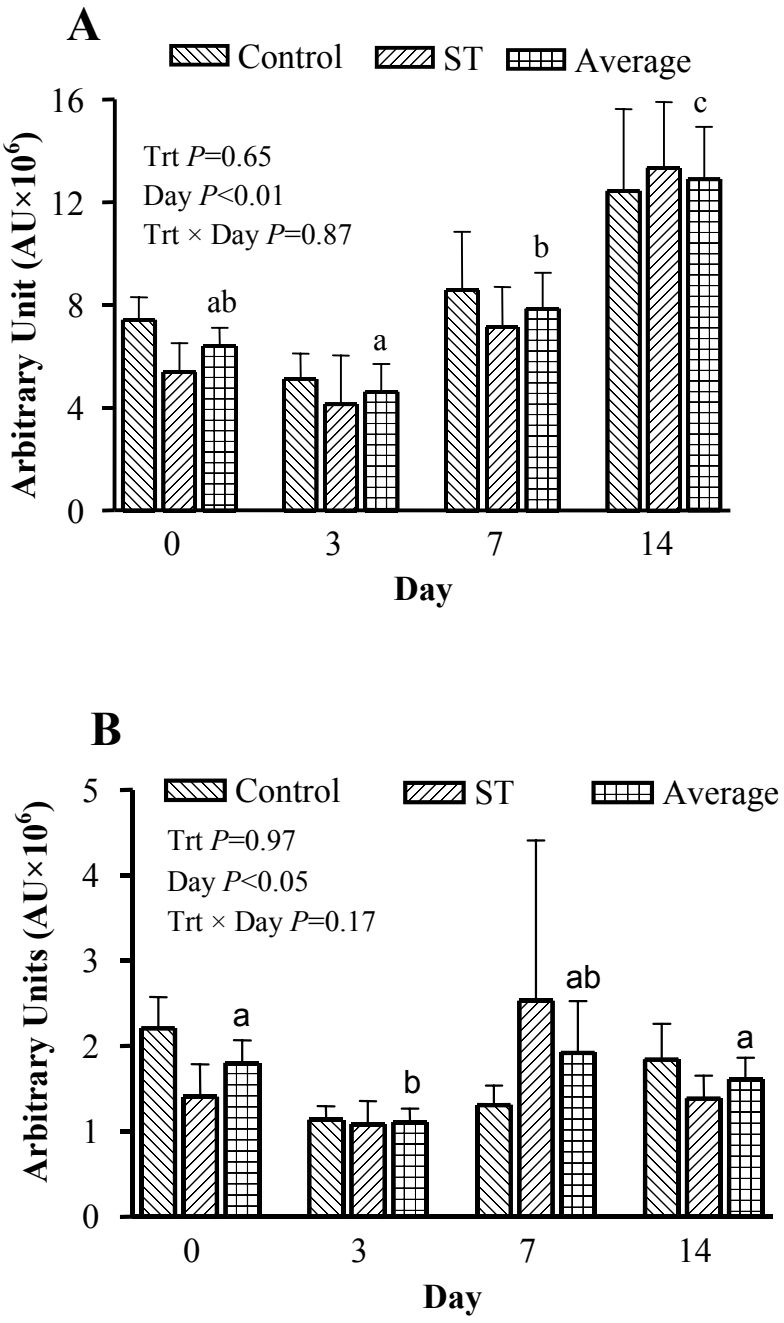

Figure 3. **A) Steady-State Muscle IGF-1 mRNA Levels in Muscle Biopsy Samples Obtained from ST-Challenged and Control Pigs on D 0, 3, 7, and 14 Relative to Disease Challenge. IGF-1 mRNA levels were normalized to 18S rRNA and expressed as arbitrary units. B) Steady-state muscle IGFBP-3 mRNA levels in muscle biopsy samples obtained from ST-challenged and control pigs. IGFBP-3 mRNA levels were normalized to 18S rRNA and expressed as arbitrary units similar to IGF-1.**

EFFECT OF DOSE OF CHLORATE ON GROWTH PERFORMANCE OF NURSERY PIGS

T. E. Burkey, S. S. Dritz[1], and J. E. Minton

Summary

A 14-day growth study was conducted to evaluate the effects of feeding varied levels of chlorate on weanling pig growth performance. A previous experiment with weanling pigs fed diets containing added chlorate (800 ppm) resulted in numerical decreases in ADG, ADFI and F/G as compared to diets with no added antimicrobial, a commonly used antimicrobial (carbadox), or another feed additive, mannanoliogsaccharide. The negative effects of feeding 800 ppm chlorate were confirmed in this study. Additionally, the current trial demonstrated that pigs fed diets containing 200 ppm sodium chlorate had greater ADG, ADFI, and d 14 average weights than pigs fed diets containing 800 ppm sodium chlorate and numerically greater ADG and ADFI than those fed diets without chlorate.

(Key Words: Sodium Chlorate, Antimicrobials, Weanling Pigs.)

Introduction

Oral treatment with sodium chlorate significantly reduced cecal populations of *Salmonella* 16 h after the final dosing with sodium chlorate. In a more recent preliminary report, feeding weaned pigs up to 0.04 g sodium chlorate/kg body weight reduced the number of pathogenic organisms in the intestines by 150-fold. Thus, feeding of sodium chlorate short term appears to offer potential as a preharvest food safety tool to reduce *Salmonella* in the gastrointestinal tract of pigs prior to transport. Based on this data, we hypothesized that feeding chlorate may be used as an alternative to commonly fed antimicrobials. However, feeding sodium chlorate to pigs to enhance growth performance or other physiological parameters has not been extensively evaluated. Additionally, in a study reported elsewhere in this publication, feeding 800 ppm sodium chlorate to weaned pigs reduced feed intake and had a negative impact on growth. Therefore, our objective was to determine if lower rates of dietary sodium chlorate inclusion would affect nursery pig growth performance.

Procedures

A total of 84 pigs (averaging 31.7 lb) were blocked by weight and randomly allotted to one of four dietary treatments (Table 1) in a randomized complete block design at approximately 17 d after weaning. Each pen contained 3 pigs, with 7 replicates (pens) per treatment. Experimental diets were fed in meal form for a total of 14 d. Dietary energy, mineral, and vitamin levels were held constant across all treatments. The dietary treatments included a control (0 ppm sodium chlorate) and three levels of sodium chlorate (200, 400, and 800 ppm). Pigs were weighed and feed disappearance was measured on d 0, 7, and 14 to determine ADG, ADFI, F/G. Data were analyzed using the Mixed procedure of SAS.

[1]Food Animal Health and Management Center.

Results and Discussion

Overall (d 0 to 14), pigs fed diets containing 200 ppm sodium chlorate had greater ADG ($P<0.01$) and ADFI ($P<0.01$) than pigs fed diets containing 800 ppm sodium chlorate (Table 2). Generally, ADG, ADFI, and F/G improved linearly as chlorate content of the diets decreased from 800 to 200 ppm ($P<0.01$, $P<0.02$, and $P<0.08$, respectively). Additionally, there were numerical improvements in ADG and ADFI of pigs fed the 200 ppm chlorate compared to those fed the diets without chlorate. At d 14, pigs fed 200 ppm sodium chlorate had increased body weight ($P<0.01$) compared to pigs fed the diet containing 800 ppm sodium chlorate. Also, there was a strong linear trend for d 14 average weights to be increased as sodium chlorate content decreased from 800 to 200 ppm.

The linear decreases in ADG and ADFI confirm the negative effects observed in a separate experiment when feeding 800 ppm chlorate. Interestingly, results from this experiment indicate that feeding chlorate at levels less than 800 ppm may be beneficial in improving ADG and ADFI in nursery pigs. The initial premise for adding sodium chlorate to weanling pig diets was for the chlorate to function as an antimicrobial agent against enteric pathogens. Thus, further work is warranted to determine if feeding lower levels of chlorate (<800 ppm) result in similar production responses as feeding a commonly used antimicrobial such as carbadox.

Table 1. Composition of Diets

	Chlorate, ppm			
	0	200	400	800
Corn	50.735	50.735	50.735	50.735
Soybean meal	27.94	27.94	27.94	27.94
Soy oil	3.00	3.00	3.00	3.00
Monocalcium phosphate, 21% P	1.20	1.20	1.20	1.20
Limestone	0.675	0.675	0.675	0.675
Salt	0.35	0.35	0.35	0.35
Vitamin premix	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15
Corn starch	1.00	0.98	0.96	0.92
Sodium chlorate	--	0.02	0.04	0.08
Lysine HCl	0.15	0.15	0.15	0.15
DL-methionine	0.05	0.05	0.05	0.05
Select menhaden fish meal	4.50	4.50	4.50	4.50
Spray dried whey	10.00	10.00	10.00	10.00
Total	100.00	100.00	100.00	100.00

[a]All diets were formulated to contain 1.4% total dietary lysine.

Table 2. Effect of Dietary Sodium Chlorate on Growth Performance of Nursery Pigs[a]

	Chlorate					*P*<	
Item	0	200	400	800	SEM	Chlorate	Linear
D 0 to 14							
ADG, lb	1.28	1.35	1.29	1.19	.05	.07	.01
ADFI, lb	1.86	1.93	1.85	1.76	.07	.10	.02
Feed/gain	1.42	1.43	1.44	1.47	.02	.23	.08
Avg. Weight, lb							
d 0	31.7	31.7	31.7	31.6	1.9	.99	.79
d 7	38.1	38.2	38.3	38.1	2.1	.99	.86
d 14	49.6	50.6	49.7	48.4	2.4	.08	.01

[a]Values are means of seven replicate pens (3 pigs/pen).

EFFECTS OF MANNANOLIGOSACCHARIDE AND SODIUM CHLORATE ON GROWTH PERFORMANCE OF NURSERY PIGS DURING AN ACUTE ENTERIC DISEASE CHALLENGE WITH *Salmonella enterica* SEROTYPE TYPHIMURIUM

T. E. Burkey, S. S. Dritz[1], J. C. Nietfeld[2], B. J. Johnson, and J. E. Minton

Summary

A 28-day experiment was conducted to compare the effects of feeding mannanoligosaccharides (mannan) and sodium chlorate (chlorate) to weanling pigs as a possible substitute for the commonly used antimicrobial carbadox. Pigs were fed experimental diets for 2 wk, then challenged orally with *Salmonella enterica* serotype typhimurium to establish enteric disease. Average daily gain and ADFI were greater for pigs fed carbadox than all other treatments in the 2 wk following infection. During the first week after infection, pigs fed chlorate had greater G/F than control pigs, and pigs fed mannan tended to have greater G/F than control pigs. There were no differences in feed efficiency among treatments during the second week following infection.

(Key Words: Mannanoligosaccharides, Sodium Chlorate, Antimicrobials, Weanling Pigs.)

Introduction

Dietary mannan has been shown to enhance growth performance in nursery-aged swine. Mannan may also directly affect gut health in pigs. Another novel feed additive for pigs that shows promise is chlorate, which appears to be effective in reducing the pathogenesis and shedding of *Salmonella* organisms in pigs. In a recent preliminary report, feeding weaned pigs up to 0.04 g chlorate/kg body weight reduced the number of pathogenic organisms in the intestines by 150-fold. Thus, feeding of chlorate short term appears to offer potential as a preharvest food safety tool to reduce *Salmonella* in the gastrointestinal tract of pigs prior to transport. However, the effect of chronic feeding of chlorate to pigs on growth performance and other physiological parameters has not been evaluated.

The current study was designed to evaluate growth in pigs fed mannan or chlorate prior to and after enteric disease challenge with *Salmonella enterica* serotype typhimurium. Although statistically it was possible to compare the effectiveness of mannan versus chlorate, the primary objective was to compare each of the additives individually to either feeding a diet without antimicrobial or to pigs fed diets containing the commonly fed antimicrobial carbadox.

Procedures

Weaned pigs (n=96) were blocked by weight and assigned randomly within blocks to four dietary treatments. The negative control diet contained neither of the two additives or carbadox, while the positive control contained carbadox (55 ppm; Table 1). Test diets

[1]Food Animal Health and Management Center.
[2]Department of Diagnostic Medicine/Pathobiology.

contained mannan (1500 ppm) or chlorate (800 ppm). None of the diets contained other antimicrobial agents. There were 12 pens per treatment with 2 pigs/pen. Pigs were fed diets for 2 wk and then all pigs were given 1.33×10^9 CFU *S. enterica* serotype typhimurium orally and the study continued for an additional 2 wk. Body weights were obtained weekly and feed consumption was measured to estimate average daily gain (ADG), feed intake (ADFI) and feed efficiency (G/F).

Results and Discussion

During week 1 of the study, pigs fed the carbadox grew faster than pigs fed the chlorate diet ($P<0.05$), and in week 2 carbadox fed pigs had greater ADG than pigs fed the mannan or chlorate treatments ($P<0.05$; Figure 1). In week 2, this enhancement in performance was associated with increased ADFI in carbadox fed pigs ($P<0.05$). In week 3, the week following bacterial challenge, negative control pigs had reduced ADG, ADFI, and G/F compared to carbadox-fed pigs ($P<0.05$). During this same time pigs fed chlorate had greater ADG and G/F than negative control pigs ($P<0.05$), although ADG during that time was less than carbadox-fed pigs ($P<0.05$). During week 3, pigs fed mannan tended to have improved G/F relative to negative control pigs ($P<0.07$). Pigs fed the carbadox treatment maintained greater ADG and ADFI than all other treatments during week 4.

Data from the current study are generally consistent with the growth benefits associated with feeding antimicrobials both prior to and following challenge with an enteric pathogen. In general, the pigs fed mannan and chlorate performed similarly to pigs fed no added antimicrobial. However, both mannan and chlorate tended to improve G/F in the week following bacterial challenge and this may suggest improved gut function in the face of the pathogenic insult. In addition, it is clear that this model of enteric disease provides a robust experimental setting in which to test potential alternatives to conventional antimicrobial feed additives for pigs.

Table 1. Diet Composition[a]

	Diet			
Ingredient, %	Negative Control	Carbadox	Mannan	Chlorate
Corn	50.735	50.735	50.735	50.735
Soybean meal	27.94	27.94	27.94	27.94
Soy oil	3.00	3.00	3.00	3.0
Monocalcium phosphate, 21% P	1.20	1.20	1.20	1.20
Limestone	0.675	0.675	0.675	0.675
Salt	0.35	0.35	0.35	0.35
Vitamin premix	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15
Corn starch	1.00		0.85	0.92
Carbadox, 2.5 g/lb		1.00		
Mannan			0.15	
Sodium chlorate				0.08
Lysine HCl	0.15	0.15	0.15	0.15
DL-methionine	0.05	0.05	0.05	0.05
Select menhaden fish meal	4.50	4.50	4.50	4.50
Spray dried whey	10.00	10.00	10.00	10.00
Total	100.00	100.00	100.00	100.00

[a]All diets were formulated to contain 1.4% total dietary lysine.

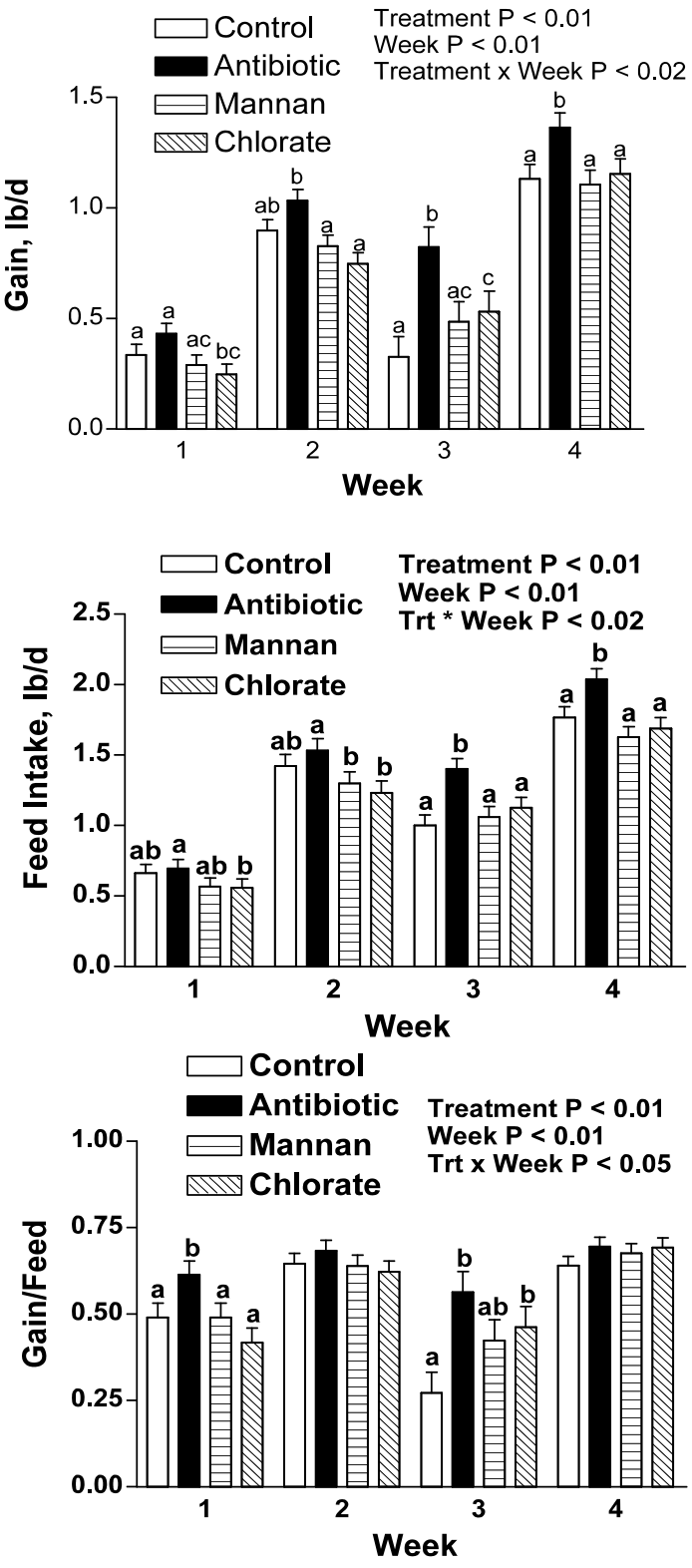

Figure 1. Growth Performance of Pigs Fed Various Dietary Additives Before (Weeks 1 and 2) and After Infection with *S. enterica* serotype typhimurium (Weeks 3 and 4). Within week, bars without common superscripts differ (*P*<0.05).

PILUS GENES IN *Escherichia coli* ISOLATED FROM PIGS WITH DIARRHEA

J. C. Nietfeld[1] and T. Yeary[1]

Summary

A retrospective survey of the Kansas State Veterinary Diagnostic Laboratory records was made for *Escherichia coli* isolated from pigs with diarrhea. There were 111 *E. coli* isolates that carried genes for attachment pili that are necessary for *E. coli* to cause diarrhea. Of the 111 isolates, 103 had one pilus gene and eight had two pilus genes. The most common pilus type was the K88 pilus accounting for 73% of the isolates. All but one of the K88 isolates also carried at least one toxin gene indicating that they were virulent for pigs. The next most common pilus type was F18 accounting for 21% of the isolates. However, more than half of the F18 isolates did not have detectable toxin genes. F41, K99, and 987P pilus types made up 7%, 4%, and 2% of the isolates, respectively (percentages total greater than 100% because some isolates had 2 pilus genes). *Escherichia coli* expressing pilus types K88 and F41 are currently the major causes of colibacillosis in pigs.

Introduction

Enterotoxigenic *Escherichia coli* is an important cause of diarrhea in nursing and weaned pigs. In order for *E. coli* to cause diarrhea it must have two virulence factors: 1) an attachment factor or pilus that allows the bacteria to adhere to epithelial cells lining the small intestine, and 2) the ability to produce one or more toxins that cause active secretion of fluid by the intestinal epithelial cells into the intestine. The pili that are known to occur on enterotoxigenic *E. coli* that affect pigs are K88 (F4), K99 (F5), 987P (F6), F41, and F18. Strains of *E. coli* that express K99 and 987P pili cause diarrhea only during the first week of life. Strains that express F18 pilus cause diarrhea only in weaned pigs, and K88 positive strains cause diarrhea in both nursing and weaned pigs. The majority of strains that express F41 also express other pili, usually K99. F18 pilus also occurs on strains of *E. coli* that cause edema disease in weaned pigs. Toxins associated with enterotoxigenic *E. coli* are heat labile toxin (LT), heat stable toxin a (STa), and heat stable toxin b (STb). Edema disease-causing strains of *E. coli* produce what is known as Shiga-like toxin variant 2e (SLT-2e). The purpose of this study was to determine the *E. coli* pilus types associated with diarrhea in pigs that had samples submitted to the Kansas State University Veterinary Diagnostic Laboratory.

Procedures

Escherichia coli isolates from nursing and weaned pigs with diarrhea are routinely tested by a multiplex polymerase chain reaction (PCR) technique for genes that encode the following pili and toxins: K88, K99, 987P, F18, F41, LT, STa, STb, and SLT-2e. The *E. coli* PCR records for the past 3.5 years were examined and all isolates that contained one or more pilus genes were identified. The types of toxin gene(s) carried by the isolates were also recorded.

[1]Department of Diagnostic Medicine/Pathobiology.

Results and Discussion

There were 111 isolates of *E. coli* carrying genes for pilus production: 103 isolates with one pilus gene and eight isolates with two pilus genes. Eighty-one isolates (73%) possessed genes for K88 pilus and all but one of those isolates carried genes for one or more toxins. Of the K88 positive isolates, 73 carried genes for heat labile toxin (LT) and heat stable toxin b (STb) and one isolate carried the gene for F18 pilus. One isolate had no toxin genes.

The next most common pilus type was F18 with 23 (21%) isolates. However, 13 of the 23 isolates did not have genes for any of the toxins. Of the 10 isolates with toxin genes, nine had genes for both heat stable toxin a and b, and one carried only the heat stable toxin b gene. Five isolates with both heat stable toxin genes also had genes for Shiga-like toxin 2e (SLT-2e), which is associated with edema disease. Two toxin positive F18 isolates also possessed genes for F41 pilus and one isolate carried the gene for K88.

Eight (7%) isolates possessed the gene for F41 pilus. Five of the isolates also had genes for K99 pilus and for heat stable toxin a, and two isolates had genes for F18 pilus plus both heat stable toxins. One F41 isolate had no other pilus or toxin genes.

There were five (4%) isolates that had genes for K99 and all five also had genes for F41 and heat stable toxin a. Two (2%) isolates were positive for the 987P pilus gene. One 987P positive isolate had a gene for heat stable toxin a, and one had genes for both heat stable toxins.

The results of this survey had similarities and differences with those of a similar study from South Dakota State University (SDSU) in 1986 that examined 223 strains of *E. coli* from pigs with colibacillosis (Wilson RA, Francis DH. Fimbriae and enterotoxins associated with *Escherichia coli* isolated from pigs with colibacillosis. American Journal of Veterinary Research 1986;47:213-217). In both studies, K88 was the most common pilus type identified in *E. coli* isolates from pigs, but the percentage of K88 positive isolates in our study (73%) was considerably higher than in the South Dakota study (48%). The primary reason for the increase in the percentage of K88 isolates appears to be a decrease in 987P and K99 positive isolates. In the South Dakota study, 987P accounted for 30% and K99 for 13% of the enterotoxigenic *E. coli* from pigs, whereas their prevalences in our study were 2% and 7%, respectively. These changes are not just restricted to the Kansas State Diagnostic Lab. The K99 and 987P pilus types have almost disappeared from submissions to the SDSU Laboratory, which also tests *E. coli* isolates for the Veterinary Diagnostic Laboratories at Iowa State University and the University of Minnesota (D.F. Francis, personal communication).

The second most common pilus type, F18, is associated with diarrhea and edema disease in weaned pigs and had not been identified when the South Dakota study was performed. The prevalence of F18 positive *E. coli* strains isolated at the Kansas State Laboratory is lower than at some other Midwestern laboratories. The interesting thing about the F18 positive isolates is that over half did not have genes for any of the toxins. If these isolates do not produce an as-of-yet unknown toxin, they should not cause disease.

In the instances where there was an age given for the pigs from which the *E. coli* isolates originated, 87% of the pilus positive isolates were from weaned pigs (data not shown). Based on the results of this survey, the *E. coli* pilus types that swine producers need to be most concerned about are K88 and F18 in re-

cently weaned pigs. Vaccinating sows for the various pilus types is effective in preventing diarrhea in nursing pigs and may be the reason that 987P and K99 pilus types have become uncommon. Both K88 and F18 positive *E. coli* can cause diarrhea in weaned pigs and it is much more difficult to induce protective immunity in the immediate postweaning period. Immunity from the sow's milk and colostrums can inhibit a protective response to vaccination in young pigs, and the level of antibodies in the pigs' sera that were derived from the sow is usually beginning to decline at weaning. Also, when pigs are weaned there is a sudden complete lack of milk antibodies in the intestinal tract, which makes them more susceptible. The trick is to induce immunity during the nursing period in spite of interference by passive colostral and milk antibodies from the sow.

Susceptibility to colonization and diarrhea caused by K88 and F18 pilus positive *E. coli* is inherited. It is possible that there has been inadvertent selection for susceptibility to K88 *E. coli* while selecting for other traits and that this is a major factor in the increase in the importance of the K88 pilus. Currently, different groups are working on control of diarrhea caused by F18 and K88 pilus producing *E. coli* by production of pigs genetically resistant to infection.

THE OPTIMAL TRUE ILEAL DIGESTIBLE LYSINE REQUIREMENT FOR NURSERY PIGS BETWEEN 27 to 44 lb[1]

B. W. James, M. D. Tokach, R. D. Goodband, J. L. Nelssen, S. S. Dritz[2], C. W. Hastad, K. R. Lawrence, and J. L. Usry

Summary

A 20-d growth assay was conducted to determine the appropriate true ileal digestible lysine requirement to maximize growth performance of pigs between 27 to 44 lb. The basal diet (1.0% true ileal digestible lysine; 20.1% CP) was corn-soybean meal-based and was formulated to contain 3% added fat. Sand was substituted with L-lysine·HCl to form the other treatment diets (1.1, 1.2, 1.3, and 1.4% true ileal digestible lysine). The positive control contained more soybean meal than the basal diet (44.2 vs. 32.2% of the diet) and no L-lysine·HCl to provide 1.3% true ileal digestible lysine. Growth performance improved (quadratic, $P<0.04$) with increasing true ileal digestible lysine and was maximized at 1.1% true ileal digestible lysine. Feed efficiency was better (quadratic, $P<0.01$) for pigs fed increasing true ileal digestible lysine and was best for pigs fed 1.3% true ileal digestible lysine. These results indicate that the true ileal digestible lysine requirement for the 27 to 44 lb pig is at least 1.1% for ADG and 1.3% for feed efficiency.

(Key Words: Lysine, Growth Performance, Nursery Pigs.)

Introduction

Lysine, the first limiting amino acid, has been researched extensively in all growth phases of swine. This is because the lysine requirement of pigs is one of the most critical factors affecting profit margin over feed cost. The primary dietary source of lysine and other amino acids is soybean meal, but when the cost of soybean meal increases or cost of crystalline amino acids decreases, the use of other amino acid sources becomes economical. Determining the actual lysine requirement is also an essential element in determining the optimal ratio of other amino acids to lysine. This is especially important as the use of crystalline threonine increases. Recent research conducted at the University of Missouri indicated that the optimal lysine level for 25 to 55 lb pigs may be close to 1.32% true ileal digestible lysine or 1.46% total lysine (PIC female × Dalland boar). However, the requirement may be different for pigs with a different growth capacity. Therefore the objective of this experiment was to determine the appropriate true ileal digestible lysine requirement of nursery pigs between 27 and 44 lb.

Procedures

A total of 180 pigs (PIC L42) were used in a 20-d growth assay. Pigs were weaned at approximately 18-d of age and fed typical nursery diets for 20 d following weaning. On d 20 post-weaning (27.0 lb BW), pigs were blocked by weight and allotted randomly to six dietary treatments in a randomized complete block design. Each treatment had six replications

[1]Appreciation is expressed to Ajinomoto-Heartland lysine, Chicago, IL, for partial support of this experiment.
[2]Food Animal Health and Management Center.

(pens) and five pigs per pen. Pigs were housed in an environmentally controlled nursery. Each pen (4 × 4 ft) contained a stainless steel self-feeder and one nipple waterer to allow ad libitum access to feed and water. Pigs were weighed and feed disappearance measured on d 7, 14, and 20 of the experiment to determine ADG, ADFI, and F/G.

The basal diet (Table 1) was corn-soybean meal-based and contained 3% added fat. In the basal diet (1.0% true ileal digestible lysine; 20.1% CP), sand was substituted with L-lysine·HCl to form the other experimental diets (1.1, 1.2, 1.3, and 1.4% true ileal digestible lysine). In addition, a positive control diet was formulated to contain more soybean meal than the basal diet (44.2 vs. 32.2% of the diet) and no L-lysine·HCl to provide 1.3% true ileal digestible lysine. Diets were formulated using NRC (1998) estimated amino acid concentrations and true digestibility values. Diets were fed in meal form.

Data were analyzed in randomized complete block design using the GLM procedures of SAS with pen as the experimental unit. Linear and quadratic polynomial contrasts were performed to determine the effects of increasing true ileal digestible lysine. Pigs fed the positive control diet (1.3% true ileal digestible lysine; no L-lysine·HCl) were contrasted with pigs fed the experimental treatment containing 1.3% true ileal digestible lysine to determine if there was a difference in growth performance based on lysine source. Pigs fed the positive control diet were also contrasted with the experimental treatment containing 1.0% true ileal digestible lysine to ensure that lysine was below the pigs' requirement in the basal diet.

Results and Discussion

Pigs fed the positive control diet (1.3% true ileal digestible lysine; no L-lysine·HCl) had similar ($P>0.20$) growth performance (Table 2) as those fed 1.3% true ileal digestible lysine (0.38% L-Lysine·HCl). This indicates that pigs respond similarly to lysine from L-Lysine·HCl or soybean meal. Pigs fed the positive control diet had better ($P<0.01$) ADG and F/G than pigs fed 1.0% true ileal digestible lysine which demonstrated that the basal diet was deficient in lysine.

Increasing true ileal digestible lysine improved (quadratic, $P<0.04$) ADG and F/G throughout the experiment. Average daily gain was maximized in pigs fed the diet containing 1.1% true ileal digestible lysine. However, feed efficiency improved as true ileal digestible lysine increased to 1.3%. It is not uncommon to observe that the level needed to maximize feed efficiency is slightly higher than that needed to maximize ADG.

These results suggest that the optimal true ileal digestible lysine requirement for the 27 to 44 lb pig is 1.1% and 1.3% for ADG and F/G, respectively. The requirement observed in this experiment is equal to 1.23% and 1.43% total dietary lysine. These estimates are slightly higher than suggested by the 1998 NRC estimate of 1.01% true ileal digestible lysine. Other recent experiments have shown improvements in growth performance with higher levels of lysine, including the threonine trial in this publication, which observed an improvement in gain as the true ileal digestible lysine level increased from 1.1% to 1.2%. Also, research from the University of Missouri has estimated the lysine requirement at 1.32% true ileal digestible lysine, similar to the requirement for F/G in this experiment.

Table1. Basal Diet Composition (As-Fed Basis)

Ingredient, %	1.0% True Ileal Digestible Lysine	Positive Control
Corn	59.85	47.95
Soybean meal (46.5% CP)	32.27	44.22
Soybean oil	3.00	3.00
Monocalcium phosphate (21% P)	1.65	1.60
Sand	1.00	0.94
Limestone	0.95	0.95
Antimicrobial[a]	0.50	0.50
Salt[b]	0.35	0.35
Vitamin premix	0.25	0.25
Trace mineral premix	0.15	0.15
DL-Methionine	0.04	0.10
Calculated composition		
CP (N × 6.25), %	20.10	24.60
ME, kcal/lb	1,538	1,536
Cal, %	0.79	0.82
P, %	0.74	0.78
Lysine, %	1.13	1.46
Methionine, %	0.36	0.48
Threonine, %	0.77	0.96

[a]Provided 25 g/ton carbadox.

[b]L-Lysine replaced sand to provide either 1.1, 1.2, 1.3, and 1.4% true ileal digestible lysine.

Table 2. Effect of True Ileal Digestible Lysine on Nursery Pig Growth Performance[a,b]

	True Ileal Digestible Lysine, %					Positive		Probability (*P*<)		
Item	1.0	1.1	1.2	1.3	1.4	Control[c,d]	SEM	Lysine	Linear	Quadratic
Day 0 to 7										
ADG, lb	0.79	0.88	0.88	0.82	0.91	0.88	0.05	0.64	0.33	0.74
ADFI, lb	1.34	1.34	1.32	1.20	1.26	1.23	0.06	0.41	0.12	0.87
Feed/gain[e]	1.72	1.52	1.51	1.49	1.40	1.40	0.05	0.01	0.01	0.32
Day 7 to 14										
ADG, lb[e]	1.48	1.56	1.62	1.64	1.54	1.69	0.05	0.04	0.16	0.03
ADFI, lb	2.28	2.23	2.23	2.15	2.04	2.17	0.05	0.06	0.01	0.38
Feed/gain[e]	1.54	1.43	1.37	1.31	1.32	1.29	0.03	0.01	0.01	0.03
Day 14 to 20										
ADG, lb	1.70	1.80	1.70	1.72	1.65	1.76	0.06	0.61	0.39	0.37
ADFI, lb	2.70	2.70	2.59	2.46	2.39	2.55	0.07	0.02	0.01	0.51
Feed/gain[e]	1.59	1.50	1.52	1.44	1.46	1.44	0.04	0.06	0.01	0.36
Day 0 to 20										
ADG, lb[e]	1.30	1.39	1.38	1.38	1.35	1.43	0.03	0.07	0.45	0.04
ADFI, lb	2.08	2.06	2.02	1.91	1.87	1.96	0.04	0.01	0.01	0.48
Feed/gain[e]	1.59	1.48	1.45	1.39	1.39	1.37	0.02	0.01	0.01	0.01

[a]Average initial BW, 27.0 lb.

[b]Values are means of six replicates (pens) and 5 pigs per pen.

[c]Positive control contained 1.3% true digestible lysine with no L-lysine·HCl.

[d]Contrast vs. 1.3% true ileal digestible lysine (P>0.20).

[e]Contrast 1.0% true ileal digestible lysine vs. positive control (P<0.01).

THE OPTIMAL TRUE ILEAL DIGESTIBLE THREONINE REQUIRMENT FOR NURSERY PIGS BETWEEN 24 to 49 lb[1]

B. W. James, M. D. Tokach, R. D. Goodband, S. S. Dritz[2], J. L. Nelssen, and J. L. Usry

Summary

A 22-d growth assay was conducted to determine the appropriate true ileal digestible threonine requirement to maximize growth performance of pigs between 24 and 49 lb. The 10 experimental treatments consisted of two basal diets (1.1% and 1.2% true ileal digestible lysine; 16.1% and 17.4% CP) with increasing levels of threonine (50, 55, 60, 65, 70% threonine:lysine). Pigs fed 1.2% true ileal digestible lysine had improved ADG and F/G compared to pigs fed 1.1% lysine, this suggest that the requirement was greater than 1.1% true ileal digestible lysine. There was a threonine × lysine interaction for feed efficiency. Pigs fed 1.1% true ileal digestible lysine had a greater response to increasing levels of threonine than pigs fed the diet containing 1.2% lysine. Increasing levels of threonine had no effect on ADG. Feed efficiency improved with increasing levels of true ileal digestible threonine:lysine and was maximized at 70% and 65% threonine:lysine for pigs fed 1.1% and 1.2% true ileal digestible lysine, respectively. However, the greatest improvements in feed efficiency were observed as the ratio increased to approximately 60%.

(Key Words: Threonine, Growth Performance, Nursery Pigs.)

Introduction

Several studies have been conducted at Kansas State University to determine the optimal level of threonine for nursery pigs. However, results have been conflicting. As the cost of crystalline amino acids decreases, the use of crystalline threonine and less soybean meal becomes more economical. The objective of this experiment was to determine the appropriate true ileal digestible threonine requirement of nursery pigs between 24 and 49 lb.

Procedures

Three hundred eighty pigs were weaned at approximately 18 d of age. Before initiating the experiment, pigs were allowed a 20-d adjustment period following weaning. At approximately 25 lbs, pigs were randomly allotted to pens (5 pigs/pen and 7 pens/treatment) within blocks based on initial weight. Ten treatments were randomly allotted to pens within blocks. Pigs were housed for the 22-d growth assay in an environmentally controlled nursery. Each pen (4 × 4 ft) contained a stainless steel self-feeder and one nipple waterer to allow ad libitum consumption of feed and water.

Corn and soybean meal were analyzed for complete amino acid profiles. These levels were multiplied by the 1998 NRC true ileal

[1]Appreciation is expressed to Ajinomoto-Heartland Lysine, Chicago, IL, for partial support of this experiment.
[2]Food Animal Health and Management Center.

digestible coefficients and used in diet formulation. The 10 experimental treatments consisted of two basal diets (Table 1) containing 1.1% and 1.2% true ileal digestible lysine with 0.55% and 0.60% true ileal digestible threonine, respectively, and all other amino acids except threonine formulated to meet or exceed NRC requirements. Crystalline L-threonine was added to the basal diets to provide 55, 60, 65, and 70% true ileal digestible threonine:lysine. Experimental treatment diets were fed from 20 to 41 d post-weaning. Pigs were weighed and feed disappearance measured on d 8, 15, and 22 of the experiment.

The performance criteria (ADG, ADFI, F/G) were analyzed in a randomized complete block design using the general linear model (GLM) procedure of SAS with pen as the experimental unit. Linear and quadratic polynomial contrasts were performed to determine the effects of increasing levels of dietary threonine.

Results and Discussion

For the 22-d experiment there was a threonine × lysine interaction ($P<0.04$) for F/G. Pigs fed 1.1% lysine had optimal feed efficiency when fed 70% threonine:lysine with the greatest response occurring as the level of threonine increased from 50% to 55%, whereas pigs fed 1.2% true ileal digestible lysine had optimal feed efficiency when fed the diet containing 65% threonine:lysine. Pigs fed the diets containing 1.2% true ileal digestible lysine had better ADG ($P<0.01$) and feed efficiency than pigs fed 1.1% lysine. This would suggest that the lysine requirement of these pigs was greater than 1.1% true ileal digestible lysine.

Average daily gain was not affected ($P > 0.07$) by increasing levels of true ileal digestible threonine. However, F/G improved (quadratic, $P < 0.01$) with increasing levels of true ileal digestible threonine and was lowest for pigs fed diets containing 70% and 65% threonine:lysine for the 1.1% and 1.2% true ileal digestible lysine diets, respectively. However, feed efficiency started to stabilize as the level of threonine increased to approximately 60% threonine:lysine. These results would support data from our previous studies. In previous research, it was found that the true ileal digestible threonine requirement was approximately 62% of lysine, no improvements in ADG were found but an increase in feed efficiency with increasing levels of dietary threonine was noted.

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

Ingredient, %	1.1% TID Lysine Basal Diet	1.2% TID Lysine Basal Diet
Corn	68.94	65.20
Soybean meal (46.5% CP)	23.61	27.06
Soybean oil	3.00	3.00
Monocalcium phosphate (21% P)	1.70	1.70
Limestone	0.95	0.95
Antimicrobial[b]	0.50	0.50
L-Lysine·HCl	0.41	0.43
Salt[c]	0.35	0.35
Sand	0.25	0.25
Vitamin premix	0.25	0.25
Trace mineral premix	0.15	0.15
DL-Methionine	0.14	0.17
Calculated composition		
CP (N × 6.25), %	16.10	17.40
ME, kcal/lb	1,542	1,541
Cal, %	0.78	0.79
P, %	0.71	0.73
Lysine, %	1.21	1.32
Methionine, %	0.44	0.48
Threonine, %	0.64	0.70

[a]Basal diets contained 50% true digestible threonine:lysine.

[b]Provided 25 g/ton carbadox.

[c]L-Threonine replaced sand to provide either 55, 60, 65, or 70% true digestible threonine:lysine.

Table 2. Effect of Tue Digestible Threonine:Lysine Ratio on Growth Performance of the Nursery Pig[a,b]

	True digestible lysine, %															
	1.10					1.20										
	Threonine, % of lysine											Probability (*P*<)				
Item	50	55	60	65	70	50	55	60	65	70	SEM	Thr×Lys	Lys	Thr	Linear	Quad
Day 0 to 8																
ADG, lb	0.58	0.78	0.74	0.66	0.69	0.79	0.76	0.81	0.79	0.78	0.04	0.09	0.01	0.24	0.60	0.09
ADFI, lb	1.33	1.38	1.27	1.22	1.24	1.34	1.30	1.30	1.24	1.26	0.04	0.54	0.98	0.01	0.01	0.82
Feed/gain	2.33	1.79	1.77	1.89	1.82	1.71	1.74	1.64	1.60	1.66	0.07	0.01	0.01	0.01	0.01	0.01
Day 8 to 15																
ADG, lb	1.22	1.35	1.19	1.15	1.22	1.36	1.40	1.28	1.25	1.37	0.05	0.87	0.01	0.04	0.16	0.36
ADFI, lb	2.06	2.19	1.89	1.78	1.83	2.09	2.04	1.88	1.76	1.90	0.06	0.47	0.69	0.01	0.01	0.13
Feed/gain	1.71	1.63	1.59	1.56	1.51	1.55	1.47	1.48	1.41	1.39	0.04	0.95	0.01	0.01	0.01	0.53
Day 15 to 22																
ADG, lb	1.51	1.49	1.39	1.42	1.47	1.48	1.58	1.54	1.52	1.52	0.05	0.42	0.01	0.62	0.49	0.78
ADFI, lb	2.52	2.35	2.16	2.15	2.15	2.34	2.37	2.28	2.19	2.21	0.06	0.18	0.77	0.01	0.01	0.16
Feed/gain	1.67	1.58	1.55	1.51	1.47	1.58	1.49	1.48	1.44	1.46	0.04	0.80	0.01	0.01	0.01	0.16
Day 0 to 15																
ADG, lb	0.89	1.05	0.95	0.89	0.94	1.05	1.06	1.03	1.02	1.05	0.04	0.27	0.01	0.09	0.53	0.65
ADFI, lb	1.69	1.76	1.56	1.48	1.52	1.69	1.65	1.57	1.50	1.56	0.04	0.38	0.80	0.01	0.01	0.26
Feed/gain	1.92	1.68	1.65	1.68	1.63	1.60	1.56	1.53	1.48	1.48	0.03	0.04	0.01	0.01	0.01	0.01
Day 0 to 22																
ADG, lb	1.08	1.19	1.09	1.06	1.11	1.19	1.22	1.19	1.17	1.20	0.03	0.75	0.01	0.07	0.43	0.80
ADFI, lb	1.95	1.95	1.75	1.69	1.72	1.90	1.88	1.80	1.72	1.76	0.04	0.40	0.97	0.01	0.01	0.13
Feed/gain	1.80	1.64	1.61	1.60	1.55	1.59	1.53	1.51	1.46	1.47	0.02	0.04	0.01	0.01	0.01	0.01

[a]Initial BW, 24.1 lb.
[b]Values are means of seven replications (pens) and five pigs per pen in a 22-d experiment.

EFFECT OF B-VITAMIN SUPPLEMENTATION ON NURSERY PIG GROWTH PERFORMANCE[1]

B. W. James, J. L. Nelssen, R. D. Goodband, M. D. Tokach, and S. S. Dritz[2]

Summary

A 35-d growth assay was conducted to determine the effect of added dietary B-vitamins on growth performance of nursery pigs (12.9 lb initial BW). The basal diet (Phase I, 1.5% lysine; Phase II, 1.3% lysine) was formulated to contain no added B-vitamins. The other treatment diets were formed by adding a B-vitamin premix (biotin, folacin, niacin, pantothenic acid, riboflavin, thiamin, B_6, and B_{12}) to the basal diet with the vitamins added at 1, 2, or 4 times NRC (1998) recommendations. In phase I (d 0 to 14) and for the overall trial, pigs fed increasing B-vitamins had increased (linear, $P<0.04$) ADFI and improved (quadratic, $P<0.04$) feed efficiency. Feed efficiency was best for pigs fed the diet with B-vitamins added at the NRC requirement. There was no effect of B-vitamin level ($P>0.09$) on growth performance in phase II (d 14 to 35). These results suggest that B-vitamin supplementation is necessary to maximize growth performance of early-weaned pigs; however, typical margins of safety for B-vitamins can be lowered without affecting growth performance.

(Key Words: B-vitamins, Growth Performance, Nursery Pigs)

Introduction

Frequently B-vitamins are added to nursery pig diets in excess of recommendations of the 1998 NRC. These high levels are provided as a "safety factor"; however, there is economic interest to lower the amount of vitamins added to these diets that are already relatively expensive. Research conducted at Iowa State University has suggested that the B-vitamin requirement of weanling pigs is higher than what is typically fed in the swine industry. However, that study estimated the requirement from pigs that were previously depleted in B-vitamins. Therefore, the objective of this experiment was to determine the appropriate level of B-vitamins to add to nursery pig diets.

Procedures

One hundred and sixty-eight pigs were weaned at approximately 21 d of age. At weaning, pigs were allotted by weight (12.9 lb BW), ancestry, and sex (equal barrows and gilts in each pen) to four dietary treatments within blocks based on initial weight (6 pigs/pen and 7 pens/treatment). Pigs were housed for the 35-day growth assay in an environmentally controlled nursery. Temperature was maintained at 90°F for the first week and reduced to 85°F the second

[1]Appreciation is expressed to the NCR-42 committee for supplying the vitamin test premix and A, D, E, and K premix. This study is a portion of a larger regional experiment evaluating the effects of increased B-vitamin supplementation.

[2]Food Animal Health and Management Center.

week. Each pen (4 ft^2 with slatted metal flooring) contained a stainless steel self-feeder and one nipple waterer to allow ad libitum consumption of feed and water. Pigs were weighed and feed disappearance measured at d 7, 14, 21, 28 and 35 of the experiment. Pigs subject to removal were weighed and feed consumption determined. Reason for removal or treatment was documented.

Pigs were fed a complex starter diet for phase I (1.5% lysine; 20.9% CP) from d 0 to 14 and a corn-soybean meal spray-dried whey-based diet for phase II (1.3% lysine; 19%CP) from d 14 to 35 (Table 1). The basal diet was formulated with no added B-vitamins. For the other treatment diets, a B-vitamin premix (Table 2) was added to the basal diet to provide B-vitamins at 1, 2, and 4 times the NRC (1998) recommendation. Therefore, those diets contained the added B-vitamins in addition to the concentrations in the base ingredients. The phase I diet was pelleted and phase II was fed in meal form.

Data were analyzed in a randomized complete block design using the GLM procedure of SAS with pen as the experimental unit. Linear and quadratic polynomial contrasts were performed to determine the effects of increasing levels of B-vitamins in weanling pig diets.

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

Ingredient, %	Phase I[b]	Phase II[b]
Corn[c]	35.41	48.54
Soybean meal (46.5% CP)	23.19	24.17
Spray dried whey	20.00	20.00
Lactose	10.00	-
Spray-dried animal plasma	6.00	-
Spray-dried blood cells	-	2.00
Monocalcium phosphate	1.45	1.52
Soybean oil	1.00	1.00
Medication[d]	1.00	1.00
Limestone	0.89	0.76
Salt	0.35	0.35
Zinc oxide	0.28	0.28
L-Lysine·HCL	0.15	0.12
Trace mineral premix[e]	0.13	0.13
DL-Methionine	0.11	0.09
Vitamin A, D, E, K premix	0.05	0.05
B-Vitamin premix[f]	-	-
Calculated composition		
CP (N × 6.25), %	20.9	19.6
ME, kcal/lb	1,494	1,478
Ca, %	0.85	0.82
P, %	0.81	0.77
Total lysine, %	1.50	1.30
Methionine, %	0.41	0.39
Threonine, %	0.96	0.79

[a]Diets were formulated to meet or exceed NRC (1998) requirements.

[b]Phase I was fed from days 0 to 14, phase II from days 14 to 35.

[c]B-vitamin premix replaced corn to provide 1, 2, or 4 lb/ton of premix.

[d]Provided 50 g/ton carbadox.

[e]Contributed per pound of complete diet: Zn (from zinc oxide), 75.97 mg; Fe (from ferrous sulfate), 75.97 mg; Mn (from manganese oxide), 18.0 mg; Cu (from copper sulfate), 7.48 mg; I (from calcium iodate), 0.14 mg; and Se (from sodium selenite), 0.15 mg.

[f]Contributed per lb of complete diet: biotin, 0.023 mg; folacin, 0.14 mg; niacin (available), 8.21 mg; pantothenic acid, 5.10 mg; riboflavin, 1.74 mg; thiamin, 0.45 mg; vitamin B_6, 0.83 mg; and vitamin B_{12}, 8.84 μg. One pound of premix provided the suggested B-vitamin requirement (NRC, 1998) for the 11 lb pig in the complete diet.

Results and Discussion

In phase I (d 0 to 14), there were no differences (P>0.12) in ADG (Table 2). However, pigs fed increasing additions of B-vitamins had increased (linear, P<0.02) ADFI. There were no improvements in F/G from d 0 to 7 or 7 to 14 because of the low variation in the response. Feed efficiency was improved (quadratic, P<0.04) from d 0 to 14 with increasing additions of B-vitamins and was best for pigs fed the B-vitamins added to the NRC requirement.

In phase II, from d 14 to 21, F/G improved (quadratic, P<0.03) with increasing additions of B-vitamins and was also best for pigs fed B-vitamins added at the NRC requirement. From d 28 to 35, ADFI increased (linear,

P<0.01) with increasing additions of B-vitamins. However, there were no differences (*P*>0.09) in growth performance for the overall phase II period.

For the overall experiment, increased additions of B-vitamins had no effect (*P*>0.16) on ADG. This is in contrast to the regional experiment, which this trial was a part of, that demonstrated a quadratic improvement in ADG with the best gain observed in pigs fed B-vitamins added at the NRC requirement. Average daily feed intake increased (linear, *P*<0.04) and F/G improved (quadratic, *P*<0.04) with increasing additions of B-vitamins. Feed efficiency was best for pigs fed the diet containing B-vitamins added at the NRC requirement. These results support those of the regional study in which no further improvements in feed efficiency was observed with increased added B-vitamins above the NRC requirement. These results differ from findings at Iowa State University. This is probably because pigs in our experiment and the regional study were not previously depleted of B-vitamins prior to initiation of the experiment.

These results suggest that B-vitamin supplementation is necessary to maximize growth performance of early-weaned pigs; however, typical margins of safety above the added NRC requirement for B-vitamins can be lowered without affecting growth performance.

Table 2. Levels of B-Vitamin Added per Ton of Complete Feed and Current KSU Starter Diet Recommendation

	Added B-Vitamin Concentration			
Ingredient, per ton	NRC	2×NRC	4×NRC	KSU
Biotin, mg	46	92	184	0
Folacin, mg	280	560	1,120	0
Niacin (available), g	16.42	32.84	65.68	45.00
Pantothenic acid, g	10.20	20.40	40.80	25.00
Riboflavin, g	3.48	6.96	13.92	7.50
Thiamin, g	0.90	1.80	3.60	0
B_6, g	1.66	3.32	6.64	[a]
B_{12}, mg	17.68	35.36	70.72	35.00

[a]KSU recommends adding 2 g of pyridoxine per ton of complete feed for pigs weighing less than 15 lb.

Table 3. Effect of B-Vitamin Supplementation on Nursery Pig Growth Performance[a,b,c]

	B-Vitamin					Probability (*P*<)		
Item	0	NRC	2×NRC	4×NRC	SEM	B-Vitamin	Linear	Quadratic
Day 0 to 7								
ADG, lb	0.65	0.66	0.69	0.65	0.03	0.82	0.84	0.47
ADFI, lb	0.55	0.56	0.59	0.58	0.02	0.61	0.30	0.68
F/G	0.87	0.85	0.86	0.89	0.02	0.49	0.36	0.22
Day 7 to 14								
ADG, lb	0.78	0.81	0.81	0.87	0.03	0.23	0.06	0.53
ADFI, lb	0.92	0.90	0.93	1.02	0.03	0.04	0.02	0.09
F/G	1.18	1.12	1.17	1.17	0.03	0.30	0.89	0.22
Day 14 to 21								
ADG, lb	1.05	1.14	1.11	1.11	0.04	0.52	0.48	0.32
ADFI, lb	1.45	1.50	1.48	1.57	0.04	0.24	0.08	0.60
F/G	1.39	1.31	1.34	1.43	0.03	0.11	0.39	0.03
Day 21 to 28								
ADG, lb	1.26	1.20	1.23	1.28	0.05	0.71	0.71	0.29
ADFI, lb	1.97	1.96	1.97	2.04	0.06	0.81	0.45	0.56
F/G	1.56	1.64	1.61	1.60	0.04	0.59	0.58	0.31
Day 28 to 35								
ADG, lb	1.68	1.70	1.71	1.74	0.04	0.74	0.28	0.95
ADFI, lb	2.53	2.49	2.62	2.62	0.04	0.10	0.05	0.64
F/G	1.51	1.46	1.54	1.51	0.02	0.17	0.53	0.63
Day 0 to 14								
ADG, lb	0.71	0.73	0.75	0.76	0.02	0.46	0.12	0.94
ADFI, lb	0.74	0.73	0.76	0.80	0.02	0.07	0.02	0.29
F/G	1.04	0.99	1.02	1.05	0.02	0.11	0.37	0.04
Day 14 to 35								
ADG, lb	1.32	1.35	1.35	1.38	0.03	0.73	0.30	0.96
ADFI, lb	1.98	1.98	2.02	2.08	0.04	0.33	0.09	0.58
F/G	1.49	1.47	1.50	1.51	0.01	0.23	0.19	0.28
Day 0 to 35								
ADG, lb	1.08	1.10	1.11	1.13	0.02	0.53	0.16	0.99
ADFI, lb	1.48	1.48	1.52	1.57	0.03	0.20	0.04	0.50
F/G	1.37	1.34	1.37	1.38	0.01	0.03	0.07	0.04

[a]Average initial BW, 12.9 lb.

[b]Values are means of seven (pens) and six pigs per pen.

[c]Dietary lysine was 1.5% in phase I (days 0 to 14) and 1.3% in phase II (days 14 to 35).

EFFECT OF PHYTASE DOSAGE AND SOURCE ON GROWTH PERFORMANCE OF NURSERY PIGS

B. W. James, M. D. Tokach, R. D. Goodband, J. L. Nelssen, S. S. Dritz[1], and G. L. Lynch[2]

Summary

A 28-d growth assay was conducted to determine the effect of phytase dosage and source on growth performance of nursery pigs. The nine experimental treatments were control diets (0.13, 0.18, and 0.23% available phosphorus) and phytase (100, 225, or 350 FTU or FYT/kg) from either Natuphos® or Ronozyme™ P added to the 0.13% available P diet. The results of this experiment indicate that increasing available P or phytase level, through 0.23% available P and 350 FTU or FYT/kg, respectively, improves ADG and feed efficiency. Regression analysis of the ADG response indicated that, when adding less than 350 phytase units/kg, each 100 phytase units/kg will release 0.022 and 0.017% available P for Natuphos® and Ronozyme™ P, respectively.

(Key Words: Phytase, Phosphorus, Nursery Pigs.)

Introduction

Supplementing phytase in swine diets is becoming an increasingly common method to improve the availability of phosphorus in plant ingredients containing high levels of phytate phosphorus. The improved phosphorus availability lowers the amount of phosphorus in diets and thus contributes to a greater economic return. The addition of phytase to swine diets has also been shown to decrease phosphorus excretion by up to 30%. The environmental benefits associated with using phytase are becoming more important as many states are changing nutrient plans from a nitrogen to a phosphorus basis. Natuphos®, a product of *Aspergillus niger*, produced by BASF, has previously been the primary source of phytase in the United States. In 2000, Roche released a product called Ronozyme™ P (CT), a product of *Peniophoria lycii*. Data evaluating the efficacy of Ronozyme™ P compared to Natuphos® has been conflicting. Therefore, the objective of this experiment was to determine if Natuphos® and Ronozyme™ P have equal effects on growth performance and bone development of the growing pig.

Procedures

Initially, a pilot study was conducted with available phosphorus levels of 0.20, 0.30, and 0.40% to ensure a linear response to increasing available phosphorus. The pilot study response in ADG and F/G from 0.20 to 0.30% available phosphorus was not significant. Therefore, the basal diet in this experiment was corn-soybean meal based and was formulated to contain 5% added fat, 1.4% total lysine, and 0.13% available phosphorus as a negative control (Table 1).

[1]Food Animal Health and Management Center.
[2]BASF Corporation, Mount Olive, NJ.

A total of 342 pigs (PIC L42) were used in the 28-d growth assay. Pigs were fed a typical starter diet from d 0 to 10 post-weaning with 0.45% available phosphorus. From d 17 to 20 post-weaning pigs were fed a common diet without inorganic phosphorus (0.10% available phosphorus) to ensure a response to increasing phosphorus in the experiment. On d 20 post-weaning (23.4 lb BW) pigs were blocked by weight and allotted randomly to nine dietary treatments in a randomized complete block design. Each treatment had eight replications and four or five pigs per pen.

Monocalcium phosphate was substituted for sand to form the other control diets (0.18 and 0.23% available phosphorus). Phytase (100, 225, or 350 FTU or FYT/kg) from either Natuphos® or Ronozyme™ P was added to the 0.13% available phosphorus diet at the expense of sand. Calcium to total phosphorus ratio was maintained at 1.12:1 in all diets. All ingredients providing either calcium or phosphorus to the diet were analyzed for calcium and phosphorus concentration before diet formulation and analyzed values agreed with formulated values. Phytase from Natuphos® and Ronozyme™ P also was analyzed prior to diet formulation to equalize actual phytase level in the experimental treatments.

Pigs were housed in an environmentally controlled nursery. Each pen (4 × 4 ft) contained a stainless steel self-feeder and one nipple waterer to allow ad libitum access to feed and water. Pigs were weighed and feed disappearance measured every 7 d during the experiment.

Data were analyzed in randomized complete block design using the GLM procedures of SAS with pen as the experimental unit. Linear and quadratic polynomial contrasts were performed to determine the effects of increasing levels of available phosphorus and phytase. Contrasts were performed to compare phytase sources. A regression analysis of the average daily gain response was conducted by calculating the improvement in average daily gain with each incremental increase (0.05 and 0.10%) in available phosphorus over the negative control. This line was then used to calculate the percent available phosphorus that was released by comparing the average daily gain curve of each source of phytase with that of the controls.

Results and Discussion

Increasing available phosphorus linearly ($P<0.01$) improved ADG, ADFI, and feed efficiency throughout the experiment (Table 2). There were no phytase source × level interactions ($P>0.23$) or differences between phytase sources ($P>0.27$) observed. Increasing phytase linearly ($P<0.01$) increased ADG and feed efficiency. Feed intake increased (quadratic, $P<0.05$) with increasing phytase. Regression analysis of the ADG response (Figure 1) indicated that, when adding less than 350 phytase units/kg, each 100 phytase units/kg will release 0.022 and 0.017% available phosphorus for Natuphos® and Ronozyme™ P, respectively. Therefore, these values can be used in diet formulation when either of the products is added to adjust dietary phosphorus concentrations.

Table.1 Basal Diet Composition (As-Fed Basis)

	Available P, %		
Ingredient, %	0.13[a]	0.18	0.23
Corn	57.98	57.98	57.98
Soybean meal (46.5% CP)	34.15	34.15	34.15
Soybean oil	5.00	5.00	5.00
Sand	0.60	0.30	0.00
Limestone	0.52	0.56	0.60
Antimicrobial[b]	0.50	0.50	0.50
Salt	0.35	0.35	0.35
Monocalcium phosphate, 21% P	0.32	0.57	0.83
Vitamin premix	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15
L-Lysine·HCl	0.15	0.15	0.15
DL-Methionine	0.04	0.04	0.04
Calculated composition			
CP (N × 6.25), %	20.80	20.80	20.80
ME, kcal/lb	1,614	1,614	1,614
Cal, %	0.46	0.52	0.58
P, %	0.41	0.46	0.51
Available P, %	0.13	0.18	0.23
Lysine, %	1.30	1.30	1.30
Methionine, %	0.36	0.36	0.36
Threonine, %	0.81	0.81	0.81

[a]Phytase from either Natuphos® or Ronozyme™ P was added to provide 100, 225, or 350 FTU or FYT/kg at the expense of sand.
[b]Provided 25 g/ton carbadox.

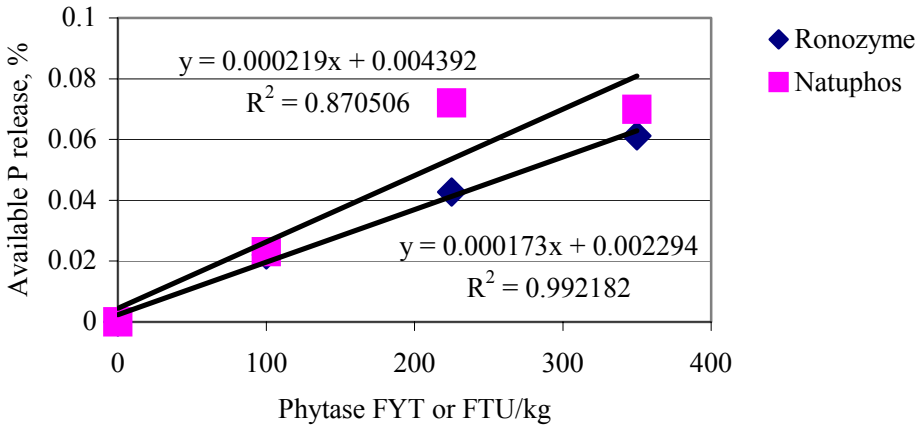

Figure 1. Regression of ADG to Determine Available P Release from Each Unit of Phytase.

Table 2. Effect of Available Phosphorus and Phytase Source on Growth Performance of Nursery Pigs[a]

				Phytase source [b,c]													
				Ronozyme™ P, FYT/kg			Natuphos®, FTU/kg				Probability (*P*<)					
	Available P, %												Available P, %		Phytase level	
Item	0.13	0.18	0.23	100	225	350	100	225	350	SEM	Trt	Source	Linear	Quad	Linear	Quad
Day 0 to 7																
ADG, lb	0.97	1.01	0.97	0.95	0.97	0.98	0.98	1.06	0.97	0.03	0.51	0.21	0.97	0.24	0.90	0.17
ADFI, lb [d]	1.39	1.39	1.30	1.30	1.33	1.33	1.40	1.44	1.31	0.04	0.10	0.07	0.09	0.25	0.51	0.17
Feed/gain	1.43	1.38	1.35	1.37	1.37	1.37	1.45	1.36	1.35	0.03	0.17	0.50	0.05	0.74	0.09	0.48
Day 7 to 14																
ADG, lb	1.36	1.40	1.56	1.34	1.39	1.40	1.35	1.45	1.48	0.04	0.01	0.13	0.01	0.31	0.02	0.41
ADFI, lb [d]	2.00	2.02	2.06	1.94	1.98	1.97	2.03	2.12	2.03	0.05	0.39	0.03	0.41	0.89	0.75	0.23
Feed/gain	1.47	1.46	1.32	1.45	1.42	1.41	1.51	1.47	1.37	0.03	0.01	0.42	0.01	0.11	0.01	0.60
Day 14 to 21																
ADG, lb	1.48	1.55	1.71	1.49	1.48	1.64	1.51	1.57	1.57	0.04	0.01	0.66	0.01	0.29	0.01	0.50
ADFI, lb	2.33	2.42	2.63	2.26	2.32	2.43	2.34	2.45	2.37	0.05	0.01	0.29	0.01	0.22	0.07	0.51
Feed/gain	1.58	1.57	1.53	1.52	1.57	1.49	1.55	1.55	1.52	0.03	0.21	0.32	0.22	0.70	0.10	0.02
Day 21 to 28																
ADG, lb	1.50	1.77	1.89	1.72	1.82	1.82	1.66	1.81	1.88	0.05	0.01	0.98	0.01	0.32	0.01	0.27
ADFI, lb	2.61	2.92	3.16	2.76	2.95	2.93	2.70	3.00	2.99	0.06	0.01	0.76	0.01	0.60	0.01	0.03
Feed/gain	1.75	1.65	1.68	1.61	1.62	1.61	1.62	1.66	1.59	0.03	0.04	0.63	0.26	0.19	0.58	0.25
Day 0 to 28																
ADG, lb	1.33	1.43	1.53	1.37	1.42	1.45	1.38	1.47	1.47	0.03	0.01	0.27	0.01	0.86	0.01	0.28
ADFI, lb [e]	2.08	2.19	2.27	2.06	2.15	2.16	2.12	2.25	2.17	0.04	0.01	0.09	0.01	0.81	0.08	0.05
Feed/gain	1.57	1.53	1.49	1.50	1.51	1.49	1.54	1.53	1.47	0.01	0.01	0.29	0.01	0.97	0.01	0.15

[a]Values are means of eight replications (pens) and four or five pigs per pen.

[b]Diets were identical to treatment containing 0.13% available phosphorus with exception of phytase.

[c]No phytase level × source interactions ($P>0.14$).

[d]Contrast Ronozyme ™ P vs Natuphos® ($P\leq0.04$).

[e]Contrast Ronozyme ™ P vs Natuphos® ($P\leq0.06$).

EFFECTS OF WEANING AGE ON POST-WEANING BELLY NOSING BEHAVIOR AND UMBILICAL LESIONS

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

Summary

Pigs (n=2272) were weaned at 12, 15, 18, or 21 days of age to determine the effect of weaning age on post-weaning belly nosing behavior and associated umbilical lesions. A reduction (quadratic, $P<0.01$) in belly nosing behavior and umbilical lesions were observed as weaning age increased. The largest decrease in belly nosing behavior was observed as wean age increased from 12 to 15 days, with smaller incremental reductions in the 18 and 21 day wean pigs. This study indicates that weaning pigs at less than 15 days of age significantly increases belly nosing behavior and associated umbilical lesions after weaning.

(Key Words: Weaning Age, Belly Nosing, Navel Sucking.)

Introduction

Belly nosing and associated navel sucking behavior can be behavioral problems in weanling pigs. Belly nosing or navel sucking behavior often leads to significant lesions in the umbilical region. These lesions are primarily due to physical irritation. However, the physical irritation also serves as a pathway for localized or blood-borne infections. Inflammation in the umbilical region due to either physical damage or localized infection is thought to be a contributing factor to umbilical hernias. Observational reports often associate the prevalence or severity of these behavioral challenges with pigs weaned at very young ages. However, limited research has been conducted to determine the effects of weaning age on belly nosing behavior and umbilical lesions. The objectives of this study were to determine the effects of weaning age on post-weaning belly nosing behavior and umbilical lesions.

Procedures

This study was conducted on pigs from a 7,300-head sow farm. Pigs were housed in single source, all-in all-out nursery sites. Treatments included weaning litters of pigs from sows at 12, 15, 18, or 21 days of lactation. This study was completed in four blocks, with all pigs within block being weaned on a single day into an independent off-site nursery. Pigs (PIC 280 x C22, n=2,272) were individually tagged and weighed 3 d before weaning. At weaning, pigs of each age group were allotted using individual pig weight and gender information. Each block had four replicate pens per weaning age. Each pen contained an equal number of barrows and gilts and was representative of the normal weight distribution of barrows and gilts being weaned within each age group. Allotting pigs to treatment in this manner ensured that each pen

[1]Food Animal Health and Management Center.

served as a replicate of the population of pigs being weaned within each age group and block. Pens contained 34 pigs in block 1 and 36 pigs in blocks 2, 3, and 4. Nursery pens were 6 by 12 ft with wire flooring and two nipple waters. Each pen contained a double-sided feeder with five holes on each side. All pigs were fed a common three-phase nursery feed budget (Table 1).

Table 1. Feed Budget and Diet Composition

	Nursery Diets		
	Phase I	Phase II	Phase III
Feed budget (lb/head)	3	6	Remainder
Composition of diet %			
Spray-dried animal plasma, %	2.85	-	-
Lactose, %	20	12	-
Lysine, (true digestible) %	1.37	1.21	1.14
Kcal of ME / lb	1580	1580	1570

Each nursery pen was observed for 15 minutes during the morning of day 7, 14, and 21 after weaning. The number of pigs demonstrating belly nosing behavior in each pen was recorded. The umbilical region of each pig was examined on day 21 post-weaning after the observation period. The umbilical region was classified as to the extent of visual lesions present. The umbilical region classifications were normal, moderate lesion, or severe lesion. Amount of inflammation, swelling, and physical deformity were used to determine the classification. Umbilical region classifications were assigned numeric values of normal = 0; moderate lesion = 5; severe lesion = 15. The belly nosing behavior prevalence and 21-day umbilical scores were analyzed for linear and quadratic effects with pen serving as the experimental unit for all statistical analyses.

Results and Discussion

Belly nosing behavior (Figure 1) and umbilical lesions (Figure 2) were reduced (quadratic, $P<0.01$) as weaning age increased. These data indicate weaning age significantly affects both belly nosing behavior and associated umbilical lesions within a segregated early wean production scheme. Although numeric reductions in both belly nosing prevalence and umbilical lesion scores continued up through the 21-day wean pigs, the most pronounced decrease in prevalence and lesion scores were observed as weaning age increased from 12 to 15 days of age. This study indicates that weaning pigs of less than 15 days of age significantly increases belly nosing behavior and associated umbilical lesions. Therefore, weaning age is an important factor to consider when investigating increased rates of belly nosing behavior or umbilical lesions.

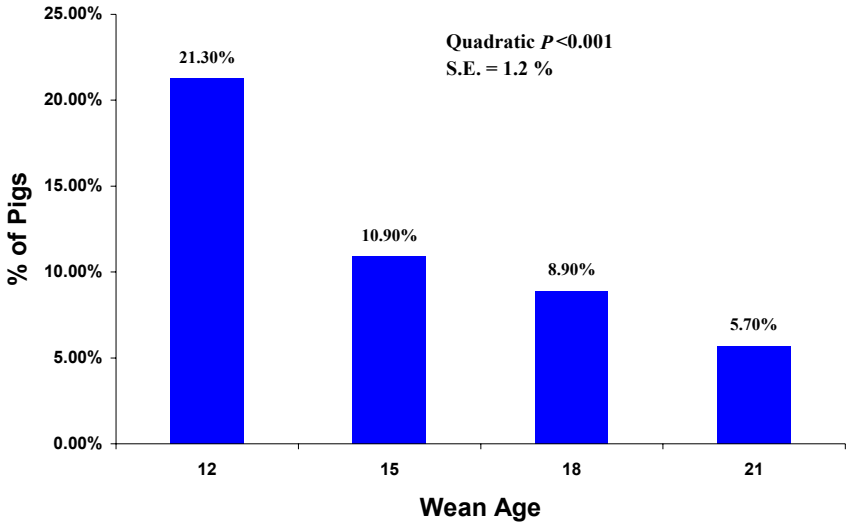

Figure 1. Proportion of Pigs Demonstrating "Belly Nosing/Navel Sucking" Behavior Post-weaning (as observed on day 7, 14, 21 post-weaning for 15 minutes/pen).

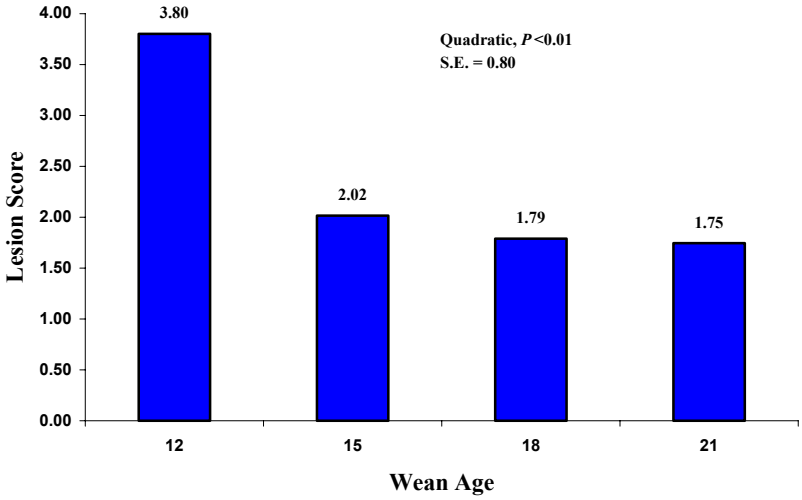

Figure 2. Mean "Navel/Umbilical Lesion" Score (Normal = 0, Moderate = 5, Severe = 15).

EVALUATION OF THE EFFECTS OF WHEAT GLUTEN SOURCE AND ANIMAL PLASMA BLENDS ON THE GROWTH PERFORMANCE OF NURSERY PIGS

K. R. Lawrence, R. D. Goodband, M. D. Tokach, J. L. Nelssen, S. S. Dritz[1], J. M. DeRouchey, S. M. Hanni, C. N. Groesbeck, C. W. Hastad, M. G. Young, B. W. James, and T. P. Keegan

Summary

A total of 472 weanling pigs (initially 13.5 lb) were used in two experiments to evaluate the effects of wheat gluten source (WG) and combinations with spray-dried animal plasma (SDAP) on growth performance of nursery pigs. In Exp. 1, the five dietary treatments included a control diet containing 6% SDAP, wheat gluten that was enzymatically hydrolyzed (Source 1), and a non-hydrolyzed wheat gluten (Source 2). The wheat gluten sources replaced L-lysine HCl and replaced 50% or 100% of the spray-dried animal plasma. From d 0 to 7, 7 to 14, and 0 to 21, increasing wheat gluten decreased (linear; $P<0.05$) ADG. There were no differences between wheat gluten sources. Average daily feed intake decreased similar to ADG, with the exception that ADFI of pigs fed wheat gluten Source 2 had only a slight decreasing trend ($P<0.11$) from d 0 to 7. Pigs fed the diet containing 6% SDAP had the greatest ADG and ADFI from d 0 to 21. When the SDAP was replaced with either wheat gluten source, ADG and ADFI linearly decreased ($P<0.01$) but F/G improved ($P<0.04$). When pigs were fed the common diet from d 21 to 35, there were no differences ($P<0.05$) in ADG, ADFI or F/G. In Exp. 2, the six dietary treatments included a negative control with no SDAP or WG (0:0 ratio), 9% WG (100:0 ratio), 6.75% WG and 1.25% SDAP (75:25 ratio) combination, 4.5% WG and 2.5% SDAP (50:50 ratio) combination, 2.25% WG and 3.75% SDAP (25:75 ratio) combination, and a positive control with 5% SDAP (0:100 ratio). The wheat gluten (Source 1) was enzymatically hydrolyzed, but from a different lot than Exp. 1. From d 0 to 14, pigs fed 6% SDAP had numerically greater ADG and ADFI compared to pigs fed the negative control diet. However, replacing SDAP with increasing amounts of WG tended to decrease ($P<0.10$) ADG and ADFI. These results confirm the improved ADG and ADFI of pigs fed SDAP immediately after weaning. In these experiments, replacing SDAP with WG resulted in decreased ADG.

(Key Words: Wheat Gluten, Spray-Dried Animal Plasma, Nursery Pigs.)

Introduction

Wheat gluten is derived from wheat flour that is mixed with water to form a dough and then is separated into gluten, starch, and effluents. After the separation process, wheat gluten is washed to remove excess starch and then dried at low temperatures in ring driers. This results in a wheat by-product, vital wheat gluten. The dried wheat gluten can be further processed by enzymatic hydrolysis. Enzymatic hydrolysis results in a wheat protein that is highly soluble, has a high protein content, and is very digestible. Previous research at Kansas State University has shown that pigs fed a 50:50 blend of spray-dried porcine

[1]Food Animal Health and Management Center.

plasma (SDPP):wheat gluten had greater ADG and ADFI compared to those fed a control diet containing 8% SDPP. Wheat gluten has become increasingly available from a variety of sources. The objective of this experiment was to determine the effects of substituting enzymatically hydrolyzed and non-modified ring-dried wheat gluten for spray-dried animal plasma (SDAP). Our second objective was to determine the effects of combinations of WG and SDAP on the growth performance of nursery pigs.

Procedures

In Exp. 1, a total of 220 pigs (initially 13.4 lb and 21 ± 3 d of age) were used in a 35-d growth assay. There were six pigs per pen and eight pens per treatment. Experimental diets were fed to all pigs from d 0 to 21 after weaning. All diets were corn-soybean meal-based and formulated to 1.26% digestible lysine corresponding to a range of 1.46% to 1.51% total lysine, 1.04% Ca, and 0.56% available phosphorus (Table 1). The control diet contained 6% SDAP, with SDAP being replaced with either 50% or 100% enzymatically hydrolyzed wheat gluten Source 1 or non-modified flash-dried wheat gluten Source 2 and L-lysine HCl for the other diets to consist of 3% SDAP combined with 3% wheat gluten Source 1 or 2 (50:50 blend), or 6% wheat gluten Source 1 or 2 (0:100 ratio). Pigs were fed the same common diet from d 21 to 35 after weaning.

In Exp. 2, a total of 252 pigs (initially 13.7 lb and 21 ± 3 d of age) were used in a 28-d growth assay. There were six pigs per pen and six pens per treatment. Experimental diets were fed to all pigs from d 0 to 14 after weaning. All diets were corn-soybean meal-based and formulated to 1.50% total lysine, 0.85% Ca, and 0.43% available phosphorus (Table 2). The six dietary treatments included a negative control with no SDAP or WG (0:0 ratio), 9% wheat gluten (100:0 ratio), 6.75% WG and 1.25% SDAP (75:25 ratio) combination, 4.5% WG and 2.5% SDAP (50:50 ratio) combination, 2.25% WG and 3.75% SDAP (25:75 ratio) combination, and 5% SDAP (0:100 ratio). All pigs were fed the same common diet from d 14 to 28 after weaning.

In both experiments, all pigs were housed in the Kansas State University Swine Teaching and Research Center's environmentally controlled nursery, with a self-feeder and nipple waterer in each pen to allow ad libitum access to feed and water. Average daily gain, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance every 7 d upon initiation of the experiments.

Data were analyzed using the MIXED procedure of SAS as a randomized complete block design with pen as the experimental unit. For Exp. 1, linear and quadratic contrasts were used to determine the effects of wheat gluten sources. In Exp. 2, linear and quadratic contrasts were used to determine the effects of an increasing wheat gluten to decreasing SDAP ratio. Least significant differences also were used for making pairwise comparisons of the treatment means in each experiment.

Results and Discussion

In Exp. 1, ADG and ADFI decreased (linear, $P<0.05$) from d 0 to 7 and d 7 to 14 with increasing wheat gluten Source 1. Also, increasing wheat gluten Source 2, decreased (linear, $P<0.05$) ADG from d 0 to 7 and ADG and ADFI (linear, $P<0.05$) from d 7 to 14. From d 14 to 21 there were no differences in ADG or F/G, but there was a decrease (linear, $P<0.05$) in ADFI when either wheat gluten source was fed. Pigs fed the control diet had the highest intake with the diet containing 6% wheat gluten source having the lowest ADFI. For the overall treatment period, d 0 to 21,

there was a decrease (linear, $P<0.05$) for both ADG and ADFI when either wheat gluten source was added. However, there was also an improvement in F/G (linear, $P<0.05$) when wheat gluten Source 2 was added to diets. Feed efficiency was best for pigs fed 6% wheat gluten Source 2, with the pigs fed 5% SDAP having the poorest F/G, but with no differences between wheat gluten sources. In the common period, d 21 to 35, there were no differences in ADG, ADFI, or F/G. Overall, the pigs fed the control diet had the highest ADG and ADFI. There was a decrease (linear, $P<0.05$) in ADG and ADFI when either wheat gluten source was fed. However, pigs had improved F/G (linear, $P<0.05$) when either source of wheat gluten was fed.

From d 0 to 7 and 7 to 14 in Exp. 2, there was an improvement (linear, $P<0.06$) in F/G with increasing wheat gluten. There was a decrease (linear, $P<0.05$) in ADG from d 7 to 14 when wheat gluten increased. For the overall treatment period, d 0 to 14, pigs fed 5% plasma had the highest ADG with a decrease (linear, $P<0.05$) when wheat gluten was increased in the diets. There were no differences in ADFI or F/G for the treatment period. For the common period, d 14 to 28, there were no differences seen in growth performance. The overall results (d 0 to 28) show no differences in ADG, ADFI, or F/G. In conclusion, as in many past trials, spray-dried animal plasma will stimulate feed intake and improve growth performance of nursery pigs. In these two experiments, when different wheat gluten sources are combined with spray-dried animal plasma at increasing levels, ADG and ADFI decreased.

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

	Wheat Gluten:SDAP Ratio		
Ingredient, %	0:100	50:50	100:0
Corn	47.03	46.69	46.37
Soybean meal (46.5% CP)	19.21	19.21	19.21
Spray-dried whey	15.00	15.00	15.00
Spray-dried plasma	6.00	3.00	-
Wheat gluten[b]	-	3.00	6.00
Soy oil	5.00	5.00	5.00
Menhaden fish meal	3.00	3.00	3.00
Monocalcium phosphate, 21% P	1.08	1.30	1.50
Limestone	1.30	1.18	1.08
Antimicrobial[c]	1.00	1.00	1.00
Salt	0.30	0.30	0.30
Vitamin premix	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15
Zinc oxide	0.35	0.35	0.35
Threonine	0.04	0.10	0.15
Tryptophan	-	0.02	0.04
Lysine HCl	0.15	0.34	0.51
DL-Methionine	0.15	0.13	0.10
Total	100.00	100.00	100.00
Calculated analysis			
Digestible lysine, %	1.29	1.29	1.29
Total lysine, %	1.51	1.49	1.46
Isoleucine:lysine, %	57	58	59
Met & Cys:lysine, %	61	60	60
Threonine:lysine, %	66	66	65
Tryptophan:lysine, %	19	19	19
Valine:lysine, %	73	70	67
ME, kcal/lb	1,573	1,548	1,542
Protein, %	21.30	21.30	21.40
Ca, %	1.05	1.04	1.04
P, %	0.79	0.79	0.78
Available P, %	0.56	0.56	0.56
Lysine:calorie ratio, g/mcal	4.35	4.36	4.35

[a]Values calculated on an as-fed basis.
[b]Wheat gluten was fed from two different sources consisting of four of the five experimental treatments consisting of enzymatically hydrolyzed (Source 1) and a non-hydrolyzed wheat gluten (Source 2).
[c]Provided 50g/ton carbadox.

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

	Wheat Gluten:SDAP Ratio					
Ingredient, %	0:0	100:0	75:25	50:50	25:75	0:100
Corn	35.93	38.48	39.59	40.71	41.82	42.94
Soybean meal, 46.5%	36.71	24.79	24.79	24.79	24.79	24.79
Spray-dried whey	20.00	20.00	20.00	20.00	20.00	20.00
Wheat gluten[b]	-	9.00	6.75	4.50	2.25	-
Spray-dried animal plasma	-	-	1.25	2.50	3.75	5.00
Soy oil	3.00	3.00	3.00	3.00	3.00	3.00
Monocalcium phosphate, 21%	1.04	1.11	1.02	0.93	0.84	0.75
Limestone	0.98	1.03	1.07	1.11	1.15	1.19
Antimicrobial[c]	1.00	1.00	1.00	1.00	1.00	1.00
Salt	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin premix	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15
Zinc oxide	0.35	0.35	0.35	0.35	0.35	0.35
Threonine	0.04	0.06	0.45	0.03	0.02	-
Lysine HCl	0.15	0.45	0.38	0.30	0.23	0.15
DL-Methionine	1.05	0.04	0.07	0.09	0.12	0.14
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated analysis						
Digestible lysine, %	1.27	1.32	1.31	1.29	1.28	1.27
Total lysine, %	1.50	1.50	1.50	1.50	1.50	1.50
Isoleucine:lysine, %	67	67	65	63	61	60
Met & Cys:lysine, %	56	61	61	61	60	60
Threonine:lysine, %	64	64	64	64	64	64
Tryptophan:lysine, %	20	19	19	19	19	19
Valine:lysine, %	73	74	74	74	73	73
ME, kcal/lb	1,518	1,518	1,522	1,525	1,529	1,532
Protein, %	22.50	24.40	23.70	23.00	22.20	21.50
Ca, %	0.85	0.85	0.85	0.85	0.85	0.85
P, %	0.72	0.67	0.67	0.67	0.68	0.68
Available P, %	0.43	0.43	0.43	0.43	0.43	0.43
Lysine:calorie ratio, g/mcal	4.48	4.48	4.47	4.46	4.45	4.44

[a]Values calculated on an as-fed basis.
[b]Wheat gluten was enzymatically hydrolyzed and fed from one lot consisting of four of the six experimental diets.
[c]Provided 50g/ton carbadox.

Table 3. Evaluation of Two Wheat Gluten Sources and Spray-Dried Animal Plasma in Diets for Early Wean Pigs[a]

	Treatment (Wheat Gluten:SDAP Ratio)					Contrasts, Probability (*P*<)					
	6% SDAP	WG Source 1		WG Source 2		Source 1		Source 2		Source	
Item	0:100	50:50	100:0	50:50	100:0	Linear[d]	Quadratic[e]	Linear[f]	Quadratic[g]	1 vs 2[h]	SEM
Diet no.	1	2	3	4	5						
Day 0 to 7											
ADG, lb	0.53	0.43	0.40	0.45	0.41	0.02	0.52	0.04	0.68	0.63	0.04
ADFI, lb	0.49	0.41	0.36	0.42	0.38	0.05	0.78	0.11	0.74	0.72	0.06
Feed/gain	0.93	0.98	0.92	0.94	0.93	0.77	0.20	0.99	0.80	0.75	0.03
Day 7 to 14											
ADG, lb	0.98	0.90	0.79	0.93	0.84	<0.01	0.71	0.01	0.76	0.30	0.04
ADFI, lb	1.11	0.99	0.84	1.05	0.86	<0.01	0.76	<0.01	0.26	0.40	0.06
Feed/gain	1.13	1.10	1.08	1.14	1.02	0.29	0.98	0.03	0.14	0.83	0.03
Day 14 to 21											
ADG, lb	1.21	1.15	1.14	1.23	1.14	0.22	0.63	0.22	0.32	0.38	0.04
ADFI, lb	1.49	1.36	1.33	1.43	1.34	0.02	0.43	0.03	0.80	0.42	0.06
Feed/gain	1.24	1.18	1.17	1.17	1.18	0.15	0.65	0.23	0.34	0.95	0.03
Day 0 to 21[b]											
ADG, lb	0.91	0.83	0.77	0.87	0.80	<0.01	0.68	<0.01	0.62	0.19	0.03
ADFI, lb	1.03	0.92	0.84	0.97	0.86	<0.01	0.70	<0.01	0.60	0.32	0.04
Feed/gain	1.10	1.09	1.05	1.08	1.04	0.09	0.62	0.04	0.64	0.71	0.02
Day 21 to 35[c]											
ADG, lb	1.21	1.18	1.20	1.21	1.16	0.90	0.42	0.30	0.50	0.95	0.03
ADFI, lb	1.85	1.75	1.80	1.83	1.75	0.34	0.11	0.06	0.54	0.71	0.05
Feed/gain	1.55	1.53	1.50	1.52	1.53	0.17	0.62	0.59	0.59	0.66	0.02
Day 0 to 35											
ADG, lb	1.03	0.97	0.95	1.00	0.95	<0.01	0.42	<0.01	0.43	0.33	0.03
ADFI, lb	1.36	1.25	1.22	1.31	1.22	<0.01	0.22	<0.01	0.45	0.33	0.04
Feed/gain	1.28	1.26	1.23	1.26	1.24	0.03	0.86	0.06	0.98	0.99	0.01

[a]A total of 220 weanling pigs initially 13.4 lb.
[b]Experimental diets were fed from d 0 to 21 after weaning to all pigs.
[c]A common diet was fed from d 21 to 35 after weaning.
[d]Linear effect of Source 1, Diets 1, 2, and 3.
[e]Quadratic effect of Source 1, Diets 1, 2, and 3.
[f]Linear effect of Source 2, Diets 1, 4, and 5.
[g]Quadratic effect of Source 2, Diets 1, 4, and 5.
[h]Source 1 vs. Source 2, Diets 2 and 3 vs. Diets 4 and 5.

Table 4. Effect of Wheat Gluten and Spray-Dried Animal Plasma Blends on the Growth Performance of Nursery Pigs[a]

	Wheat Gluten : SDAP Ratio						Contrasts, Probability (*P*<)				
Item	0:0	100:0	75:25	50:50	25:75	0:100	Linear Effect[d]	Quadratic Effect[e]	Diet 1 vs Diet 2[f]	Diet 1 vs Diet 6[g]	SEM
Day 0 to 7											
ADG, lb	0.52	0.53	0.59	0.51	0.57	0.58	0.50	0.83	0.86	0.24	0.04
ADFI, lb	0.43	0.42	0.48	0.45	0.49	0.51	0.13	0.99	0.85	0.17	0.04
Feed/gain	0.85	0.81	0.81	0.87	0.87	0.88	0.02	0.68	0.28	0.45	0.03
Day 7 to 14											
ADG, lb	0.85	0.77	0.81	0.83	0.84	0.88	0.02	0.87	0.06	0.64	0.04
ADFI, lb	0.97	0.90	0.96	0.93	0.93	0.99	0.19	0.82	0.18	0.67	0.04
Feed/gain	1.14	1.18	1.18	1.13	1.11	1.13	0.06	0.48	0.30	0.87	0.03
Day 0 to 14[b]											
ADG, lb	0.69	0.65	0.70	0.67	0.70	0.73	0.05	0.97	0.25	0.27	0.03
ADFI, lb	0.70	0.66	0.72	0.69	0.71	0.75	0.10	0.89	0.37	0.29	0.04
Feed/gain	0.99	0.99	0.99	1.00	0.99	1.01	0.72	0.83	0.98	0.65	0.02
Day 14 to 28[c]											
ADG, lb	1.05	1.06	1.04	1.07	1.04	1.03	0.54	0.61	0.79	0.67	0.03
ADFI, lb	1.47	1.43	1.46	1.50	1.45	1.44	0.91	0.20	0.47	0.57	0.04
Feed/gain	1.41	1.36	1.41	1.40	1.41	1.40	0.12	0.15	0.12	0.54	0.02
Day 0 to 28											
ADG, lb	0.87	0.85	0.87	0.87	0.87	0.88	0.37	0.74	0.54	0.64	0.03
ADFI, lb	1.08	1.05	1.09	1.10	1.08	1.10	0.28	0.47	0.32	0.76	0.03
Feed/gain	1.20	1.17	1.20	1.20	1.20	1.20	0.17	0.36	0.15	0.83	0.01

[a]A total of 252 pigs initially 13.7 lb.
[b]D 0 to 14 treatment diets.
[c]D 14 to 28 common Phase II Diets.
[d]Linear effect, Diets 2, 3, 4, 5, 6.
[e]Quadratic effect, Diets 2, 3, 4, 5, 6.
[f]0% SDAP and WG vs. 9%WG, Diets 1 vs. 2.
[g]0% SDAP and WG vs. 5% P, Diets 1 vs. 6.

EVALUATION OF WHEAT GLUTEN AND SPRAY-DRIED ANIMAL PLASMA ON GROWTH PERFORMANCE OF NURSERY PIGS

K. R. Lawrence, R. D. Goodband, M. D. Tokach, J. L. Nelssen, S. S. Dritz[1], J. M. DeRouchey, C. W. Hastad, S. M. Hanni, M. R. Barker, and B. W. James

Summary

A total of 440 weanling pigs (initially 14.3 lb) were used in two studies to evaluate the effects of increasing wheat gluten (WG) and spray-dried animal plasma (SDAP) on growth performance of early weaned pigs. In Exp. 1, the six dietary treatments included a negative control, containing no wheat gluten or animal plasma, the control diet containing either 3, 6, 9, or 12% lightly modified spray-dried wheat gluten, and a positive control diet containing 5% spray-dried animal plasma. The diets containing 9% WG and 5% SDAP had the same amount of soybean meal to make a direct comparison of the two protein sources. From d 0 to 7, 7 to 14, and 0 to 14, increasing wheat gluten had no effect on ADG, ADFI, or feed efficiency. From d 0 to 7, pigs fed 5% SDAP had greater ADG than pigs fed the diet containing 9% WG but similar ADG to pigs fed the negative control. For the common period, d 14 to 28, a quadratic ($P<0.01$) response was observed for feed efficiency with F/G becoming poorer as wheat gluten was added up to 9% then improving as wheat gluten increased up to 12%.

In Exp. 2, the five dietary treatments included a negative control, which contained no SDAP or WG, or the control diet with 4.5% and 9% WG, or 2.5% and 5% SDAP. The wheat gluten source used was different than in Exp. 1 and was enzymatically hydrolyzed. The diets containing 4.5% and 9% wheat gluten contained the same amount of soybean meal as the diets with 2.5% and 5% SDAP, respectively. From d 0 to 7 and 0 to 14, increasing SDAP increased ($P<0.04$) ADG. Increasing WG had no effect. There were no differences found in ADG from d 7 to 14 and no differences found in feed intake from d 0 to 7. No differences ($P<0.05$) were found in feed efficiency. During the common period, d 14 to 35, no differences were found in ADG and ADFI. Pigs previously fed the diets containing 2.5% and 5% SDAP had ($P<0.05$) the best feed efficiency with the pigs previously fed the control having the worst. The pigs fed the diets containing 4.5% WG and 9% WG were intermediate in efficiency. These results suggest that increasing WG in diets fed immediately after weaning produced no improvement in growth performance relative to SDAP.

(Key Words: Wheat Gluten, Spray-Dried Animal Plasma.)

Introduction

Spray-dried animal plasma has been successful in improving the growth performance of nursery pigs. However, blood products are expensive compared to refined protein products of plant origin. Spray-dried wheat gluten is slightly modified to improve textural characteristics. Previous research has

[1]Food Animal Health and Management Center.

evaluated inclusion rates of up to 8% spray-dried wheat gluten in diets for weanling pigs, but no research data is available that has evaluated wheat gluten at higher levels. Another processing method of wheat gluten is enzymatic hydrolyzation. Enzymatically hydrolyzed ring-dried wheat gluten is designed specifically for use in feed application. Protein hydrolysis increases the digestibility of wheat gluten and also obtains a soluble wheat protein that may be used in milk replacers. This wheat gluten is dried with a low temperature process to ensure maximal protein digestibility. Therefore, our first objective was to determine the optimal inclusion rate of spray-dried wheat gluten and our second objective is to compare that inclusion rate on the same protein basis with spray-dried animal plasma.

Procedures

In Exp. 1, a total of 240 pigs (initially 13.4 lb and 21 ± 3 d of age) were used in a 28-d growth assay. Five replications consisted of six pigs per pen and two replications consisted of five pigs per pen for a total of seven pens per treatment. Experimental diets were fed to all pigs from d 0 to 14 after weaning. All diets were corn-soybean meal-based and formulated to 1.50% total lysine and at least 1.27% digestible lysine, 1.04% Ca, and 0.56% available phosphorus (Table 1). The six dietary treatments were a negative control diet with no WG or SDAP, the control with 3, 6, 9, and 12% WG, and a positive control containing 5% SDAP. Pigs were fed the same common diet from d 14 to 28 after weaning. All pigs were housed in the Kansas State University Swine Teaching and Research Center's environmentally controlled nursery.

In Exp. 2, a total of 200 pigs (initially 13.3 lb and 21 ± 3 d of age) were used in a 35-d growth assay. There were five pigs per pen and eight pens per treatment. Experimental diets were fed to all pigs from d 0 to 14 after weaning. All diets were corn-soybean meal-based and formulated to 1.27% digestible lysine corresponding to 1.50% total lysine, 0.85% Ca, and 0.43% available phosphorus (Table 2). The five dietary treatments were a negative control containing no WG or SDAP, and diets containing 4.5% and 9% WG, or 2.5% and 5% SDAP. The diets containing 2.5% and 5% SDAP were replaced with 4.5% and 9% wheat gluten, respectively, and L-lysine on an equal lysine basis. Pigs were fed the same Phase II diet from d 14 to 35 after weaning. All pigs were housed in the Kansas State University Segregated Early Weaning Facility. In both experiments each pen contained one self-feeder and one nipple waterer to provide ad libitum access to feed and water. Average daily gain, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance every 7 days.

Data were analyzed using the MIXED procedures of SAS as a randomized complete block design with pen as the experimental unit. For Exp. 1, linear and quadratic contrasts determined the effects of increasing wheat gluten. In Exp. 2, linear and quadratic contrasts determined the effects of 9% wheat gluten to 5% SDAP. Least significant differences were used for making pairwise comparisons of the treatment means in each experiment.

Results and Discussion

In Exp. 1, from d 0 to 7, 7 to 14, and d 0 to 14, increasing WG had no affect on ADG, ADFI, or F/G. Pigs fed the diet containing 5% SDAP had greater ADG ($P<0.05$) than the pigs fed the diet containing 9% WG. However, pigs fed 5% SDAP had only numerically greater ADG than pigs fed the control diet. For the common period, d 14 to 28, there were no differences in ADG or ADFI from either protein source fed from d 0 to 14. However, F/G became poorer (quadratic, $P<0.01$) as WG increased to 9% then became better as WG increased to 12%.

In Exp. 2, ADG increased (linear, $P<0.06$) from d 0 to 7 and d 0 to 14 with increasing spray-dried animal plasma. Increasing WG had no affect on growth performance and the mean ADG of pigs fed SDAP ($P<0.10$) was greater than pigs fed WG. From d 14 to 35, pigs previously fed diets containing WG had similar ADG and ADFI to those fed SDAP. However, pigs previously fed increasing SDAP had poorer F/G (linear, $P<0.05$). In conclusion, in diets for early-weaned pigs, increasing wheat gluten had no effect on ADG, ADFI, or F/G. In both studies, from d 0 to 7 after weaning, spray-dried animal plasma improved nursery pig ADG compared to wheat gluten.

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

	Wheat Gluten, %					5%
Ingredient, %	0%	3%	6%	9%	12%	Plasma
Corn	36.07	36.75	37.44	38.13	38.82	42.52
Soybean meal, 46.5%	36.70	32.92	29.13	25.34	21.55	25.34
Spray-dried whey	20.00	20.00	20.00	20.00	20.00	20.00
Wheat gluten	-	3.00	6.00	9.00	12.00	-
Spray-dried animal plasma	-	-	-	-	-	5.00
Lysine	0.15	0.24	0.33	0.41	0.50	0.13
Soy oil	3.00	3.00	3.00	3.00	3.00	3.00
Monocalcium phosphate, 21% P	1.05	1.06	1.08	1.09	1.10	0.75
Limestone	0.85	0.86	0.88	0.89	0.90	1.08
Antimicrobial[b]	1.00	1.00	1.00	1.00	1.00	1.00
Salt	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin premix	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15
Zinc oxide	0.35	0.35	0.35	0.35	0.35	0.35
Threonine	0.04	0.04	0.04	0.04	0.04	0.04
DL-Methionine	0.10	0.09	0.07	0.06	0.04	0.10
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated analysis						
Digestible lysine, %	1.27	1.28	1.29	1.31	1.32	1.27
Total lysine, %	1.50	1.50	1.50	1.50	1.50	1.50
Isoleucine:lysine, %	67	67	67	68	68	60
Met & Cys:lysine, %	55	56	56	56	56	58
Threonine:lysine, %	64	65	65	65	66	67
Tryptophan:lysine, %	20	19	19	18	18	20
Valine:lysine, %	73	73	74	75	75	74
ME, kcal/lb	1,520	1,520	1,521	1,521	1,522	1,534
Protein, %	22.6	23.3	24.1	24.8	25.6	21.7
Ca, %	0.80	0.80	0.80	0.80	0.80	0.80
P, %	0.72	0.71	0.69	0.68	0.67	0.68
Available P, %	0.43	0.43	0.43	0.43	0.43	0.43
Lysine:calorie ratio, g/mcal	4.48	4.48	4.47	4.47	4.47	4.44

[a]Values calculated on an as-fed basis.
[b]Provided 50g/ton carbadox.

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

	Wheat gluten, %			Spray-dried animal plasma	
Ingredient, %	0	4.5	9.0	2.5	5.0
Corn	35.93	37.23	38.47	39.44	42.94
Soybean meal, 46.5%	36.71	30.74	24.79	30.74	24.79
Spray-dried whey	20.00	20.00	20.00	20.00	20.00
Wheat gluten	-	4.50	9.00	-	-
Spray-dried animal plasma	-	-	-	2.50	5.00
Soy oil	3.00	3.00	3.00	3.00	3.00
Monocalcium phosphate, 21% P	1.04	1.07	1.11	0.89	0.75
Limestone	0.98	1.00	1.03	1.09	1.19
Antimicrobial[b]	1.00	1.00	1.00	1.00	1.00
Salt	0.30	0.30	0.30	0.30	0.30
Vitamin premix	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15
Zinc oxide	0.35	0.35	0.35	0.35	0.35
Threonine	0.38	0.38	0.06	0.02	-
Lysine HCl	0.15	0.30	0.45	0.15	0.15
DL-Methionine	0.11	0.08	0.05	0.13	0.14
Total	100.00	100.00	100.00	100.00	100.00
Calculated analysis					
Digestible lysine, %	1.27	1.29	1.32	1.27	1.27
Total lysine, %	1.50	1.50	1.50	1.50	1.50
Isoleucine:lysine, %	67	67	67	63	60
Met & Cys:lysine, %	56	59	62	58	59
Threonine:lysine, %	64	64	64	64	64
Tryptophan:lysine, %	20	19	19	20	19
Valine:lysine, %	73	74	74	73	73
Protein, %	22.50	23.50	24.40	22.00	21.50
Calcium, %	0.85	0.85	0.85	0.85	0.85
Phosphorus, %	0.72	0.69	0.67	0.70	0.68
Available phosphorus , %	0.43	0.43	0.43	0.43	0.43
Lysine:calorie ratio, g/mcal	4.48	4.48	4.48	4.46	4.44

[a]Values calculated on an as-fed basis.
[b]Provided 50g/ton carbadox.

Table 3. Effect of Increasing Wheat Gluten on Growth Performance of Nursery Pigs[a]

	Wheat gluten, %						Contrasts, Probability (*P*<)				
Item	0	3	6	9	12	5% Plasma	Linear Wheat Gluten[d]	Quad Wheat Gluten[e]	9% WG vs 5% Plasma[f]	0% WG vs 5% Plasma[g]	SEM
D 0 to 7											
ADG, lb	0.45	0.42	0.44	0.37	0.43	0.51	0.55	0.64	0.04	0.36	0.05
ADFI, lb	0.36	0.32	0.35	0.30	0.34	0.40	0.72	0.57	0.15	0.61	0.05
Feed/gain	0.81	0.75	0.79	0.79	0.82	0.79	0.69	0.42	0.96	0.72	0.05
D 7 to 14											
ADG, lb	0.96	0.98	0.89	0.95	0.93	0.95	0.60	0.76	0.95	0.91	0.05
ADFI, lb	1.07	1.07	1.00	0.98	1.00	1.07	0.15	0.62	0.21	0.99	0.05
Feed/gain	1.12	1.09	1.12	1.03	1.08	1.13	0.27	0.79	0.13	0.96	0.05
D 0 to 14[b]											
ADG, lb	0.70	0.70	0.67	0.66	0.68	0.73	0.43	0.59	0.17	0.58	0.04
ADFI, lb	0.72	0.69	0.67	0.64	0.67	0.73	0.26	0.51	0.10	0.76	0.05
Feed/gain	0.97	0.92	0.95	0.91	0.95	0.96	0.58	0.41	0.26	0.81	0.03
D 14 to 28[c]											
ADG, lb	1.13	1.15	1.05	1.04	1.09	1.09	0.11	0.23	0.36	0.39	0.04
ADFI, lb	1.49	1.55	1.48	1.45	1.49	1.47	0.38	0.37	0.79	0.67	0.05
Feed/gain	1.36	1.44	1.43	1.48	1.38	1.42	0.45	<0.01	0.19	0.15	0.03
D 0 to 28											
ADG, lb	0.92	0.92	0.86	0.85	0.89	0.91	0.10	0.22	0.11	0.82	0.03
ADFI, lb	1.10	1.12	1.08	1.05	1.08	1.10	0.20	0.69	0.21	0.94	0.04
Feed/gain	1.16	1.18	1.19	1.19	1.16	1.19	0.88	0.15	0.89	0.38	0.02

[a]A total of 240 pigs initially 15.3 lb.
[b]D 0 to 14 treatment diets.
[c]D 14 to 28 common Phase II diets.
[d]Linear effect of wheat gluten (0, 3, 6, 9, and 12%).
[e]Quadratic effect of wheat gluten (0, 3, 6, 9, and 12%).
[f]9% wheat gluten vs. 5% plasma.
[g]0% wheat gluten/plasma vs. 5% plasma.

Table 4. Effect of Spray-Dried Animal Plasma and Wheat Gluten on the Growth Performance of Nursery Pigs[a]

						Contrasts, Probability (*P*<)					
	Control	Wheat gluten, %		Animal plasma, %		Wheat gluten		Animal plasma		WG vs	
Item	0	4.5	9.0	2.5	5.0	Linear[d]	Quadratic[e]	Linear[f]	Quadratic[g]	Plasma[h]	SEM
D 0 to 7											
ADG, lb	0.27	0.29	0.27	0.36	0.39	0.97	0.75	0.04	0.53	0.04	0.05
ADFI, lb	0.24	0.26	0.24	0.30	0.34	0.97	0.77	0.17	0.84	0.16	0.06
Feed/gain	0.94	0.93	0.92	0.85	0.87	0.73	0.95	0.19	0.21	0.33	0.03
D 7 to 14											
ADG, lb	0.87	0.87	0.82	0.91	0.92	0.40	0.63	0.37	0.84	0.08	0.05
ADFI, lb	0.95	0.91	0.88	0.97	1.02	0.28	0.93	0.28	0.82	0.03	0.06
Feed/gain	1.09	1.05	1.07	1.08	1.11	0.62	0.39	0.76	0.53	0.43	0.03
D 0 to 14[b]											
ADG, lb	0.57	0.58	0.55	0.63	0.66	0.60	0.61	0.06	0.59	0.02	0.04
ADFI, lb	0.59	0.58	0.56	0.64	0.68	0.51	0.90	0.15	0.99	0.04	0.05
Feed/gain	1.01	0.99	0.99	0.96	0.99	0.52	0.54	0.44	0.16	0.89	0.02
D 14 to 35[c]											
ADG, lb	1.25	1.22	1.23	1.32	1.22	0.61	0.47	0.33	0.38	0.65	0.04
ADFI, lb	1.67	1.65	1.70	1.66	1.68	0.60	0.47	0.90	0.79	0.97	0.05
Feed/gain	1.33	1.36	1.37	1.38	1.38	0.16	0.69	0.05	0.21	0.56	0.02
D 0 to 35											
ADG, lb	0.98	0.96	0.96	0.98	0.99	0.48	0.81	0.68	0.74	0.27	0.03
ADFI, lb	1.24	1.23	1.24	1.25	1.28	0.99	0.65	0.38	0.84	0.69	0.04
Feed/gain	1.20	1.21	1.22	1.22	1.22	0.49	0.93	0.29	0.96	0.71	0.01

[a]A total of 200 pigs initially 13.3 lb.
[b]D 0 to 14 treatment diets.
[c]D 14 to 35 common Phase II diets.
[d]Linear effect of wheat gluten (0, 4.5, and 9%).
[e]Quadratic effect of wheat gluten (0, 4.5, and 9.0%).
[f]Linear effect of plasma (0, 2.5, and 5.0%).
[g]Quadratic effect of plasma (0, 2.5, and 5.0%).
[h]9% wheat gluten vs. 5% plasma.

EFFECTS OF SOYBEAN MEAL SOURCE AND LEVEL ON GROWTH PERFORMANCE OF WEANLING PIGS

K. R. Lawrence, R. D. Goodband, M. D. Tokach, J. L. Nelssen, S. S. Dritz[1], J. M. DeRouchey, C. W. Hastad, S. M. Hanni, M. G. Young, M. J. Webster, M. R. Barker, B. W. James and C. N. Groesbeck

Summary

A total of 525 weanling pigs (initially 13.0 lb) were used in two experiments to evaluate the effects of soybean meal source and level on growth performance of early weaned pigs. In both experiments, dietary treatments included a control diet containing no soybean meal, or diets containing 20% or 40% of either solvent extracted soybean meal (SBM) or extruded-expelled soybean meal (EESoy). In Exp. 1, diets were formulated with NRC (1998) nutrient values for the solvent extracted soybean meal and previously determined values (1998 KSU Swine Day Report of Progress) for the extruded-expelled soybean meal. In Exp. 1, from d 0 to 7, increasing solvent extracted soybean meal or extruded-expelled soybean meal decreased (linear, $P<0.05$) ADG. Feed efficiency was reduced with an increase of either soybean meal source (SBM quadratic, $P<0.05$; EESoy linear, $P<0.05$). However, the mean ADG and F/G of pigs fed solvent extracted soybean meal were better than the mean of pigs fed extruded-expelled soybean meal. No differences were found in growth performance from d 7 to 14 and 14 to 21. However, from d 0 to 14, F/G became poorer (linear, $P<0.06$) as either soybean meal source increased, and the mean F/G of pigs fed solvent extracted soybean meal was better than those fed extruded-expelled soybean meal. For the overall growth period, d 0 to 21, F/G became poorer (linear, $P<0.04$) as solvent extracted soybean meal increased. After the trial was completed, the soybean meal sources were chemically analyzed and the extruded-expelled soybean meal was found to be lower in crude protein (43.6% vs 46.5%) than what was used in diet formulation. We speculated that the differences in growth performance between the two soybean meal sources could have been a result of the low protein (lysine) concentrations. Therefore, in Exp. 2 diets were formulated with actual analyzed nutrient soybean meal values.

In Exp. 2, from d 0 to 7, increasing either soybean meal source resulted in decreased (linear, $P<0.01$) ADG and ADFI, and reduced (quadratic, $P<0.04$) F/G. The mean ADG, ADFI, and F/G of pigs fed solvent extracted soybean meal were better than the mean of those fed extruded-expelled soybean meal. From d 7 to 14, ADG and F/G improved (linear, $P<0.05$) with increasing solvent extracted soybean meal. Increasing extruded-expelled soybean meal had no affect on ADG or F/G but decreased (linear, $P<0.03$) ADFI. From d 0 to 14, increasing solvent extracted soybean meal decreased (linear, $P<0.02$) ADFI. Increasing extruded-expelled soybean meal decreased ADG, ADFI, and decreased F/G (linear, $P<0.01$). The mean ADG, ADFI, and F/G of pigs fed solvent extracted soybean meal

[1]Food Animal Health and Management Center.

was better than the mean of pigs fed extruded-expelled soybean meal. For the overall trial, increasing extruded-expelled soybean meal decreased ADG and ADFI (linear, $P<0.01$) and the mean ADG and ADFI, were less than those fed solvent extracted soybean meal. Because of previous research demonstrating equal or better growth performance of pigs fed extruded-expelled soybean meal, the results of these trials led us to suspect that poor quality extruded-expelled soybean meal was used in this trial. At the conclusion of the study, soybean meal sources from both trials were analyzed for trypsin inhibitor. Results of the trypsin inhibitor assay suggest that the extruded-expelled soybean meal from both experiments was underprocessed, resulting in poor growth performance. In conclusion, trypsin inhibitor values are extremely important in verifying quality of extruded-expelled soybean meal.

(Key Words: Soybean Meal, Weanling Pigs.)

Introduction

Commercial diets for early-weaned pigs contain relatively low levels of soybean meal. Previous research suggests that the amount of soybean meal in diets is limited because of delayed-type hypersensitivity reactions of young pigs to high levels of glycinin and beta conglycinin found in soybean meal. However, it is important to include some soybean meal in the initial diets in order to acclimate pigs to soybean meal so its levels can be increased in later diets. Processing methods of soybean meal, such as extruding and expelling, may allow for greater inclusions of soy proteins in the diet without negatively affecting pig performance. This would offer a large economic incentive to the producer. Previous research has shown that pigs (>25 lb) fed extruded-expelled soybean meal have better growth performance than pigs fed solvent extracted soybean meal. Therefore, the objective of this study was to compare the effects of increasing levels of solvent extracted soybean meal and extruded-expelled soybean meal on weanling pig performance.

Procedures

In Exp. 1, a total of 175 pigs (initially 13.1 lb and 21 ± 3 d of age) were used in a 21-d growth assay. There were five pigs per pen and seven pens per treatment. Experimental diets were fed to all pigs from d 0 to 14 after weaning. All diets were corn-soybean meal-based and formulated to 1.50% total lysine, 0.76% Ca, and 0.50% available phosphorus (Table 1). The five dietary treatments included a control containing no soybean meal, diets containing 20% and 40% of either solvent extracted soybean meal or extruded-expelled soybean meal. Pigs were fed the same common diet from d 14 to 21 after weaning.

In Exp. 2, a total of 350 pigs (initially 12.9 lb and 21 ± 3 d of age) were used in a 21-d growth assay. There were five pigs per pen and 14 pens per treatment. Experimental diets were fed to all pigs from d 0 to 14 after weaning. All diets were corn-soybean meal-based and formulated to 1.50% total lysine, 0.76% Ca, and 0.50% available phosphorus (Table 2). The five dietary treatments were identical to Exp. 1, which included a control containing no soybean meal, diets containing 20% and 40% of either solvent extracted soybean meal or extruded-expelled soybean meal. Diets in Exp. 2 were formulated on actual chemical analysis of the solvent extracted and extruded-expelled soybean meal. Pigs were fed the same common diet from d 14 to 21 after weaning. In both experiments, pigs were housed in the Kansas State University Segregated Early Weaning Facility. Each pen was 4 × 4 ft and contained one self-feeder and one nipple waterer to provide ad libitum access to feed and water. Average daily gain, ADFI, and F/G were determined by weighing pigs

and measuring feed disappearance every 7 days.

Data were analyzed using the MIXED procedures of SAS as a randomized complete block design with pen as the experimental unit. Linear and quadratic contrasts were determined for each source of soybean meal and contrasts determined differences between soybean meal source.

Results and Discussion

In Exp. 1, from d 0 to 7, increasing solvent extracted soybean meal or extruded-expelled soybean meal decreased (linear, $P<0.05$) ADG (Table 3). Feed efficiency was reduced as either soybean meal source increased (SBM quadratic, $P<0.05$; EESoy linear, $P<0.05$). However, the mean ADG and F/G of pigs fed solvent extracted soybean meal were better than the mean of pigs fed extruded-expelled soybean meal. No differences were found in growth performance from d 7 to 14 and 14 to 21. From d 0 to 14, F/G was reduced (linear, $P<0.06$) as either soybean meal source increased, and the mean F/G of pigs fed solvent extracted soybean meal was better than those fed extruded-expelled soybean meal. For the overall experimental period, d 0 to 21, F/G decreased (linear, $P<0.04$) as solvent extracted soybean meal increased.

In Exp. 2, from d 0 to 7, increasing either soybean meal source resulted in decreased (linear, $P<0.01$) ADG and ADFI, and F/G (quadratic, $P<0.04$) (Table 4). The mean ADG, ADFI, and F/G of pigs fed solvent extracted soybean meal were better than the mean of those fed extruded-expelled soybean meal. From d 7 to 14, ADG and F/G improved (linear, $P<0.05$) with increasing solvent extracted soybean meal. Increasing extruded-expelled soybean meal had no affect on ADG or F/G but decreased (linear, $P<0.03$) ADFI. From d 0 to 14, increasing solvent extracted soybean meal decreased (linear, $P<0.02$) ADFI. Increasing extruded-expelled soybean meal decreased ADG, ADFI, and F/G (linear, $P<0.01$). The mean ADG, ADFI, and F/G of pigs fed solvent extracted soybean meal was better than the mean of pigs fed extruded-expelled soybean meal. For the overall trial, increasing extruded-expelled soybean meal decreased ADG and ADFI (linear, $P<0.01$). The mean ADG and ADFI were less than those fed solvent extracted soybean meal.

Previous research suggests improved growth performance in pigs fed extruded-expelled soybean meal. Results of this trial indicate otherwise. Therefore, samples of the different batches of soybean meal used in both trials were analyzed for trypsin inhibitor, urease, protein solubility (KOH), nitrogen solubility (NSI), and mycotoxins. These tests can identify whether or not soybean meal has been over- or underprocessed. Results of the trypsin inhibitor assay and other tests suggest that the solvent extracted soybean meal for both trials was processed properly. However, the trypsin inhibitor assay results of the extruded expelled soybean meal were above recommended values and indicate that the extruded-expelled soybean meal in both studies was underprocessed. Interestingly, the other analytical procedures would have suggested that the extruded-expelled soybean meal was properly processed. We speculate that there may be factors or conditions in soybean thermal processing that result in some quality indicator tests to be normal but not others. For example, the urease, PSI, and NSI results suggested adequately processed soybean meal but trypsin inhibitor did not.

In conclusion, results of the trypsin inhibitor assay suggest that the extruded-expelled soybean meal from both experiments was undercooked, resulting in poor growth performance.

Trypsin inhibitor values are extremely important in verifying the quality of extruded-expelled soybean meal while other quality tests may not be as accurate in testing soybean meal quality, especially at the mill. Soybean meal processors must ensure soybean meal is adequately processed to a high enough temperature to reduce anti-nutritional factors that result in decreased growth performance.

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

		SBM		EESOY	
Ingredient, %	Control	20%	40%	20%	40%
Corn	52.52	39.80	27.15	41.75	31.05
Soybean meal	-	20.00	40.00	-	-
EESOY	-	-	-	20.00	40.00
Spray-dried whey	22.50	22.50	22.50	22.50	22.50
Spray-dried animal plasma	8.60	4.30	-	4.30	-
Fish meal	7.50	3.95	0.40	3.84	0.18
Blood meal	2.50	1.25	-	1.25	-
Soy oil	3.90	4.80	5.70	2.95	2.00
Monocalcium phosphate, 21% P	-	0.63	1.25	0.63	1.25
Limestone	0.45	0.65	0.85	0.65	0.85
Salt	0.30	0.30	0.30	0.30	0.30
Vitamin premix	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15
Antimicrobial[b]	1.00	1.00	1.00	1.00	1.00
Zinc oxide	0.38	0.38	0.38	0.38	0.38
L-Isoleucine	0.19	-	-	-	-
DL-Methionine	0.08	0.08	0.08	0.08	0.08
Total	100.00	100.00	100.00	100.00	100.00
Calculated analysis					
Digestible lysine, %	1.28	1.27	1.27	1.26	1.26
Lysine, %	1.50	1.50	1.50	1.50	1.50
Isoleucine:lysine, %	60	59	59	72	72
Met & Cys:lysine, %	53	54	53	55	53
Threonine:lysine, %	63	62	62	61	62
Tryptophan:lysine, %	18	19	19	20	20
Valine:lysine, %	80	77	77	75	75
ME, kcal/lb	1,584	1,585	1,583	1,585	1,584
Protein, %	21.10	22.40	23.90	22.50	24.10
Ca, %	0.76	0.82	0.89	0.82	0.88
P, %	0.69	0.74	0.79	0.74	0.79
Available P, %	0.54	0.52	0.51	0.52	0.50
Lysine:calorie ratio, g/mcal	4.30	4.29	4.30	4.29	4.30

[a]Values calculated on an as-fed basis. Both protein sources were assumed to contain 46.5% crude protein, but the solvent extracted soybean meal contained 46.7% and the extruded-expelled soybean meal contained 43.6%.
[b]Provided 50g/ton carbadox.

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

		SBM		EESOY	
Ingredient, %	Control	20%	40%	20%	40%
Corn	52.20	39.30	26.40	40.95	29.70
Soybean meal	-	20.00	40.00	-	-
EESOY	-	-	-	20.00	20.00
Spray-dried whey	22.50	22.50	22.50	22.50	22.50
Spray-dried animal plasma	8.60	4.30	-	4.30	-
Fish meal	7.50	4.30	1.10	4.45	1.40
Blood meal	2.50	1.25	-	1.25	-
Soy oil	3.90	4.83	5.75	3.03	2.15
Monocalcium phosphate, 21% P	-	0.63	1.25	0.63	1.25
Limestone	0.45	0.65	0.85	0.65	0.85
Salt	0.30	0.30	0.30	0.30	0.30
Vitamin premix	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15
Antimicrobial[b]	1.00	1.00	1.00	1.00	1.00
Zinc oxide	0.38	0.38	0.38	0.38	0.38
L-Isoleucine	0.19	0.09	-	0.09	-
DL-Methionine	0.08	0.08	0.08	0.08	0.08
Total	100.00	100.00	100.00	100.00	100.00
Calculated analysis					
Digestible lysine, %	1.28	1.27	1.26	1.27	1.25
Lysine, %	1.50	1.50	1.50	1.50	1.50
Isoleucine:lysine, %	59	59	72	59	72
Met & Cys:lysine, %	57	57	56	57	57
Threonine:lysine, %	67	66	66	67	66
Tryptophan:lysine, %	18	20	21	20	21
Valine:lysine, %	80	79	77	79	78
ME, kcal/lb	1,584	1,584	1,584	1,584	1,584
Protein, %	21.10	22.40	23.80	22.50	23.90
Ca, %	0.76	0.84	0.92	0.85	0.94
P, %	0.69	0.75	0.81	0.76	0.83
Available P, %	0.54	0.53	0.52	0.54	0.53
Lysine:calorie ratio, g/mcal	4.30	4.29	4.29	4.30	4.30

[a]Values calculated on an as-fed basis. Diets were formulated on actual analyzed crude protein values of soybean meal. The solvent extracted soybean meal contained 45.3% crude protein and the extruded-expelled soybean meal contained 44.4% crude protein.
[b]Provided 50g/ton carbadox.

Table 3. Effects of Soybean Meal Source and Level on Growth Performance of Weanling Pigs (Exp.1)[a]

Item	Control	SBM		EESOY		SEM	SBM		EESOY		SBM vs. EESOY
		20%	40%	20%	40%		Linear	Quad	Linear	Quad	
D 0 to 7											
ADG, lb	0.48	0.46	0.38	0.43	0.34	0.06	0.05	0.38	0.05	0.69	0.03
ADFI, lb	0.47	0.44	0.37	0.42	0.37	0.06	0.17	0.74	0.15	0.94	0.21
Feed/gain	0.99	0.96	1.12	0.98	1.10	0.04	0.02	0.05	0.05	0.22	<0.01
D 7 to 14											
ADG, lb	0.66	0.64	0.75	0.61	0.62	0.06	0.20	0.24	0.56	0.63	0.20
ADFI, lb	0.65	0.61	0.75	0.64	0.64	0.06	0.17	0.17	0.84	0.96	0.20
Feed/gain	0.98	0.98	1.00	1.05	1.03	0.04	0.73	0.79	0.35	0.31	0.99
D 14 to 21[c]											
ADG, lb	1.11	1.10	1.11	1.09	1.15	0.06	0.95	0.87	0.55	0.57	0.50
ADFI, lb	1.39	1.44	1.47	1.39	1.41	0.06	0.30	0.94	0.84	0.87	0.62
Feed/gain	1.28	1.31	1.33	1.29	1.22	0.04	0.34	0.91	0.28	0.38	0.51
D 0 to 14[b]											
ADG, lb	0.57	0.55	0.55	0.52	0.48	0.05	0.65	0.84	0.11	0.96	0.57
ADFI, lb	0.56	0.53	0.56	0.53	0.50	0.06	0.99	0.53	0.32	0.99	0.98
Feed/gain	0.98	0.97	1.06	1.02	1.06	0.03	0.06	0.11	0.04	0.87	0.02
D 0 to 21											
ADG, lb	0.75	0.73	0.73	0.71	0.70	0.04	0.75	0.81	0.33	0.74	0.91
ADFI, lb	0.84	0.83	0.86	0.82	0.80	0.05	0.63	0.65	0.51	0.95	0.80
Feed/gain	1.08	1.08	1.15	1.08	1.12	0.02	0.04	0.21	0.29	0.69	0.10

[a]A total of 175 pigs (five pigs per pen and seven pens per treatment) with an average initial BW of 13.1 lb.
[b]Treatment diets were fed from d 0 to 14.
[c]D 14 to 21 common SEW diet.

Table 4. Effects of Soybean Meal Source and Level on Growth Performance of Weanling Pigs (Exp. 2)[a]

		SBM		EESOY		SEM	SBM		EESOY		SBM vs. EESOY
Item	Control	20%	40%	20%	40%		Linear	Quad	Linear	Quad	
D 0 to 7											
ADG, lb	0.50	0.47	0.32	0.43	0.26	0.03	<0.01	0.12	<0.01	0.17	<0.01
ADFI, lb	0.48	0.43	0.32	0.41	0.29	0.03	<0.01	0.31	<0.01	0.40	<0.01
Feed/gain	0.96	0.93	1.02	0.97	1.11	0.02	0.08	0.04	<0.01	0.03	<0.01
D 7 to 14											
ADG, lb	0.64	0.66	0.71	0.62	0.57	0.03	0.05	0.75	0.11	0.57	0.98
ADFI, lb	0.65	0.65	0.68	0.64	0.57	0.03	0.40	0.61	0.03	0.35	0.47
Feed/gain	1.02	0.98	0.95	1.03	1.00	0.02	0.03	0.76	0.53	0.56	0.25
D 14 to 21[c]											
ADG, lb	0.97	1.08	1.10	0.99	1.05	0.03	<0.01	0.20	0.06	0.47	0.15
ADFI, lb	1.24	1.31	1.32	1.19	1.19	0.03	0.03	0.29	0.15	0.38	0.89
Feed/gain	1.30	1.23	1.20	1.22	1.14	0.02	<0.01	0.70	<0.01	0.91	0.02
D 0 to 14[b]											
ADG, lb	0.57	0.56	0.52	0.53	0.41	0.03	0.10	0.42	<0.01	0.21	<0.01
ADFI, lb	0.56	0.54	0.50	0.52	0.43	0.03	0.02	0.75	<0.01	0.26	<0.01
Feed/gain	0.99	0.95	0.98	1.00	1.06	0.02	0.76	0.11	<0.01	0.26	0.01
D 0 to 21											
ADG, lb	0.70	0.74	0.71	0.68	0.63	0.03	0.72	0.19	<0.01	0.53	0.04
ADFI, lb	0.79	0.80	0.77	0.75	0.68	0.02	0.42	0.44	<0.01	0.65	0.01
Feed/gain	1.09	1.05	1.05	1.07	1.08	0.02	0.08	0.13	0.77	0.40	0.47

[a]A total of 350 pigs (five pigs per pen and fourteen pens per treatment) with an average initial BW of 12.9 lb.
[b]Treatment diets were fed from d 0 to 14.
[c]D 14 to 21 common SEW diet.

Table 5. Soybean Meal Quality Analysis[a]

	Soybean Meal Source			
Lab Analysis	SBM 1[h]	SBM 2[i]	EESOY 1[j]	EESOY 2[k]
Crude protein[b]	46.7	45.3	43.6	44.4
Trypsin inhibitor, mgTI/g[c]	1.2	2.0	9.3	8.2
Urease[d]	0.02	0.02	0.04	0.03
Protein solubility index (KOH)[e]	78.9	81.6	83.2	83.1
Nitrogen solubility index (NSI)[f]	11.4	19.5	21.0	17.7
Mycotoxin[g]	----	Negative	----	Negative

[a]Urease, PSI, TI, and NSI results are reported on average from two different labs (KSU Swine Labs, Manhattan, KS and Woodson-Tenent, Des Moines, IA).
[b]Crude protein is on an as-fed basis.
[c]Trypsin inhibitor is a heat liable anti-nutritional factor (TI values of 1 to 4 mgTI/g of soybean meal are adequately processed).
[d]Urease is useful to determine if soybean meal has been heated enough to reduce anti-nutritional factors sufficiently (low urease value 0 to .2 is optimal value).
[e]KOH protein solubility index detects excessive heating or over-processing of soybean meal (decrease from 71 to 66 has shown a decreased pig performance).
[f]NSI is also a measure of protein solubility in water, but less sensitive than KOH (values of 12.5 have shown over-processing, 25.1 adequately processed, and 27.8 under-processed).
[g]Mycotoxins may cause reduced growth and feed efficiency.
[h]Soybean meal Exp. 1.
iSoybean meal Exp. 2.
[j]Extruded-expelled soybean meal Exp. 1.
[k]Extruded-expelled soybean meal Exp. 2.

EFFECTS OF DIFFERENT PROTEIN SOURCES ON GROWTH PERFORMANCE OF NURSERY PIGS

K. R. Lawrence, R. D. Goodband, M. D. Tokach, J. L. Nelssen, S. S. Dritz[1], J. M. DeRouchey, C. W. Hastad, S. M. Hanni, M. R. Barker, and B. W. James

Summary

A total of 170 weanling pigs (initially 16.4 lb) were used to evaluate the effects of alternative protein sources on growth performance of pigs fed from d 5 to 26 after weaning. All pigs were fed a common diet from weaning to d 5. The five dietary treatments were corn-soybean meal-based and included a control diet containing 10% dried whey, or the control diet with 5% select menhaden fish meal, 2.5% spray-dried blood cells, 3.73% enzymatically hydrolyzed wheat gluten (Source 1), or 3.51% flash-dried wheat gluten (Source 2). No differences were observed in overall ADG and ADFI; however, pigs fed the diets containing 2.5% blood cells or 5% select menhaden fish meal numerically had the best overall ADG compared to pigs fed the control diet, with pigs fed either wheat gluten sources having intermediate growth. Feed efficiency was improved for pigs fed 5% select menhaden fish meal compared with those fed the control diet, and pigs fed the other diets were intermediate. There were no differences ($P<0.05$) in ADG, ADFI, or F/G between wheat gluten sources.

(Key Words: Protein Sources, Wheat Gluten, Weanling Pigs.)

Introduction

Wheat gluten is a protein concentrate that is prepared by removing starch from wheat flour and drying the remaining high protein gluten. It is mainly used in a wide variety of baking applications, including breads, rolls, bakery mixes, and pastries, as well as other consumer goods. Data presented in the 1991 KSU Swine Industry Day Report of Progress suggest that spray-dried wheat gluten substituted for dried skim milk in nursery diets will improve growth performance of nursery pigs while lowering diet costs. In the present experiment, we looked at two different wheat gluten sources. Wheat gluten Source 1 was processed by low temperature drying, called ring drying, and enzymatic hydrolyzation. Source 1 is used in the feed industry to increase digestibility of the diet and, as a soluble wheat protein, can be used in milk replacers. Wheat gluten Source 2 is non-modified flash-dried gluten. Because of the enzymatic hydrolyzation, Source 1 should have higher digestibility and therefore be of higher quality for nursery pigs than Source 2. This experiment was designed to determine the effects of two wheat gluten sources processed by different methods compared with select menhaden fish meal and spray-dried blood cells on growth performance of nursery pigs.

[1]Food Animal Health and Management Center.

Procedures

A total of 170 pigs (initially 16.4 lb and 26 ± 3 d of age) were used in a 35-d growth assay. Two replications consisted of five pigs/pen and four replications consisted of 6 pigs/pen per treatment for a total of 30 pens. Pigs were weaned at 21 d of age and fed the same common phase I diet from d 0 to 5 postweaning. Experimental diets (Table 1) were fed to all pigs from d 5 to 26 postweaning. All diets were corn-soybean meal-based and formulated to 1.35% total lysine corresponding to a range of 1.13% to 1.16% digestible lysine, 0.85% Ca, and 0.45% to 0.48% available phosphorus. Pigs were fed the same common phase III diet from d 26 to 40 post weaning (21 to 35 of the experiment).

All pigs were housed at the Kansas State University Swine Teaching and Research Center in an environmentally controlled nursery, with a self-feeder and nipple waterer in each pen to allow ad libitum access to feed and water. Average daily gain, average daily feed intake, and feed efficiency were determined by weighing pigs and measuring feed disappearance on d 7, 14, 21, 28, and 35 of the experiment.

Data were analyzed using the MIXED procedure of SAS as a randomized complete block design with pen as the experimental unit. Least significant differences were used for making pairwise comparisons of the treatment means.

Results and Discussion

From d 0 to 7, no differences ($P>0.05$) were observed in growth performance. However, from d 7 to 14, pigs fed the diet containing 2.5% spray-dried blood cells had greater ADG compared to pigs fed the control diet. Pigs fed all other diets were intermediate. There were no differences ($P>0.05$) in ADFI or F/G. From d 14 to 21, pigs fed 5% select menhaden fish meal had greater ADG and ADFI ($P<0.05$) compared to pigs fed the control diet and wheat gluten Source 1. Pigs fed 2.5% spray-dried blood cells and wheat gluten Source 2 were intermediate. For the overall treatment period, d 0 to 21, no differences ($P>0.05$) were observed in ADG or ADFI. However, pigs fed either 2.5% spray-dried blood cells and 5% select menhaden fish meal had numerically greater ADG than those fed the control diet. Those fed either wheat gluten source had intermediate ADG. Pigs fed 5% select menhaden fish meal had improved ($P<0.05$) F/G compared to pigs fed the control diet. Pigs fed 2.5% spray-dried blood cells, wheat gluten Source 1, or wheat gluten Source 2, were intermediate in F/G from the other two diets. In previous studies evaluating pigs fed wheat gluten, in the period following feeding of the wheat gluten diet, pigs showed greater ADG compared to those not previously fed wheat gluten. Therefore, we monitored growth performance for an additional 14 d after the experimental treatment period. From d 21 to 35, when pigs were all fed a corn-soybean meal diet, there were no differences ($P>0.05$) in growth performance. For the overall period, no differences ($P>0.05$) were found in growth performance. In conclusion, pigs fed 5% select menhaden fish meal had better feed efficiency than those fed the control diet; however, neither ADG nor ADFI were affected by dietary treatments. Different processing methods of wheat gluten evaluated in this study do not appear to influence growth performance of nursery pigs.

Table 1. Diet Composition[a]

Ingredient, %	Control	5% Select Menhaden Fish Meal	2.5% Spray-Dried Blood Cells	Wheat Gluten Source 1	Wheat Gluten Source 2	Common Phase III
Corn	47.21	51.01	51.97	50.56	50.74	60.80
Soybean meal, 46.5%	35.06	27.60	27.60	27.60	27.60	32.25
Spray-dried whey	10.00	10.00	10.00	10.00	10.00	-
Fish meal	-	4.48	-	-	-	-
Spray-dried blood meal	-	-	2.50	-	-	-
Wheat gluten source 1	-	-	-	3.72	-	-
Wheat gluten source 2	-	-	-	-	3.54	-
Soy oil	3.00	3.00	3.00	3.00	3.00	3.00
Monocalcium phosphate, 21% P	1.48	1.00	1.60	1.62	1.63	1.45
Limestone	0.98	0.65	0.98	0.95	0.95	1.05
Antimicrobial[b]	1.00	1.00	1.00	1.00	1.00	0.50
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15
Threonine	0.02	0.03	0.06	0.05	0.07	-
Zinc oxide	0.35	0.35	0.35	0.35	0.35	-
Lysine HCl	0.10	0.10	0.10	0.31	0.32	0.15
DL-Methionine	0.08	0.04	0.10	0.07	0.06	0.05
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated analysis						
Total lysine, %	1.35	1.35	1.35	1.35	1.35	1.25
Isoleucine:lysine, %	69	66	59	65	65	67
Met & Cys:lysine, %	58	56	56	57	59	58
Threonine:lysine, %	65	65	65	65	65	62
Tryptophan:lysine, %	20	19	19	18	19	20
Valine:lysine, %	77	76	82	74	74	77
Protein, %	21.5	21.2	20.8	21.2	21.2	20.2
Calcium, %	0.85	0.85	0.85	0.85	0.85	0.80
Phosphorus, %	0.76	0.75	0.75	0.75	0.76	0.70
Available phosphorus , %	0.45	0.47	0.48	0.48	0.48	0.38

[a]Values calculated on an as-fed basis.
[b]Provided 50g/ton carbadox.

Table 2. Effect of Different Protein Sources on Growth Performance of Weanling Pigs[a]

		Protein Source				
Treatment	Control	5% Select Menhaden-Fish Meal	2.5% Spray-Dried Blood Cells	Wheat Gluten Source 1	Wheat Gluten Source 2	SEM
Day 0 to 7						
ADG, lb	0.54	0.48	0.51	0.51	0.52	0.06
ADFI, lb	0.65	0.59	0.62	0.64	0.64	0.08
Feed/gain	1.24	1.24	1.23	1.25	1.29	0.05
Day 7 to 14						
ADG, lb	0.99^{d}	1.08^{de}	1.13^{e}	1.10^{de}	1.02^{de}	0.06
ADFI, lb	1.34	1.41	1.46	1.42	1.36	0.08
Feed/gain	1.36	1.29	1.29	1.28	1.33	0.03
Day 14 to 21						
ADG, lb	0.93^{d}	1.12^{e}	1.02^{de}	0.95^{d}	1.01^{de}	0.06
ADFI, lb	1.44^{d}	1.60^{f}	1.58^{ef}	1.43^{d}	1.48^{de}	0.08
Feed/gain	1.56	1.43	1.54	1.51	1.46	0.05
Day 0 to 21[b]						
ADG, lb	0.82	0.89	0.89	0.86	0.85	0.05
ADFI, lb	1.14	1.20	1.22	1.16	1.16	0.07
Feed/gain	1.38^{e}	1.32^{d}	1.36^{de}	1.35^{de}	1.36^{de}	0.02
Day 21 to 35[c]						
ADG, lb	1.37	1.42	1.42	1.39	1.35	0.06
ADFI, lb	2.17	2.22	2.29	2.21	2.19	0.09
Feed/gain	1.60	1.61	1.63	1.59	1.62	0.02
Day 0 to 35						
ADG, lb	1.04	1.10	1.10	1.07	1.05	0.05
ADFI, lb	1.55	1.61	1.65	1.58	1.57	0.07
Feed/gain	1.47	1.44	1.46	1.44	1.46	0.02

[a]A total of 170 weanling pigs (two reps with five pigs/pen and four reps with six pigs/pen for a total of six pens/treatment) initially 16.35 lb and 26 ± 3 d of age.

[b]Treatment diets were fed from d 0 to 21. Overall, P=0.25 for ADG, P=0.13 for ADFI, and P=0.50 for F/G. For week, the overall P-value was P<.01 for ADG, ADFI, and F/G. There was no treatment by week interaction for ADG, ADFI, and F/G (P<0.05).

[c]D 21 to 35 common Phase III diet.

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

INTERACTIVE EFFECTS BETWEEN PAYLEAN (RACTOPAMINE·HCl) AND DIETARY L-CARNITINE ON FINISHING PIG GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS

B. W. James, M. D. Tokach, R. D. Goodband, J. L. Nelssen, S. S. Dritz[1], K. Q. Owen[2], J. A. Unruh, and T. E. Lawrence

Summary

Growth performance, carcass characteristics, and meat quality were evaluated from 126 pigs fed combinations of Paylean and L-carnitine arranged in a 3 × 3 factorial. Dietary L-carnitine (0, 25, or 50 ppm) was fed from 74 lb until slaughter, and Paylean (0, 4.5, or 9 g/ton) was fed the last 4 weeks prior to slaughter. These results suggest that Paylean, but not L-carnitine, increases ADG and improves F/G. However, L-carnitine enhances meat quality by improving visual color, L* (darker color), b* (less yellow), a*/b*, and Hue angle (more red and less orange) when fed with Paylean. L- carnitine also decreases drip loss and saturation index (vividness or intensity) and increases 24-h pH.

(Key Words: Carnitine, Paylean, Meat Quality.)

Introduction

In 1999 Paylean was approved by the FDA for use in finishing pig diets. Extensive research has shown that Paylean improves growth performance and carcass leanness in pigs by directing nutrients away from fat deposition and towards lean deposition. To support the increased lean tissue deposition, pigs fed Paylean need a higher dietary lysine (protein) level than pigs not fed Paylean. The increase in protein deposition is very rapid during the first 2 weeks when Paylean is fed. During this time, it is possible that pigs may be in an energy dependent phase of growth and are not consuming enough feed to maximize protein deposition. Adding carnitine to the diet could increase the amount of energy available for protein deposition and increase the response to Paylean. Therefore, the objectives of this experiment were to evaluate the effects of Paylean dosage and dietary carnitine on growth performance and carcass parameters of growing-finishing pigs and to evaluate differences in longissimus quality indicators, such as color, marbling and firmness.

Procedures

One hundred twenty-six gilts (initially 73.6 lb, PIC C22 × L326) were allotted by weight and ancestry in a randomized complete block design to each of the 9 experimental treatments in a 3 × 3 factorial arrangement. There were 2 pigs per pen and 7 replicates per treatment. Pigs were housed in an environmentally controlled building with 4 × 4-ft slatted-floor pens. Each pen had a one-hole self-feeder and a nipple waterer to allow ad libitum access to feed and water.

[1]Food Animal Health and Management Center.
[2]Lonza, Inc., Fair Lawn, NJ.

Pigs were fed a corn-soybean meal diet (Table 1) with added L-carnitine (0, 25, or 50 ppm) from 73.6 lb until slaughter (approximately 240 lb). The basal diet was formulated to contain 1.10% lysine from 73.6 to 164 lb, and 1.00% lysine from 164 lb until the end of the experiment. Dietary Paylean treatments (0, 4.5, or 9 g/ton) were fed for the last 4 weeks of the experiment.

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

Ingredient, %	73.6 to 164 lb	164 lb to slaughter
Corn	68.41	74.50
Soybean meal (46.5% CP)	26.63	22.80
Soybean oil	2.00	-
Monocalcium phosphate	1.05	0.90
Limestone	1.00	0.90
Salt	0.35	0.35
Vitamin premix[b]	0.15	0.15
Trace mineral premix[c]	0.15	0.15
L-Lysine HCL	0.15	0.15
Medication[d]	0.05	-
DL-Methionine	0.01	-
Cornstarch[e]	0.05	0.10
Calculated composition		
CP (N × 6.25), %	18.20	16.90
Lysine, %	1.10	1.00
Methionine, %	0.31	0.28
Threonine, %	0.69	0.64
ME, kcal/lb	1,542	1,505
Ca, %	0.69	0.61
P, %	0.60	0.55

[a]Diets were formulated to meet or exceed NRC (1998) requirements.

[b]Provided 44 mg tylosin/kg feed.

[c]L-Carnitine replaced cornstarch to provide either 0, 25, or 50 ppm L-Carnititne. Paylean replaced cornstarch to provide either 0, 4.5, or 9 g/ton ractopamine·HCl during the last 4 weeks of the experiment.

Weights were obtained on all pigs and feed disappearance was recorded every 14 days during the experiment until the last 4 weeks, at which time measurements were recorded weekly to calculate ADG, ADFI, and F/G. One pig (closest to 240 lb) per pen was selected and slaughtered at the Kansas State University Meat Laboratory. Standard carcass measurements, visual analyses of longissimus muscle color, marbling, and firmness, color spectrophotometry (L*, a*, and b*), drip loss, ultimate pH, and temperature were obtained from each pig at 24-h postmortem.

Data were analyzed as a randomized complete block. Pen was the experimental unit for growth performance data, carcass characteristics, and meat quality measurements. Analysis of variance was performed using the GLM procedure of SAS. Hot carcass weight was used as a covariate in the statistical analysis of backfat, carcass length, loin eye area, and percentage lean.

Results and Discussion

Growth Performance. Supplementing finishing pig diets with L-carnitine did not affect (P>0.64) growth performance of pigs between 73.6 and 164 lb (Table 2). Pigs were allotted to treatments at the initiation of feeding carnitine and remained within the same treatment groups for the duration of the experiment. This explains the numeric (P<0.22) differences in initial weight at the beginning of the Paylean feeding period (Table 3). Two pens within the same treatment (50 ppm L-carnitine and 4.5 g/ton Paylean) were removed from the experiment because of clinical ileitis, therefore values reported in the tables are means of seven or five replications. There were no Paylean × carnitine interactions (P>0.12) observed for ADG, ADFI, or F/G during the last 4 weeks of the experiment. Increasing Paylean increased ADG (quadratic, P<0.02) and improved (quadratic, P<0.01) F/G. Average daily gain decreased from 0 to 4.5 g/ton but increased and was highest for pigs fed 9 g/ton Paylean. Feed efficiency

improved with increasing Paylean and was best for pigs fed 9 g/ton Paylean.

Carcass Characteristics. There were no Paylean × carnitine interactions ($P>0.14$) for carcass characteristics (Table 4). Dressing percentage tended to be greater ($P<0.08$) for pigs fed Paylean compared to control pigs. Shrink loss (1-(cold carcass wt/hot carcass wt)×100), average backfat, 10th rib fat depth, carcass length, longissimus muscle area, and percentage lean were not affected ($P>0.12$) by Paylean or dietary L-carnitine.

A Paylean × carnitine interaction was observed ($P<0.02$) for visual color, L*, a*/b* ratio, and Hue angle (Table 5). Carnitine did not improve visual color scores in control pigs, but carnitine improved visual color when 4.5 or 9 g/ton of Paylean was fed. Pigs fed increasing carnitine had lower L* values when fed with 4.5 or 9 g/ ton of Paylean, resulting in a darker colored longissimus muscle measured at the 10th rib. Pigs fed carnitine and 4.5 or 9 g/ton Paylean, but not control pigs, had lower a*/b* and Hue angle values, resulting in more red and less orange color.

Measurements of b* decreased (quadratic, $P<0.05$) with increasing carnitine, resulting in less yellow color of the longissimus muscle. The saturation index (vividness or intensity) measured on the longissimus muscle tended to decrease (quadratic, $P<0.07$) with increasing levels of carnitine. Drip loss measured 48 hours postmortem and temperature at 45 minutes postmortem decreased (linear, $P<0.04$) with increasing carnitine. Twenty-four hour pH increased and then decreased (quadratic, $P<0.06$) with increasing Paylean and was highest for pigs fed 4.5 g/ton. Ultimate (24-h) pH also increased (linear, $P<0.07$) with increasing dietary L-carnitine.

The improvements in meat quality of pigs fed L-carnitine in combination with Paylean may be the result of carnitine's affect on the pigs' metabolic parameters either antimortem or postmortem. Carnitine has been shown to increase pyruvate carboxylase and decrease lactate dehydrogenase in pigs. An increase in pyruvate carboxylase may direct pyruvate away from lactate, thus reducing substrate for lactic acid synthesis postmortem. Furthermore, a decrease in lactate dehydrogenase may delay the onset of postmortem glycolysis. In theory, this would result in an increase in pH and therefore better water holding capacity and decreased drip loss. Subsequently, meat color would be darker.

The results of this experiment suggest that L-carnitine improves meat quality in pigs fed Paylean. Further research needs to be conducted to better understand the effects and metabolic action of carnitine on antimortem lactate levels and postmortem glycolysis. If further studies confirm pork quality benefits, such as decreased drip loss, increased pH, and improved meat color, or decreased serum lactate levels, the potential exists for dietary L-carnitine to be used in conjunction with Paylean in the late finishing phase.

Table 2. Effect of Carnitine on Growth Performance of the Finishing Pig Prior to Feeding Paylean[a]

	Carnitine, ppm				Probability ($P<$)		
Item	0	25	50	SEM	Carnitine	Linear	Quad
ADG, lb	1.98	2.02	2.03	0.04	0.64	0.37	0.76
ADFI, lb	4.41	4.44	4.45	0.06	0.90	0.65	0.91
Feed/gain	2.24	2.20	2.21	0.03	0.66	0.49	0.55

[a]Values represent the period from 73.6 to 164.0 lb BW. At 164 lb, pigs were switched to diets containing 0, 4.5, or 9 g/ton Paylean in addition to the carnitine levels. Values are means of 21 replications (pens) and 2 pigs per pen.

Table 3. Effect of Carnitine and Paylean on Finishing Pig Growth Performance[a]

	Paylean, g/ton										Probability (*P*<)						
	0			4.5			9										
	Carnitine, ppm										Paylean ×			Paylean		Carnitine	
Item	0	25	50	0	25	50	0	25	50	SEM	Carnitine	Paylean	Carnitine	Linear	Quad	Linear	Quad
Initial wt	157.7	163.7	163.8	164.8	166.2	166.4	166.8	163.4	164.9	2.98	0.58	0.22	0.72	0.11	0.56	0.43	0.87
ADG, lb	2.14	2.18	2.39	2.32	2.18	2.14	2.48	2.23	2.43	0.10	0.12	0.07	0.13	0.88	0.02	0.73	0.04
ADFI, lb	5.49	5.52	5.89	5.48	5.29	5.31	5.87	5.25	5.50	0.20	0.17	0.21	0.16	0.08	0.77	0.84	0.06
Feed/gain	2.60	2.54	2.47	2.39	2.44	2.48	2.38	2.37	2.28	0.08	0.53	0.01	0.55	0.05	0.01	0.32	0.64
Final wt	217.5	224.6	230.8	229.6	227.1	226.4	236.1	225.7	232.9	4.50	0.10	0.09	0.39	0.26	0.06	0.42	0.25

[a]Values are means of seven or five replications (pens) and two pigs per pen for 28 d.

Table 4. Carcass Characteristics of Finishing Pigs Fed Carnitine and Paylean[a,b]

	Paylean, g/ton										Probability (*P*<)						
	0			4.5			9										
	Carnitine, ppm										Paylean ×			Paylean		Carnitine	
Item	0	25	50	0	25	50	0	25	50	SEM	Carnitine	Paylean	Carnitine	Linear	Quad	Linear	Quad
Dressing, %	72.99	73.39	73.40	74.19	74.26	73.68	75.18	73.40	73.63	0.57	0.14	0.08	0.40	0.06	0.25	0.21	0.64
Shrink loss[c], %	2.15	2.12	2.13	2.15	2.64	2.08	1.32	2.01	1.96	0.40	0.69	0.13	0.37	0.53	0.05	0.45	0.24
Backfat, in																	
First rib	1.56	1.43	1.50	1.45	1.45	1.47	1.42	1.44	1.38	0.10	0.87	0.51	0.82	0.55	0.32	0.65	0.68
Tenth rib	0.66	0.57	0.60	0.57	0.55	0.53	0.58	0.57	0.46	0.06	0.64	0.13	0.19	0.10	0.22	0.07	0.96
Last rib	1.00	0.96	0.94	0.91	0.98	0.95	1.03	0.96	0.89	0.07	0.60	0.86	0.46	0.61	0.85	0.23	0.70
Last lumbar	0.69	0.64	0.67	0.60	0.56	0.67	0.60	0.57	0.60	0.06	0.94	0.20	0.43	0.16	0.27	0.77	0.21
Average	1.08	1.01	1.04	0.99	0.99	1.03	1.02	0.99	0.96	0.07	0.86	0.48	0.74	0.34	0.45	0.55	0.63
Carcass length, in	31.51	31.56	31.34	31.75	31.32	31.43	31.14	31.30	31.46	0.28	0.53	0.56	0.93	0.85	0.29	0.80	0.77
Loin eye area, in^2	6.81	7.10	6.60	6.89	6.94	7.14	7.27	7.28	7.28	0.38	0.88	0.23	0.85	0.62	0.10	0.99	0.57
Lean, %	56.17	58.04	56.56	57.47	57.96	58.50	58.30	59.72	59.72	1.31	0.78	0.12	0.52	0.26	0.09	0.31	0.64

[a]Hot carcass weight was used as a covariate in the statistical analysis except for dressing (%) and shrink loss (%).

[b]Values are means of seven or five replications (pig closest to 240 lb in each pen).

[c]Shrink loss was calculated as 1-(cold carcass wt/hot carcass wt) × 100.

Table 5. Carcass Quality Measures of Finishing Pigs Fed Carnitine and Paylean[a]

	Paylean, g/ton										Probability (*P*<)						
	0			4.5			9							Paylean		Carnitine	
	Carnitine, ppm										Paylean ×						
Item	0	25	50	0	25	50	0	25	50	SEM	Carnitine	Paylean	Carnitine	Linear	Quad	Linear	Quad
Visual color[b]	3.35	2.78	31.4	2.57	3.28	3.49	2.57	3.00	2.85	0.25	0.02	0.15	0.18	0.99	0.08	0.11	0.82
Firmness[b]	1.93	1.65	1.93	1.79	1.93	2.05	1.79	2.15	1.79	0.24	0.43	0.88	0.88	0.66	0.81	0.66	0.81
Marbling[b]	2.00	1.71	1.85	1.35	2.07	1.82	1.64	2.00	1.71	0.21	0.08	0.76	0.22	0.46	0.91	0.42	0.13
L*[c]	55.37	58.01	56.80	60.78	56.39	55.06	61.53	58.46	57.88	1.25	0.01	0.01	0.02	0.42	0.01	0.01	0.68
a*[c]	7.61	6.17	6.45	5.78	6.22	7.00	6.30	6.71	6.51	0.53	0.08	0.49	0.81	0.23	0.99	0.94	0.52
b*[c]	15.25	14.61	15.10	15.69	14.09	14.19	15.90	14.98	15.04	0.53	0.67	0.25	0.01	0.42	0.14	0.03	0.05
a*b*[c]	0.50	0.42	0.43	0.37	0.44	0.50	0.39	0.45	0.43	0.03	0.01	0.52	0.33	0.42	0.49	0.27	0.90
Hue angle	63.60	67.38	67.05	69.95	66.31	63.71	68.65	65.91	66.69	1.44	0.01	0.55	0.31	0.44	0.52	0.25	0.84
Saturation index[c]	17.06	15.89	16.44	16.79	15.42	15.84	17.12	16.43	16.41	0.64	0.97	0.32	0.04	0.30	0.26	0.09	0.07
Drip loss	2.68	2,80	2.07	3.13	31.48	1.49	3.68	2.29	2.94	0.66	0.47	0.16	0.06	0.33	0.09	0.04	0.22
Temperature, °C	34.72	34.83	32.98	34.39	34.38	33.80	35.72	34.15	33.76	0.83	0.60	0.74	0.04	0.97	0.44	0.01	0.62
pH																	
45 m postmortem	6.22	6.55	6.46	6.41	6.44	6.34	6.33	6.23	6.39	0.10	0.10	0.38	0.39	0.99	0.17	0.24	0.49
24 h postmortem	5.75	5.79	5.76	5.79	5.86	5.86	5.71	5.79	5.78	0.04	0.91	0.01	0.04	0.01	0.06	0.07	0.08

[a]Values are means of seven or five replications (pig closest to 240 lb in each pen).

[b]Scoring system of 1 to 5: 2 = grayish pink, traces to slight, or soft and watery; 3 = reddish pink, small to modest, or slightly firm and moist; and 4 = purplish red, moderate to slightly abundant, or firm and moderately dry for color, firmness, and marbling, respectively.

[c]Means were derived from 2 sample readings per loin. Measures of dark to light (L*), redness (a*), yellowness (b*), red to orange (hue angle), or vividness or intensity (saturation index).

EFFECT OF L-CARNITINE AND PAYLEAN (RACTOPAMINE·HCl) SUPPLEMENTATION ON GROWTH PERFORMANCE, CARCASS CHARACTERISTICS, AND POSTMORTEM pH DECLINE

B. W. James, M. D. Tokach, R. D. Goodband, J. L. Nelssen, S. S. Dritz[1], K. Q. Owen[2], J. A. Unruh, and T. E. Lawrence

Summary

Growth performance, carcass characteristics, and meat quality were evaluated from 126 pigs fed combinations of Paylean and L-carnitine arranged in a 2 × 3 factorial. Dietary L-carnitine (0, 25, or 50 ppm) and Paylean (0 or 9 g/ton) were fed the last 4 weeks prior to slaughter. Feeding Paylean to pigs improved (P<0.01) ADG and F/G. Supplemental L-carnitine did not affect (P>0.46) ADG, but there was a trend for improved (quadratic, P<0.07) F/G in pigs fed increasing carnitine. A carnitine × Paylean interaction (P<0.05) was observed for dressing percentage and visual firmness, percentage transmission (soluble protein), temperature measured 1.5 h postmortem, and percentage drip loss. Dressing percentage was higher for pigs fed 25 ppm carnitine with no Paylean and lower for pigs fed 25 ppm carnitine with Paylean. Visual firmness scores decreased in pigs fed increasing carnitine and no Paylean but increased when adding carnitine to diets containing Paylean. Soluble protein increased (more soluble protein indicates higher quality muscle) and drip loss decreased when pigs were fed increasing L-carnitine with Paylean. A trend (P<0.07) was observed for pigs fed increasing carnitine to have lower 10th rib and average backfat. Feeding Paylean to pigs increased (P<0.01) percentage lean, L*, and hue angle, and decreased (P<0.02) visual color scores and a*/b* values. Pigs fed Paylean had higher temperature and lower pH measured 3 h postmortem (P<0.01) and tended (P<0.06) to have lower pH measured 6 h postmortem. These results suggest that Paylean improves growth performance when fed to finishing pigs. Carnitine decreased drip loss and improved meat quality when fed to pigs in combination with Paylean.

(Key Words: Carnitine, Paylean, Meat Quality.)

Introduction

Previous research conducted with L-carnitine and Paylean demonstrated that Paylean, but not carnitine, improved growth performance when fed during the late finishing phase. However, pigs fed L-carnitine had improved visual color, L*, b*, a*/b*, and Hue angle when fed in combination with Paylean. In addition pigs fed L-carnitine had decreased percentage drip loss and saturation index, which was supported by a higher ultimate pH. These results led us to hypothesize that carnitine may be having an affect on the pigs' metabolic parameters either antimortem or postmortem. Carnitine has been shown to increase pyruvate carboxylase and decrease lactate dehydrogenase in pigs. This may explain the increase in pH and decreased drip loss when adding carnitine to the diet. Therefore, the objective of this experiment was to verify

[1]Food Animal Health and Management Center.
[2]Lonza, Inc., Fair Lawn, NJ.

the affect of L-carnitine and Paylean supplementation on growth performance, carcass characteristics, and postmortem pH decline in finishing pigs.

Procedures

One hundred twenty gilts (initially 192.2 lb, PIC C22 × L326) were allotted by weight and ancestry in a randomized complete block design to each of the six experimental treatments arranged in a 2 × 3 factorial. There were 2 pigs/pen and 10 replicates/treatment. Pigs were fed a corn-soybean meal basal diet (1.00% lysine; 16.9% CP) with added L-carnitine (0, 25, or 50 ppm) and Paylean (0 or 9 g/ton) for the four-week experiment (Table 1).

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

Ingredient, %	
Corn	74.50
Soybean meal (46.5% CP)	22.80
Monocalcium phosphate, 21%P	0.90
Limestone	0.90
Salt	0.35
Vitamin premix	0.15
Trace mineral premix	0.15
L-Lysine HCL	0.15
Cornstarch[b]	0.10
Calculated composition	
CP (N × 6.25), %	16.90
Lysine, %	1.00
Methionine, %	0.28
Threonine, %	0.64
ME, kcal/lb	1,505
Calcium, %	0.61
Phosphorus, %	0.55

[a]Diets were formulated to meet or exceed NRC (1998) requirements.

[b]L-Carnitine replaced cornstarch to provide either 0, 25, or 50 ppm L-Carnitine and Paylean replaced cornstarch to provide either 0 or 0 g/ton ractopamine·HCl.

Pigs were housed in an environmentally controlled building with 4 × 4-ft slatted-floor pens. Each pen had a one-hole self-feeder and a nipple waterer to allow ad libitum access to feed and water. Weights were obtained on all pigs and feed disappearance was recorded every 14 d during the experiment to calculate ADG, ADFI, and F/G. One pig (closest to 240 lb) per pen was randomly selected and slaughtered at the Kansas State University Meats Laboratory. Blood was collected as soon as possible after exsanguination and pH, glucose, and lactate were measured from whole blood. Longissimus pH and temperature were measured as soon as possible after exsanguination and at 15 min, 45 min, 1.5 h, 3 h, and 6 h postmortem. Standard carcass measurements; visual analyses of longissimus muscle color, marbling, and firmness; color spectrophotometry (L*, a*, and b*); drip loss; and ultimate pH were obtained from each pig at 24-h postmortem. A 10-g tissue sample was obtained from the longissimus muscle at the 11th rib to measure transmission value. The sample was thoroughly mixed with 20 ml of distilled water and stored at 3 ^{o}C for 24 h. It was then centrifuged at 500 × g for 20 min and the supernatant was filtered through #1 Whatman filter paper. The filtrate (1 ml) was mixed with citric acid-phosphate buffer (5 ml), stored for 30 min at 24^{o}C, and percentage turbidity measured at 600 nm. High transmission values indicate less soluble protein and lower quality muscle.

Data were analyzed as a randomized complete block. Pen was the experimental unit for growth performance data, carcass characteristics, and meat quality measurements. Analysis of variance was performed using the GLM procedure of SAS. Hot carcass weight was used as a covariate in the statistical analysis of backfat, carcass length, loin eye area, and percentage lean.

Results and Discussion

Growth Performance. There were no Paylean × carnitine interactions ($P>0.87$) observed for ADG, ADFI, or F/G (Table 2). Feeding pigs Paylean improved ($P<0.01$) ADG and feed efficiency. There was no effect ($P>0.46$) of feeding L-carnitine on ADG. However, pigs fed carnitine tended (quadratic, $P<0.07$) to have improved F/G, which was best for pigs fed 25 ppm carnitine. The major differences between this experiment and our previous experiment are: 1) only two levels of Paylean (0 and 9 g/ton) were fed compared to three (0, 4.5, and 9 g/ton) levels fed in the previous experiment; and 2) L-carnitine was only fed for four weeks compared to approximately six or seven weeks. Paylean improved both ADG and F/G in both experiments.

Carcass Characteristics. A Paylean × carnitine interaction was observed ($P>0.01$) for dressing percentage (Table 3). Dressing percentage was higher for pigs fed 25 ppm carnitine and no Paylean and was lower for pigs fed 25 ppm carnitine and 9 g/ton Paylean.

Shrink loss (1-(cold carcass wt/hot carcass wt)×100), carcass length, and longissimus muscle area were not affected ($P>0.37$) by feeding either Paylean or L-carnitine. Tenth rib fat depth and average backfat were not affected ($P>0.30$) by feeding Paylean; however, there was a trend (linear, $P<0.07$) for pigs fed increasing L-carnitine to have lower 10^{th} rib and average backfat. Feeding Paylean to pigs increased ($P<0.01$) percentage lean.

A Paylean × carnitine interaction ($P<0.04$) was observed for visual firmness, percentage drip loss, percentage transmission, and temperature measured 1.5 h postmortem (Table 4). Visual firmness scores decreased when pigs were fed increasing carnitine and no Paylean but increased with increasing carnitine when Paylean was in the diet. Percentage drip loss and percentage transmission value decreased with increasing carnitine when fed with Paylean. A high transmission value indicates less soluble protein and higher quality muscle. Therefore, feeding carnitine improves meat quality when fed in combination with Paylean. In addition, longissimus muscle temperature was lower for pigs fed increasing levels of carnitine when Paylean was fed. Feeding carnitine to pigs did not affect ($P>0.07$) any of the other measured carcass characteristics. Visual color scores and a*/b* decreased ($P<0.02$) and L* and hue angle increased ($P<0.01$) when pigs were fed Paylean, resulting in a lighter colored longissimus muscle. Pigs fed Paylean also had higher temperature and lower pH measured 3 h postmortem ($P<0.01$) and tended ($P<0.06$) to have lower pH measured 6 h postmortem.

The results of this experiment suggest that L-carnitine improves meat quality in pigs fed Paylean. The postmortem pH was not as greatly affected as previously hypothesized. However, improvements in other meat quality indicators, such as transmission value (more soluble protein indicating higher muscle quality) and decreased drip loss, were observed, which support the findings of our initial research. Because postmortem pH was not significantly affected by feeding carnitine, the mode of action for the improved meat quality is likely occurring prior to slaughter. The duration of carnitine supplementation was shorter in this experiment and may contribute to some of the variation from the results of other experiments. The affect of carnitine may be different at a commercial finishing facility where pigs have lower feed intake and different metabolic stressors compared to these that were reared at a university research facility. These factors support the need for further research to better understand the affects of carnitine under different situations.

Table 2. Effect of Carnitine and Paylean on Growth Performance of the Finishing Pig[a]

	Paylean, g/ton							Probability (*P*<)				
	0			9							Carnitine	
	Carnitine, ppm							Paylean ×				
Item	0	25	50	0	25	50	SEM	Carnitine	Paylean	Carnitine	Linear	Quadratic
Day 0 to 14												
ADG, lb	2.22	2.26	2.21	2.76	2.72	2.60	0.13	0.82	0.01	0.72	0.48	0.70
ADFI, lb	6.04	5.76	5.53	6.04	6.00	5.74	0.20	0.65	0.91	0.09	0.05	0.36
Feed/gain	2.76	2.58	2.52	2.19	2.06	2.30	0.12	0.36	0.01	0.43	0.50	0.27
Day 14 to 28												
ADG, lb	2.37	2.35	2.24	2.15	2.40	2.29	0.15	0.55	0.73	0.68	0.97	0.39
ADFI, lb	7.33	7.00	6.98	7.14	6.89	6.73	0.25	0.96	0.37	0.28	0.13	0.65
Feed/gain	3.18	3.09	3.15	3.43	2.93	3.03	0.20	0.54	0.95	0.33	0.29	0.29
Day 0 to 28												
ADG, lb	2.30	2.31	2.23	2.47	2.55	2.45	0.07	0.90	0.01	0.46	0.50	0.30
ADFI, lb	6.69	6.38	6.25	6.53	6.22	6.24	0.18	0.90	0.44	0.10	0.05	0.41
Feed/gain	2.92	2.77	2.82	2.66	2.43	2.55	0.09	0.87	0.01	0.10	0.23	0.07

[a]Average initial BW, 192.2 lb.
[b]Values are means of 10 replications (pens) and one or two pigs per pen.

Table 3. Carcass Characteristics of Finishing Pigs fed Carnitine and Paylean[a,b]

	Paylean, g/ton							Probability (*P*<)				
	0			9							Carnitine	
	Carnitine, ppm							Paylean ×				
Item	0	25	50	0	25	50	SEM	Carnitine	Paylean	Carnitine	Linear	Quadratic
Dressing, %	72.30	74.48	72.71	74.90	73.56	74.25	0.39	0.01	0.35	0.01	0.79	0.23
Shrink loss, %	2.27	1.72	1.73	1.76	1.79	1.74	0.24	0.41	0.46	0.42	0.24	0.56
Backfat, in												
First rib	1.41	1.41	1.25	1.42	1.48	1.35	0.07	0.83	0.25	0.08	0.09	0.14
Tenth rib	0.68	0.65	0.63	0.67	0.63	0.56	0.04	0.77	0.30	0.18	0.06	0.86
Last rib	0.81	0.83	0.79	0.89	0.78	0.79	0.05	0.47	0.84	0.46	0.24	0.70
Last lumbar	0.73	0.66	0.68	0.71	0.65	0.59	0.05	0.85	0.35	0.26	0.11	0.63
Average	0.98	0.96	0.91	1.01	0.97	0.91	0.05	0.96	0.76	0.19	0.07	0.73
Carcass length, in	32.65	32.83	32.55	32.63	32.68	32.65	0.26	0.89	0.90	0.83	0.88	0.55
Loin eye area, in^2	6.60	7.09	6.73	7.81	7.21	7.90	0.23	0.94	0.76	0.37	0.65	0.60
Lean, %	54.85	55.50	55.80	56.71	56.19	58.09	0.71	0.50	0.01	0.19	0.10	0.40

[a]Hot carcass weight was used as a covariate in the statistical analysis except for dressing (%) and shrink loss (%).
[b]Values are means of 10 replications (one pig selected randomly from each pen).

Table 4. Carcass Characteristics of Finishing Pigs fed Carnitine and Paylean[a]

	Paylean, g/ton											
	0			9				Probability ($P<$)				
	Carnitine, ppm							Paylean ×			Carnitine	
Item	0	25	50	0	25	50	SEM	Carnitine	Paylean	Carnitine	Linear	Quadratic
Visual color[b]	3.20	3.10	2.90	2.75	2.75	2.80	0.16	0.52	0.02	0.72	0.93	0.43
Firmness[b]	2.59	2.44	2.34	1.99	2.59	2.34	0.15	0.04	0.25	0.33	0.75	0.15
Marbling[b]	1.65	1.75	1.55	1.85	1.75	1.60	0.18	0.85	0.57	0.53	0.33	0.57
L*[c]	57.18	57.23	58.00	59.72	59.63	58.44	0.83	0.37	0.01	0.95	0.78	0.89
a*[c]	7.54	7.58	7.93	7.94	6.73	6.61	0.38	0.07	0.07	0.29	0.24	0.30
b*[c]	15.81	15.86	16.27	16.97	15.75	15.29	0.47	0.08	0.95	0.37	0.22	0.51
a*/b*[c]	0.48	0.48	0.49	0.46	0.43	0.43	0.02	0.40	0.01	0.44	0.46	0.30
Hue angle[c]	64.49	64.61	64.07	65.14	66.99	66.70	0.78	0.39	0.01	0.45	0.47	0.30
Saturation index[c]	17.52	17.59	18.11	18.74	17.13	16.67	0.56	0.06	0.64	0.321	0.20	0.42
Drip loss, %	2.04	3.07	2.73	4.85	2.47	2.82	0.64	0.02	0.48	0.15	0.32	0.56
Transmission, %	50.40	53.09	60.00	66.69	49.85	58.27	3.52	0.01	0.19	0.06	0.87	0.02
Temperature, °C												
5 min postmortem	38.59	39.79	39.17	39.60	39.74	39.68	0.56	0.60	0.24	0.40	0.51	0.25
15 min postmortem	40.20	39.92	39.56	40.42	40.18	40.06	0.31	0.88	0.16	0.23	0.09	0.97
45 min postmortem	37.72	39.03	38.73	39.43	38.35	38.76	0.69	0.18	0.16	0.23	0.73	0.93
1.5 h postmortem	32.91	32.87	33.17	35.99	33.51	32.65	0.72	0.04	0.06	0.07	0.05	0.46
3 h postmortem	21.38	22.12	20.89	24.38	22.37	22.76	0.63	0.10	0.01	0.26	0.11	0.85
6 h postmortem	10.74	11.28	11.22	12.04	11.09	10.97	0.48	0.20	0.47	0.82	0.55	0.89
Blood												
Glucose	109.73	107.07	108.44	109.21	103.82	108.89	3.74	0.88	0.71	0.51	0.83	0.26
Lactate	12.46	11.78	10.41	11.71	9.93	10.36	1.51	0.84	0.47	0.50	0.26	0.77
pH	7.14	7.13	7.21	7.16	7.16	7.21	0.05	0.94	0.76	0.37	0.23	0.47
Longissimus pH												
5 min postmortem	6.93	6.84	6.82	6.79	6.80	6.94	0.07	0.17	0.76	0.66	0.74	0.40
15 min postmortem	6.55	6.60	6.58	6.59	6.47	6.49	0.07	0.48	0.35	0.84	0.62	0.76
45 min postmortem	6.16	6.16	6.02	6.14	6.21	6.13	0.10	0.82	0.57	0.54	0.44	0.43
1.5 h postmortem	5.95	5.91	5.97	5.89	5.95	5.92	0.10	0.87	0.74	0.96	0.77	0.94
3 h postmortem	5.77	5.76	5.88	5.59	5.67	5.69	0.08	0.77	0.01	0.33	0.15	0.73
6 h postmortem	5.76	5.70	5.70	5.61	5.66	5.68	0.04	0.23	0.06	0.98	0.90	0.89
24 h postmortem	5.64	5.61	5.60	5.58	5.64	5.59	0.02	0.19	0.57	0.46	0.60	0.26

[a]Values are means of 10 replications (one pig selected randomly from each pen).

[b]Scoring system of 1 to 5: 2 = grayish pink, traces to slight, or soft and watery; 3 = reddish pink, small to modest, or slightly firm and moist; and 4 = purplish red, moderate to slightly abundant, or firm and moderately dry for color, firmness, and marbling, respectively.

[c]Means were derived from two sample readings per loin. Measures of dark to light (L*), redness (a*), yellowness (b*), red to orange (hue angle), or vividness or intensity (saturation index).

INTERACTIVE EFFECTS AMONG L-CARNITINE, PAYLEAN (RACTOPAMINE·HCl), AND DIETARY ENERGY DENSITY ON COMMERCIAL FINISHING PIG GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS

B. W. James, M. D. Tokach, R. D. Goodband, J. L. Nelssen, S. S. Dritz[1], K. Q. Owen[2], and J. C. Woodworth[2]

Summary

Growth performance and carcass characteristics were evaluated on 1,104 pigs fed combinations of L-carnitine, Paylean, and added fat in a 2 × 2 × 2 factorial arrangement. Dietary treatments of L-carnitine (0 or 50 ppm) and fat (0 or 6%) were initiated at approximately 97 lb. Paylean (0 or 9 g/ton) was fed for the last 4 weeks prior to market. Supplementing dietary carnitine did not affect (P>0.25) growth performance of pigs between 97 to 203 lb. The addition of 6% dietary fat improved (P<0.01) ADG and F/G during this period. During the last 4 weeks of the experiment, when Paylean was fed, a carnitine × Paylean interaction was observed (P<0.04) for ADG and F/G. Both carnitine and Paylean improved growth performance; however, the responses were not additive. Pigs fed added fat had improved (P<0.05) feed efficiency during the Paylean supplementation period.

A carnitine × Paylean interaction (P<0.03) was observed for fat thickness and percentage lean. Fat thickness decreased and lean percentage increased in pigs fed carnitine or Paylean, but the responses were not additive. Pigs fed added fat had greater (P<0.01) fat thickness and lower percentage lean than pigs not fed added fat. A carnitine × Paylean × fat interaction was observed (P<0.04) for longissimus muscle area. In general, adding carnitine, Paylean or fat to the diet increased longissimus muscle area; however, the responses were not fully additive. Carcass weight was greater (P<0.01) for pigs fed 6% added fat and tended (P<0.07) to be greater for pigs fed carnitine.

Adding Paylean to the diet increased (P<0.04) ultimate longissimus pH and reduced drip loss as measured by the filter paper method. Similar to other experiments, adding carnitine to the diet tended to decrease drip loss (P<0.06) as measured by the suspension method.

These results suggest that adding L-carnitine and Paylean to the diet increases ADG and that L-carnitine, Paylean, and fat improve feed efficiency when fed to late finishing pigs reared in a commercial facility. These data also support our previous research that demonstrated improvements in carcass characteristics of pigs fed L-carnitine.

(Key Words: Carnitine, Paylean, Meat Quality.)

Introduction

Recent research conducted at Kansas State University has demonstrated beneficial effects of feeding L-carnitine in combination with Paylean in the late finisher phase. Previous

[1]Food Animal Health and Management Center.
[2]Lonza, Inc., Fair Lawn, NJ.

studies have also shown improvements in drip loss and other meat quality indicators, such as higher longissimus pH. These improvements may be a result of carnitine's affect on either antimortem or postmortem metabolic parameters. Carnitine has been shown to influence the enzymes involved in lactic acid production. However, carnitine may produce a different response in pigs housed in commercial finishing facilities where they have lower levels of feed intake and different metabolic stressors compared to pigs reared in university research facilities. In addition, because of carnitine's known function of transporting fatty acids across the mitochondrial membrane, its affect may differ depending on the energy density of the diet. Therefore, the objective of this experiment was to determine the interactive effects among L-carnitine, Paylean (ractopamine·HCl), and dietary energy density on commercial finishing pig growth performance and carcass characteristics.

Procedures

A total of 1,104 barrows (initially 97 lb, PIC C22 × L326) were allotted by weight in a randomized complete block design to each of the eight experimental treatments arranged in a 2 × 2 × 2 factorial. There were 23 pigs/pen and 6 replicates/treatment. The main effects included dietary carnitine (0 or 50 ppm), Paylean (0 or 9 g/ton), and added fat (0 or 6%).

Pigs were fed a corn-soybean meal diet (Table 1) with or without added L-carnitine and with or without added fat from 92 lb until slaughter (approximately 260 lb). Dietary Paylean treatments (0 or 9 g/ton) were fed for the last 4 weeks of the experiment. The basal diet was formulated on a total lysine:calorie ratio basis with ratios of 3.16 g/Mcal from 97 to 135 lb, 2.70 g/Mcal from 135 to 203 lb, and 3.00 g/Mcal from 203 lb until the end of the experiment. The corresponding lysine levels in the 0 and 6% added fat diets were 1.05 and 1.14%; 0.90 and 0.97%, and 1.00 and 1.08% lysine for the three phases, respectively.

Weights were obtained on every pen and feed disappearance recorded every 14 days during the experiment until the last 4 weeks, at which time measurements were taken weekly to calculate ADG, ADFI, and F/G. At the end of the experiment, eight pigs were randomly selected from each pen and slaughtered at a commercial facility. Standard carcass measurements, visual analyses of longissimus muscle color, marbling, and firmness, longissimus area, color spectrophotometry (L*, a*, and b*), drip loss, and ultimate pH were obtained from each pig at approximately 24 h postmortem.

Data were analyzed as a randomized complete block. Pen was the experimental unit for growth performance data, carcass characteristics, and meat quality measurements. Analysis of variance was performed using the GLM procedure of SAS.

Results and Discussion

Growth Performance. There were no carnitine × Paylean × fat interactions ($P>0.10$) during the entire experiment (Table 2). There were no carnitine × fat interactions ($P>0.73$) observed for growth performance of pigs between 97 and 203 lb (Pre-Paylean period). During this period, supplementing finishing pig diets with L-carnitine did not significantly affect ($P>0.25$) growth performance. As expected, addition of 6% dietary fat improved ($P<0.01$) ADG and F/G during this period.

A carnitine × fat interaction was observed ($P<0.04$) for ADG from d 0 to 14 of the Paylean supplementation period. Carnitine did not affect gain when fat was added to the diet, but improved ADG in pigs fed diets without fat. A carnitine × Paylean interaction ($P<0.02$) was observed for F/G for d 0 to 14. Both carnitine and Paylean improved F/G, but the responses were not additive. Added fat also

improved (P<0.01) F/G from d 0 to 14. There were numerical improvements in growth performance from d 14 to 28 of the Paylean supplementation period for pigs fed either carnitine (ADG and F/G improved 3.8 and 4.2%, respectively) or Paylean (ADG and F/G improved 3.0 and 5.5%, respectively), the improvements were not significant (P>0.13). This supports other research that indicates that the Paylean growth response is greatest in the first two weeks of administration.

For the overall Paylean supplementation period (d 0 to 28), there were no carnitine × fat interactions (P>0.21). However, a carnitine × Paylean interaction was observed (P<0.04) for ADG and F/G. Carnitine and Paylean both improved ADG and F/G; however, the responses were not additive. Dietary fat decreased (P<0.01) ADFI and improved F/G (P<0.05).

These results suggest that supplemental carnitine and/or Paylean improve growth performance in late finisher pigs reared in a commercial environment. The marked improvement in gain and efficiency of pigs fed carnitine in the late finisher period has not been well documented in previous research. A notable difference between our experiments with carnitine and Paylean in finisher pigs and previous studies is that our pigs were fed a higher lysine level than would typically be fed in the late finishing period. This was done to assure adequate lysine for pigs consuming Paylean, which required a higher level of lysine to meet increased protein deposition needs. Therefore, one might theorize that a higher level of lysine is also needed for protein deposition to demonstrate a growth response to feeding supplemental L-carnitine. Another difference between this study and others is that these pigs were reared in commercial finishing facility. Feed intakes are typically lower compared to university facilities due to environmental and space allowance differences. In addition, previous studies have not specifically examined the last 4 weeks per se. There may be some metabolic changes that are occurring as the pig becomes heavier, and these may be affected by L-carnitine supplementation.

Carcass Characteristics. A carnitine × Paylean × fat interaction was observed (P<0.04) for longissimus muscle area. In general, adding Paylean, carnitine, or fat to the diet increased longissimus muscle area; however, the responses were not entirely additive leading to the interaction.

A carnitine × Paylean interaction (P<0.03) was observed for fat thickness and percentage lean. Fat thickness decreased and lean percentage increased in pigs fed carnitine or Paylean; however neither of the responses were additive. Pigs fed added fat had greater (P<0.01) fat thickness and lower percentage lean than pigs not fed added fat. A trend for a carnitine × Paylean interaction (P<0.06) also was observed for loin depth measured at the 10th rib. Both carnitine and Paylean increased loin depth, but the response was not as great when carnitine and Paylean were both added to the diet. Pigs fed added fat had decreased (P<0.01) loin depth compared to pigs not fed added fat.

Carcass weight was greater (P<0.01) for pigs fed 6% added fat and tended (P<0.07) to be greater for pigs fed carnitine. A trend for a carnitine × Paylean interaction (P<0.09) was observed for first rib backfat. Pigs fed carnitine or Paylean had decreased fat depth measured at the first rib, but when fed in combination, fat depth was not further decreased. Last lumbar backfat was decreased (P<0.02) in pigs fed either carnitine or Paylean. Tenth rib and average backfat were decreased (P<0.03) in pigs fed Paylean compared to pigs not fed Paylean. Pigs fed 6% added fat had greater (P<0.01) first rib, last lumbar, and average backfat than pigs fed the diet without added fat.

A carnitine × fat interaction was observed ($P < 0.04$) for visual firmness scores. Visual firmness scores were improved in pigs fed carnitine and no added fat compared to pigs fed carnitine and 6% added fat.

Hunter a* values (color spectrophotometry) were greater ($P<0.01$) indicating more redness for pigs fed Paylean and less ($P<0.01$) redness in pigs fed added fat. As expected, pigs fed 6% added fat also had increased b* values, which resulted in more yellowness of the longissimus muscle. Saturation index, or vividness, was greater ($P<0.01$) for pigs fed diets containing 6% added fat and less ($P<0.01$) for pigs fed Paylean.

In contrast to previous experiments, pigs fed Paylean in this study had higher ($P<0.04$) ultimate longissimus pH along with pigs fed the diet containing no added fat. In agreement with the pH data, pigs fed Paylean had less drip loss using the filter paper method as did the pigs fed the diet with no added fat. Pigs fed carnitine tended to have decreased drip loss ($P<0.06$) using the suspension method. The reduction in drip loss with added carnitine agrees with the results of previous experiments.

These results demonstrate an improvement in meat quality in pigs fed L-carnitine, similar to the results of our previous experiments. However, in this experiment, feeding carnitine also resulted in an increase in growth performance during the last 4 weeks of the experiment. This response was somewhat surprising. Although we have observed trends for improved growth performance in previous experiments, results of this magnitude have not been previously detected. The cause for the response observed in the commercial facility may be related to feed intake, environment, or larger sample population compared with the previous experiments. Two questions are yet to be determined: 1) Do pigs need to be fed a high lysine diet to observe a response to carnitine; and 2) What is the optimum L-carnitine supplementation duration to maximize the growth response and profitability? Further research is needed to determine the most beneficial feeding strategy.

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

	97 to 135 lb		135 to 203 lb		203 to 260 lb	
Ingredient, %	No Fat	Fat	No Fat	Fat	No Fat	Fat
Corn[b]	73.00	63.30	78.6	69.35	75.10	65.55
Soybean meal (46.5% CP)	24.60	28.25	19.15	22.35	22.75	26.25
Choice white grease	--	6.00	--	6.00	--	6.00
Limestone	0.88	0.84	0.85	0.83	0.84	0.81
Monocalcium phosphate, 21%P	0.85	0.94	0.73	0.80	0.64	0.70
Salt	0.35	0.35	0.35	0.35	0.35	0.35
L-Lysine·HCl	0.15	0.15	0.15	0.15	0.15	0.15
Trace mineral premix	0.10	0.10	0.10	0.10	0.10	0.10
Vitamin premix	0.09	0.09	0.09	0.09	0.09	0.09
Calculated composition						
CP (N × 6.25), %	17.60	18.50	15.60	16.30	17.0	17.80
Lysine, %	1.05	1.14	0.90	0.97	1.00	1.08
Lysine:calorie ratio, g/Mcal	3.16	3.16	2.70	2.70	3.00	3.00
ME, kcal/lb	1,509	1,631	1,513	1,635	1,514	1,636
Ca, %	0.60	0.61	0.55	0.56	0.54	0.55
P, %	0.55	0.57	0.50	0.52	0.50	0.51

[a]Diets were formulated to meet or exceed NRC (1998) requirements.

[b]L-Carnitine replaced corn to provide either 0, 25, or 50 ppm L-Carnitine and Paylean replaced corn to provide either 0 or 9 g/ton ractopamine·HCl.

Table 2. Interactive Effects of Carnitine, Paylean, and Fat on Growth Performance of Finishing Pigs[a]

	Fat, %															
	0				6											
	Carnitine, ppm															
	0		50		0		50									
	Paylean, g/ton									Probability (*P*<)						
Item	0	9	0	9	0	9	0	9	SEM	Carn*Paylean*Fat	Carn*Paylean	Carn*Fat	Paylean*Fat	Carn	Paylean	Fat
Pre-Paylean[b,c]																
ADG, lb	2.08	2.00	2.05	2.07	2.15	2.17	2.17	2.19	0.04	-	-	0.97	-	0.37	-	0.01
ADFI, lb	5.55	4.43	5.45	5.52	5.42	5.29	5.38	5.33	0.07	-	-	0.97	-	0.98	-	0.01
Feed/gain	2.68	2.72	2.66	2.66	2.52	2.44	2.48	2.43	0.04	-	-	0.73	-	0.25	-	0.01
Day 0 to 14[d]																
ADG, lb	1.96	2.23	2.17	2.44	2.02	2.37	2.20	2.28	0.06	0.10	0.10	0.04	0.48	0.01	0.01	0.69
ADFI, lb	5.76	5.73	6.06	6.11	5.42	5.37	5.47	5.30	0.10	0.50	0.89	0.02	0.42	0.02	0.50	0.01
Feed/gain	2.95	2.58	2.80	2.50	2.69	2.28	2.49	2.34	0.05	0.20	0.02	0.58	0.46	0.02	0.01	0.01
Day 14 to 28																
ADG, lb	1.70	1.89	1.94	1.82	1.80	1.91	1.89	1.93	0.08	0.26	0.08	0.78	0.67	0.22	0.31	0.39
ADFI, lb	6.02	5.90	5.94	5.75	6.02	5.86	5.91	5.80	0.15	0.81	0.96	0.89	0.91	0.36	0.19	0.95
Feed/gain	3.56	3.12	3.07	3.29	3.35	3.06	3.19	3.01	0.16	0.22	0.09	0.77	0.59	0.24	0.13	0.34
Day 0 to 28																
ADG, lb	1.84	2.07	2.06	2.14	1.91	2.15	2.05	2.11	0.03	0.82	0.04	0.21	0.92	0.02	0.01	0.46
ADFI, lb	5.89	5.81	6.00	5.94	5.71	5.60	5.68	5.54	0.05	0.86	0.91	0.21	0.71	0.55	0.14	0.01
Feed/gain	3.21	2.81	2.92	2.79	2.98	2.61	2.78	2.63	0.03	0.81	0.01	0.53	1.0	0.01	0.01	0.05

[a]Values are means of six replications (pens) and 22 to 26 pigs per pen.

[b]Initial BW of pre-Paylean period, 97 lb.

[c]Growth performance for pre-Paylean period was determined for d 0 to 51 prior to initiation of Paylean.

[d]Average BW at initiation of Paylean supplementation, 203 lb.

Table 3. Interactive Effects of Carnitine, Paylean, and Fat on Carcass Characteristics and Meat Quality of Finishing Pigs[a]

	Fat, %															
	0				6											
	Carnitine, ppm															
	0		50		0		50									
	Paylean, g/ton									Probability (*P*<)						
Item	0	9	0	9	0	9	0	9	SEM	Carn×Paylean×Fat	Carn×Paylean	Carn×Fat	Paylean×Fat	Carn	Paylean	Fat
Carcass wt, lb	197.96	201.44	200.27	203.44	203.48	207.10	210.06	209.64	2.62	0.64	0.53	0.48	0.67	0.07	0.19	0.01
Fat thickness, mm[b]	16.76	13.92	16.29	14.72	18.83	16.09	16.77	16.25	0.56	0.54	0.03	0.16	0.47	0.32	0.01	0.01
Loin depth, mm[b]	59.28	62.80	60.89	61.52	57.93	61.11	59.16	60.65	0.81	0.68	0.06	0.94	0.91	0.54	0.01	0.01
Lean,%[b]	56.15	59.19	56.82	58.29	54.12	57.03	56.13	56.82	0.59	0.67	0.02	0.23	0.56	0.33	0.01	0.01
Loin eye area, in^2	7.35	7.54	7.51	7.77	7.33	7.96	8.07	7.83	0.17	0.04	0.09	0.69	0.85	0.03	0.07	0.03
Backfat, in																
First rib	1.41	1.37	1.40	1.38	1.54	1.43	1.41	1.44	0.03	0.13	0.09	0.22	0.89	0.19	0.11	0.01
Tenth rib	0.66	0.62	0.67	0.65	0.68	0.65	0.64	0.65	0.02	0.53	0.29	0.12	0.53	0.70	0.03	0.47
Last rib	1.06	1.00	1.06	1.05	1.12	1.09	1.11	1.11	0.03	0.89	0.30	0.49	0.57	0.36	0.18	0.01
Last lumbar	0.61	0.55	0.60	0.55	0.67	0.63	0.60	0.58	0.02	0.93	0.74	0.11	0.54	0.02	0.01	0.01
Average backfat	1.03	0.98	1.02	0.99	1.11	1.05	1.04	1.04	0.02	0.51	0.17	0.09	0.72	0.19	0.01	0.01
Visual color[c]	3.39	3.18	3.48	3.38	3.38	3.48	3.45	3.26	0.09	0.14	0.62	0.09	0.44	0.43	0.26	0.69
Firmness[c]	2.50	2.96	2.86	2.98	2.70	2.76	2.48	2.64	0.13	0.26	0.48	0.04	0.28	0.83	0.03	0.05
Marbling[c]	2.44	2.51	2.45	2.41	2.46	2.43	2.18	2.50	0.15	0.27	0.60	0.78	0.53	0.46	0.47	0.56
L*[d]	45.44	45.73	45.28	46.14	45.29	45.81	46.31	46.45	0.43	0.42	0.78	0.27	0.64	0.10	0.10	0.32
a*[d]	6.07	5.52	6.18	5.48	6.53	5.96	6.41	5.72	0.16	0.96	0.63	0.27	0.88	0.62	0.01	0.01
b*[d]	0.97	0.95	0.92	0.83	1.05	1.12	1.29	1.28	0.16	0.87	0.94	0.29	0.77	0.48	0.91	0.03
a:b	4.64	1.86	-1.43	9.59	7.38	-15.14	3.86	2.52	6.96	0.70	0.06	0.51	0.09	0.39	0.41	0.40
Hue angle	8.88	9.20	7.52	7.03	8.95	9.80	10.64	11.23	1.39	0.99	0.99	0.14	0.78	0.91	0.58	0.06
Saturation index	6.24	5.69	6.34	5.65	6.67	6.16	6.60	5.99	0.18	0.95	0.74	0.46	0.91	0.81	0.01	0.01
Longissimus pH	5.59	5.61	5.62	5.62	5.57	5.60	5.55	5.61	0.02	0.39	0.96	0.34	0.13	0.54	0.04	0.04
Drip loss																
Filter paper	4.51	4.17	4.71	4.75	5.21	4.91	5.64	4.45	0.32	0.13	0.63	0.34	0.16	0.36	0.05	0.02
Suspension	6.92	6.52	5.81	6.07	7.29	6.65	6.98	6.22	0.41	0.48	0.56	0.52	0.27	0.06	0.22	0.12

[a]Values are means of six replications (pens) and eight pigs per pen.

[b]Measurements were determined with UFOM and collected 7 cm off the midline at the 10^{th} rib, lean percentage was calculated with these values.

[c]Scoring system of 1 to 5: 2 = grayish pink, traces to slight, or soft and watery; 3 = reddish pink, small to modest, or slightly firm and moist; and 4 = purplish red, moderate to slightly abundant, or firm and moderately dry for color, firmness, and marbling, respectively.

[d]Measures of dark to light (L*), redness (a*), yellowness (b*).

SUPPLEMENTATION OF L-CARNITINE AND PAYLEAN IMPROVE GROWTH PERFORMANCE OF PIGS IN A COMMERCIAL FINISHING FACILITY

B. W. James, M. D. Tokach, R. D. Goodband, J. L. Nelssen, S. S. Dritz[1], K. Q. Owen[2], and J. C. Woodworth[2]

Summary

Growth performance and standard carcass measurements were evaluated on 796 pigs fed dietary treatments of L-carnitine (0 or 50 ppm) and/or Paylean (0 or 9 g/ton) in a three-week experiment. Pigs fed Paylean had improved ($P<0.01$) ADG and F/G for the overall experiment. Growth performance of pigs fed carnitine also was improved ($P<0.04$) and was additive to the response of Paylean. Feeding carnitine did not affect ($P>0.18$) any of the carcass criteria in this experiment. Pigs fed Paylean had greater ($P<0.01$) carcass weight, fat free lean index, loin depth, percentage lean, and yield compared to pigs not fed Paylean. The combined growth performance results from our four research experiments evaluating L-carnitine (0 or 50 ppm) and/or Paylean (0 or 9 g/ton) suggest that Paylean improves ($P<0.01$) ADG and F/G and L-carnitine tends to increase ($P<0.07$) ADG and improves ($P<0.01$) feed efficiency.

(Key Words: Carnitine, Paylean, Carcass Characteristics.)

Introduction

Our previous experiments evaluating the interactive effects of dietary L-carnitine and Paylean have primarily focused on improved meat quality benefits of feeding carnitine in combination with Paylean. Although there were numeric trends for improved growth performance in the previous experiments conducted at university facilities, the responses were not statistically significant. A recent study conducted in a commercial finishing facility demonstrated improved growth performance in pigs fed carnitine for the 4-week period prior to slaughter. The cause for the growth response observed in the commercial facility compared to the two previous studies conducted at a university research facility may have been related to feed intake, stress, or the larger sample size compared to the first studies. In addition, pigs in the commercial facility study were fed carnitine from 97 lb until slaughter. Therefore, the objectives of this experiment were to confirm the growth performance results of the previous trial in a commercial finishing facility and to evaluate the interactive effect of L-carnitine and Paylean on growth performance and carcass characteristics when supplemented for only 3 weeks prior to slaughter.

Procedures

Seven hundred ninety-six barrows (initially 227 lb, PIC C22 × L326) were allotted by weight in a randomized complete block design to each of the four experimental treatments arranged in a 2 × 2 factorial. There were 18 or 19 pigs/pen and 10 replicates/treatment. Main effects included dietary L-carnitine (0 and 50 ppm) and Paylean (0 and 9 g/ton).

[1]Food Animal Health and Management Center.
[2]Lonza, Inc., Fair Lawn, NJ.

Pigs were fed a corn-soybean meal diet (Table 1) with or without L-carnitine or Paylean for the 3-week experiment. The basal diet was formulated to contain 1.00% lysine (total lysine:calorie ratio of 3.00 g/Mcal).

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

Ingredient, %	
Corn[b]	75.10
Soybean meal (46.5% CP)	22.75
Limestone	0.84
Monocalcium phosphate, 21%P	0.64
Salt	0.35
L-Lysine·HCl	0.15
Trace mineral premix	0.10
Vitamin premix	0.09
Calculated composition	
CP (N × 6.25), %	17.0
Lysine, %	1.00
Lysine:calorie ratio, g/Mcal	3.00
ME, kcal/lb	1,514
Calcium, %	0.54
Phosphorus, %	0.50

[a]Diets were formulated to meet or exceed NRC (1998) requirements.

[b]L-Carnitine replaced corn to provide either 0 or 50 ppm L-Carnitine and Paylean replaced corn to provide either 0 or 9 g/ton ractopamine·HCl.

Weights were obtained on every pen and feed disappearance recorded weekly to calculate ADG, ADFI, and F/G. At the end of the experiment all pigs were slaughtered at a commercial facility and standard carcass measurements were recorded.

Data were analyzed as a randomized complete block. Pen was the experimental unit for growth performance data and standard carcass measurements. Analysis of variance was performed using the GLM procedure of SAS. In addition, growth performance data from common treatments of L-carnitine (0 or 50 ppm) and Paylean (0 or 9 g/ton) from the four research experiments summarized in the 2002 KSU Swine Day report were combined and analyzed for main effects and interactions.

Results and Discussion

Growth Performance. There were no carnitine × Paylean interactions ($P>0.31$) for growth performance during any week of the experiment or for the overall experiment (Table 2). Paylean improved ($P<0.01$) ADG and F/G during each week and for the overall trial. Carnitine increased ($P<0.05$) ADG from d 7 to 14 and tended ($P<0.08$) to increase ADG from d 14 to 21. Thus, carnitine improved ($P<0.01$) ADG from d 0 to 14 and for the overall trial (d 0 to 21). The numeric improvements in F/G during week 2 and 3 of the experiment resulted in an overall improvement ($P<0.04$) with carnitine added to the diet. Researchers at Purdue University have reported a similar benefit to adding carnitine to diets containing Paylean; however, the greatest response occurred during the first 2 weeks of their 4-week feeding period. Overall, ADG and F/G was improved due to adding Paylean and carnitine to diet for the last 3 weeks before market with the response being additive in this experiment. In our previous trial conducted in a commercial finishing facility, the response was not additive.

Carcass Characteristics. There were no carnitine × Paylean interactions observed ($P>0.13$) for any of the carcass measurements in this experiment (Table 3). Pigs fed carnitine or Paylean had similar backfat ($P>0.31$) to pigs fed the control diet. Feeding carnitine to pigs did not affect ($P>0.18$) any of the carcass criteria in this experiment. Pigs fed Paylean had greater ($P<0.01$) carcass weight, fat free lean index, loin depth, percentage lean, and yield compared to pigs not fed Paylean.

Although carnitine did not affect the carcass parameters measured in this experiment, it can not be concluded that carnitine did not have an effect on meat quality. Drip loss, pH, visual color, and Hunter L*, a*, and b* measurements were not recorded in this experiment as in our other experiments. These analyses

were not conducted because the responses were consistent in the previous trials and it was not possible to do these measurements at the commercial facility where these pigs were slaughtered.

Other research on feeding Paylean to pigs has demonstrated that growth performance improvements occur with relatively short Paylean supplementation durations; however, improvements in lean tissue accretion, longissimus muscle area, and decreased backfat typically require a longer Paylean supplementation duration. It is currently not understood whether L-carnitine demonstrates a similar response. In this experiment, pigs were fed L-carnitine for 3 weeks. This may suggest that a longer duration is needed to detect differences in carcass characteristics; however, a growth performance response was observed with the 3-week supplementation period.

Combined Growth Performance. The growth performance data from common treatments of L-carnitine (0 or 50 ppm) and Paylean (0 or 9 g/ton) from our four experiments were combined (Table 4). There were no carnitine × Paylean interactions ($P>0.27$). Feeding pigs Paylean improved ($P<0.01$) ADG and F/G in these experiments. Interestingly, a trend was observed for increased ADG ($P<0.07$) when pigs were fed carnitine compared to controls. Pigs fed carnitine in the last 3 to 4 weeks of the finishing period also had improved ($P<0.01$) F/G compared to pigs not fed carnitine. These results suggest that L-carnitine and Paylean improve growth performance of finishing pigs. Future research is needed to determine the optimal lysine level to be fed in combination with L-carnitine and the optimal supplementation duration for L-carnitine.

Table 2. Interactive Effects of L-Carnitine and Paylean on Commercial Finishing Pig Growth Performance [a,b]

	Paylean, g/ton							
	0		9					
	Carnitine, ppm					Probability ($P<$)		
Item	0	50	0	50	SEM	Carnitine× Paylean	Carnitine	Paylean
Day 0 to 7								
ADG, lb	1.67	1.73	2.23	2.27	0.08	0.93	0.56	0.01
ADFI, lb	4.57	4.63	4.76	4.81	0.12	0.96	0.60	0.12
Feed/gain	2.75	2.73	2.14	2.17	0.11	0.81	0.97	0.01
Day 7 to 14								
ADG, lb	1.74	1.88	1.91	2.09	0.08	0.82	0.05	0.02
ADFI, lb	5.37	5.36	5.30	5.54	0.12	0.31	0.33	0.64
Feed/gain	3.11	2.90	2.81	2.69	0.10	0.67	0.10	0.01
Day 14 to 21								
ADG, lb	1.62	1.76	1.88	1.98	0.07	0.74	0.08	0.01
ADFI, lb	5.86	6.10	5.74	5.87	0.10	0.59	0.07	0.08
Feed/gain	3.66	3.51	3.09	2.97	0.13	0.88	0.28	0.01
Day 0 to 14								
ADG, lb	1.70	1.80	2.07	2.18	0.05	0.90	0.04	0.01
ADFI, lb	4.97	5.00	5.03	5.18	0.10	0.57	0.38	0.24
Feed/gain	2.92	2.78	2.43	2.38	0.05	0.39	0.05	0.01
Day 7 to 21								
ADG, lb	1.68	1.82	1.90	2.04	0.05	0.98	0.01	0.01
ADFI, lb	5.61	5.73	5.52	5.70	0.08	0.68	0.07	0.45
Feed/gain	3.36	3.15	2.94	2.81	0.07	0.58	0.02	0.01
Day 0 to 21								
ADG, lb	1.68	1.79	2.01	2.11	0.04	0.94	0.01	0.01
ADFI, lb	5.27	5.36	5.26	5.41	0.08	0.80	0.15	0.81
Feed/gain	3.14	3.00	2.63	2.56	0.05	0.47	0.04	0.01

[a]Values are means of 10 replications (pens) and 18 or 19 pigs per pen.
[b]Initial BW, 227 lb.

Table 3. Standard Carcass Measurements of Finishing Pigs Fed L-Carnitine and Paylean[a,b]

	Paylean, g/ton							
	0		9			Probability ($P <$)		
	Carnitine, ppm					Carnitine ×		
Item	0	50	0	50	SEM	Paylean	Carnitine	Paylean
Carcass wt, lb	196.25	199.89	204.72	207.10	2.22	0.78	0.18	0.01
Backfat, in	0.73	0.73	0.72	0.72	0.01	0.84	0.71	0.31
Fat free lean index	49.35	49.55	49.93	49.90	0.16	0.47	0.59	0.01
Loin depth, in	2.19	2.24	2.38	2.35	0.02	0.13	0.64	0.01
Lean, %	54.13	54.38	55.03	54.82	0.18	0.21	0.90	0.01
Yield	75.47	75.55	75.93	76.30	0.19	0.45	0.23	0.01

[a]Values are means of ten replications replications (pens) and 18 or 19 pigs per pen.
[b]Measurements were obtained from commercial slaughter facility slaughter records.

Table 4. Interactive Effects of L-Carnitine and Paylean on Finishing Pig Growth Performance in Four Trials Combined

	Paylean, g/ton							
	0		9					
	Carnitine, ppm					Probability ($P<$)		
Item	0	50	0	50	SEM	Carnitine × Paylean	Carnitine	Paylean
ADG, lb	1.99	2.10	2.26	2.29	0.04	0.27	0.07	0.01
ADFI, lb	5.85	5.85	5.87	5.77	0.10	0.60	0.61	0.73
Feed/gain	2.97	2.82	2.62	2.54	0.04	0.40	0.01	0.01

[a]Values are means of 33 replications from four different experiments with 2, 2, 22 to 26, and 18 to 19 pigs per pen in experiment 1, 2, 3, and 4, respectively.
[a]Treatment diets were fed for 28 d in experiment 1, 2, and 3 and for 21 d in experiment 4.

EFFECTS OF PAYLEAN (RACTOPAMINE·HCl) ON FINISHING PIG GROWTH AND VARIATION

M. R. Barker, S.S Dritz[1], R. D. Goodband, M. D. Tokach, C. N. Groesbeck, S. M. Hanni, C. W. Hastad, T. P. Keegan, K. R. Lawrence, and M. G. Young

Summary

A total of 336 pigs were used in a 21-day trial to determine the effect of Paylean (9.0 g/ton Ractopamine·HCl) on finishing pig growth and variation. Pigs were allotted based on weight so that all pens had the same initial weight and degree of variation within the pen. Pigs fed Paylean had greater ADG and better feed efficiency than control-fed pigs ($P<0.05$). However, no differences in pen coefficient of variation were observed ($P>0.70$). The results suggest that adding Paylean to the diet improves finishing pig growth performance but does not affect weight variation within the pen.

(Key Words: Ractopamine, Paylean, Variation.)

Introduction

Paylean (Ractopamine·HCl) is an effective growth promoting drug in swine. Paylean supplementation has been shown to improve ADG, F/G, and decrease fat deposition. Because of its effects on growth rate, the objective of the study was to determine if feeding Paylean might decrease the potential variation in weights of pigs in a pen.

Procedures

The experiment was conducted at the Kansas State University Swine Teaching and Research Center. A total of 336 finishing pigs (168 barrows and 168 gilts) were weighed and allotted to treatments so that within sex, each pen had the same mean weight and degree of weight variation among pigs in each pen. The experiment was divided into two identical trials conducted in May and July of 2002. Fourteen pens (seven of barrows, seven of gilts) were assigned to each treatment. Feed and water were offered ad libitum. Diets were milo-soybean meal-based and formulated to contain 1.00% total lysine with or without 9 g/ton of Paylean (Table 1).

Pigs were weighed and feed intake was determined every 7 days during the 21 day experiment. Average daily gain, ADFI, F/G, and pen coefficient of variation were determined. The coefficient of variation was determined by dividing the standard deviation of pig weight in the pen by the average weight of pigs in the pen. For example, if the average weight of pigs in a pen is 250 lb with a coefficient of variation of 8%, 68% of the pigs should weigh between 230 and 270 lb (8% * 250 lb = 20 lb). Data were analyzed using the Proc Mixed procedure of SAS.

[1]Food Animal Health and Management Center.

Table 1. Diet Composition (As-Fed Basis)

Ingredient, %	Control
Milo	74.03
Soybean meal, (46.5%)	23.82
Monocalcium Phosphate, (21% P)	0.55
Limestone	0.90
Salt	0.35
Vitamin premix	0.10
Trace mineral premix	0.10
Lysine HCl	0.15
Calculated Analysis,	
ME, kcal/lb	1,487
Lysine, %	1.00
Calcium, %	0.55
Phosphorus, %	0.49

[a]Paylean was added at .05% of the diet to provide 9 g/ton Ractopamine·HCl.

Results and Discussion

Pigs fed Paylean had greater ADG and improved feed conversion compared to control pigs ($P<0.05$, Table 2). Feed intake was not affected ($P>0.90$) by dietary treatment. The final weight of pigs fed Paylean was greater than that of control pigs at the end of the 21-day trial because of the greater ADG. However, no differences were observed in pen variation among dietary treatments ($P>0.70$). A decrease in pen variation was observed from the start to the finish of the trial for both the control and Paylean-fed pigs. Control pigs averaged a pen coefficient of variation of 7.71%. This means that 68% of the pigs were between 236.7 and 276.3 lb, or a range of 39.56 lb (Figure 1). The Paylean-fed pigs had a coefficient of variation of 8.15%. This means that 68% of the pigs were between 242.8 and 285.8 lb, or a range of 43.0 lb.

These findings suggest that although Paylean (Ractopamine·HCl) improves growth performance and feed efficiency, it does not appear to reduce weight variation within the pen.

Table 2. Effects of Paylean on Finishing Pig Growth Performance and Variation[a]

Item	Control	Paylean	SEM	P-value <
Initial wt, lb	221.07	222.29	2.45	0.62
Initial CV, %[b]	9.19	8.66	0.82	0.52
Initial SD, lb	±20.31	±19.23		
ADG, lb	1.76	2.07	0.08	0.001
ADFI, lb	6.09	6.10	0.29	0.97
Feed/gain	3.62	3.06	0.14	0.001
Final wt, lb	256.51	264.33	3.23	0.02
Final CV, %	7.71	8.15	0.54	0.42
Final SD, lb	±19.78	±21.54		

[a]Values represent the mean of 14 pens per treatment. There were 7 pens of barrows and 7 of gilts with 12 pigs per pen. Paylean was added to the diet at 9.0 g/ton and fed for 21 days.

[b]Coefficient of variation (CV) indicated that 68% of the pigs will be within this percentage or weight range of the mean weight. Coefficient of variation equals the standard deviation (SD) divided by the mean weight.

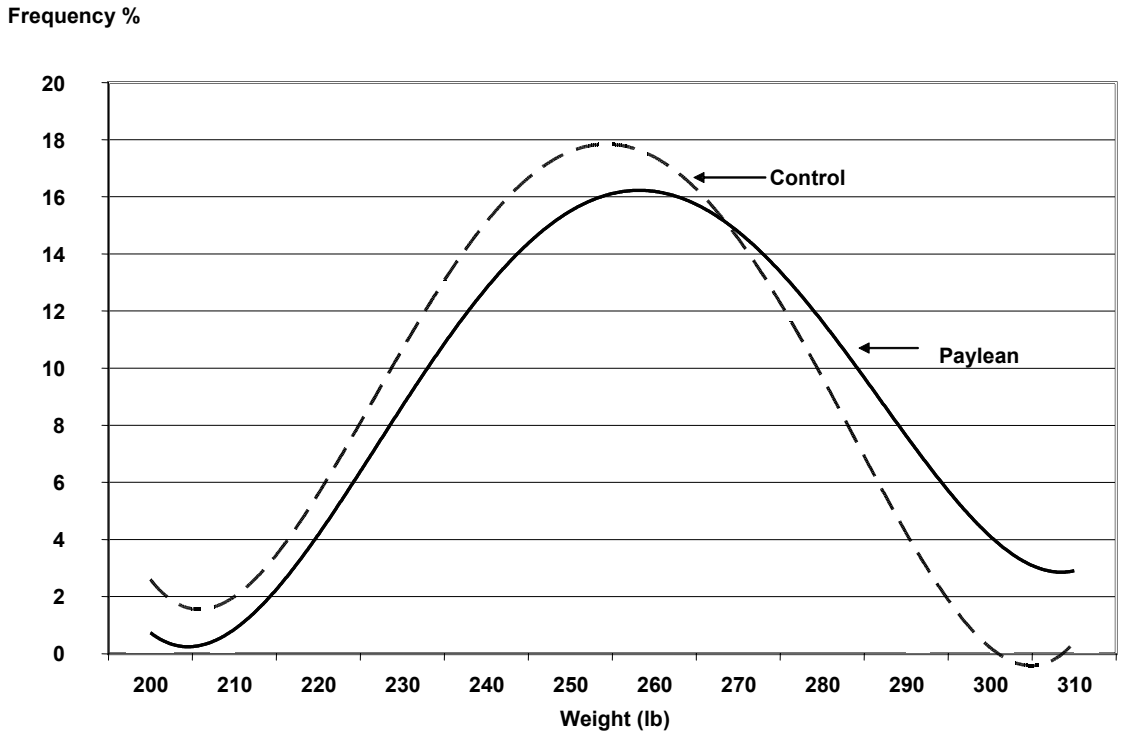

Figure 1. Final Weight Distribution of Pigs Fed 9.0 g/ton Paylean (Ractopamine HCl) for 21 Days or Control Pigs Fed a Diet Without Paylean. Final coefficient of variation was 7.71 and 8.15% (SEM = 0.54 and *P*>0.42) for control and Paylean fed pigs, respectively.

EFFECTS OF RACTOPAMINE (PAYLEAN™) DOSE AND FEEDING DURATION ON PIG PERFORMANCE IN A COMMERCIAL FINISHING FACILITY[1]

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

Summary

A total of 1,035 gilts were used in a 28-day trial conducted in a commercial research facility to determine the influence of ractopamine (Paylean™) dose (4.5 or 9.0 g/ton) and feeding duration (7, 14, 21, or 28 days prior to slaughter) on pig performance and carcass composition. Ractopamine supplementation at 4.5 g/ton for 14 to 28 days, and 9 g/ton for 7 to 28 days, improved (P<0.05) ADG by 26 to 35% (0.35 - 0.46 lb/d) and F/G by 16 to 20% (0.64 to 0.79) during the 28-days prior to slaughter. Due to these improvements in growth, carcass weights increased 8 to 10 pounds over controls. Fat depth and lean percentage improved (linear, P<0.01) with increased feeding duration. Ractopamine dose did not affect carcass lean parameters. However, carcass yield improved (P< 005) when ractopamine was fed at 9.0 g/ton. Feed cost per pound of gain increased (P<0.01) with increasing feeding duration for Paylean and was greater (P<0.05) for pigs fed the 9.0 g/ton dose for 28 days as compared to the control. However, feeding ractopamine at 4.5 g/ton for 14 to 28 days and 9 g/ton for 7 to 28 days improved income over feed costs by $3.53 to $ 4.76 per head compared to pigs fed the control diet. Return over feed costs improved due to the increased carcass weights and improved feed efficiency with the greatest values achieved with a 14 to 21 day feeding duration. These data indicate feeding ractopamine at either 4.5 or 9.0 g/ton for 14 to 21 days prior to slaughter is a cost-effective strategy to optimize return while minimizing increases in feed cost per pound of gain.

(Key Words: Ractopamine, Paylean, Economics.)

Introduction

Ractopamine is a feed additive that improves growth rate, feed conversion, and lean deposition. Due to the dietary costs associated with feeding ractopamine, determining a dose and feeding duration that provides optimum return and minimizes increases in feed cost per pound of gain is essential. The objective of this evaluation was to determine the effects of ractopamine dose (4.5 or 9.0 g/ton) and feeding duration (7, 14, 21, or 28 days prior to slaughter) on pig performance and the associated economic implications.

Procedures

This experiment was completed in a commercial finishing research facility. Forty-five pens of gilts (PIC 337 × C22, 227.5 ±1.4 lb) were allotted to treatment 28 days prior to slaughter. Treatments included pigs fed 4.5 or

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

[2]Food Animal Health and Management Center.

9.0 g/ton ractopamine for 7, 14, 21, or 28 days prior to slaughter, and a control treatment without ractopamine. Diets were corn-soybean meal-based, formulated to contain 0.75 and 1.00 % total dietary lysine for the control and ractopamine supplemented diets, respectively. Feed delivery was recorded daily, and feed remaining was determined weekly when pen weight gain was measured. Pens had totally slatted floors, were 10 × 18 ft, with 23 pigs per pen. Each pen was equipped with a 50-inch dry feeder (Staco) and cup waterer. The facility was a double curtain sided finishing barn with a deep pit.

At the conclusion of the feeding period, each pen was identified with a unique tattoo to obtain pen carcass composition and revenue information. At slaughter, fat and loin depth were measured with an optical probe and used to calculate lean percentage. Fat, loin depth, and lean percentage were adjusted to a common carcass weight for statistical evaluation. An economic evaluation was completed using actual feed costs and carcass revenue information attained from the pens in this evaluation. Data were analyzed using pair-wise orthogonal contrasts between each of the nine treatments, as well as for the main effects of ractopamine dose and duration. Pen was the experimental unit in all data analyses.

Results and Discussion

Sale weight, gain and feed efficiency improved ($P<0.04$) for pigs fed 4.5 g/ton ractopamine for 14, 21, or 28 days and for pigs fed 9.0 g/ton for all durations compared to the control treatment. The 4.5 g/ton, 7-day treatment was intermediate in sale weight, daily gain and feed efficiency. Increasing ractopamine dose from 4.5 to 9.0 g/ton tended to improve ($P<0.10$) gain (1.63 vs. 1.75 ±. 05 lb) and sale weight (273.0 vs.276.7 ± 1.4 lb). Feeding duration had no significant effects ($P>0.17$) on sale weight, gain, or feed efficiency. Pigs fed ractopamine at 4.5 g/ton for 21 or 28 days and 9.0 g/ton for 7, 14, 21, or 28 days had increased feed intake ($P<0.05$) compared to negative controls, with the 4.5 g/ton 7- and 14-day treatments being intermediate. Feed intake tended to increase (linear, $P<0.09$) with feeding duration (5.46, 5.50, 5.53, 5.65 ± 0.08 lb/d), and intake was not affected ($P>0.16$) by dose. Ractopamine dose (4.5 vs.9.0 g/ton) did not affect ($P>0.37$) carcass lean parameters. However, pigs fed 9.0 g/ton had improved ($P<0.05$) carcass yield compared to pigs fed 4.5 g/ton and the negative controls. Feeding duration did not affect ($P>0.37$) carcass yield. Fat depth (0.64, 0.62, 0.60, 0.58 ± .01 in) decreased and lean percentage (56.0, 56.6, 56.8, 57.0 ± 0.14%) increased linearly ($P<0.01$) as ractopamine feeding duration increased from 7 to 28 days. However, the control (0.62 in. backfat, 56.6% lean) treatment was intermediate to all other treatments. Ractopamine feeding duration did not affect ($P>0.78$) loin depth.

Carcass weight and revenue increased ($P<0.05$) for pigs fed 4.5 g/ton ractopamine for 14, 21, or 28 days and for pigs fed 9.0 g/ton for all durations compared to the control treatment. The treatment of 4.5 g/ton of ractopamine for 7 d was intermediate in carcass weight and revenue. Increasing ractopamine dose (4.5 vs. 9.0 g/ton) and feeding duration (7, 14, 21, or 28 days) improved carcass weight (dose effect of 4.5 vs. 9.0 g/ton, respectively; 207.2 vs. 210.2 ± .95 lb, $P<0.03$, and duration effect from 7 to 28 d before market; 205.7, 209.6, 209.9, 209.8 ± 1.4 lb, linear, $P<0.05$) and revenue (dose; 129.41 vs. 131.38 ± $0.62/hd, $P<0.03$, and duration effect; 128.14, 130.90, 131.30, 131.24 ± $0.89/hd, linear, $P<0.02$). Only pigs fed 9.0 g/ton for 21 and 28 days had improved grade premium as compared to controls. However, grade premium improved (linear, $P<0.03$) with feeding duration (6.26, 6.42, 6.52, 6.53 ± $0.07 / CWT). Ractopamine dose (4.5 vs. 9.0 g/ton)

did not affect grade premium. Feed costs per head increased (P < .05) in pigs fed 4.5 g/ton ractopamine for 14, 21, or 28 days as well as pigs fed 9.0 g/ton for all durations compared to the control treatment. Ractopamine dose (4.5 vs. 9.0 g/ton) and feeding duration (7, 14, 21, and 28 days) increased (P<0.0001) feed cost per head (dose effect; 8.12 vs. 8.92 ± $0.12/hd, P<0.0001, and duration effect; 7.69, 8.28, 8.77, 9.33 ± $0.17/hd). Only pigs fed 9.0 g/ton for 28 days prior to slaughter had an increased (P<0.05) feed cost per pound of gain over negative controls. However, feed cost per pound of gain increased (linear, P<0.03) with increasing feeding duration (0.175, 0.174, 0.185, 0.193 ± $0.006 / lb). Pigs fed 4.5 g/ton ractopamine for 14, 21, or 28 days as well as pigs fed 9.0 g/ton for all durations had improved (3.50 to 4.83 ± $1.35/hd) income over marginal feed costs (IOMFC) compared to the controls. Income over marginal feed costs (IOMFC) is defined as value of the pigs at slaughter minus the feed costs incurred during the trial period. The pigs fed 4.5 g/ton ractopamine for 7 days had intermediate improvement in IMOFC (0.93 ± $1.35/hd IOMFC) over controls. However, pigs fed 4.5 g/ton ractopamine for 28 days and 9.0 g/ton for 7 days only tended (P=0.08) to have an increased IOMFC compared to controls. Neither ractopamine dose (4.5 or 9.0 g/ton) nor feeding duration (7, 14, 21, or 28 d) statistically improved (P>0.19) IOMFC.

Income over marginal feed costs increased due to improved carcass weights and feed efficiency. Feed costs per pound of gain were only increased (P>0.05) over controls in pigs fed 9.0g/ton ractopamine for 28 days prior to slaughter. However, feed cost per pound of gain increased (linear, P<0.03) with feeding duration. These data indicate that feeding ractopamine at either 4.5 or 9.0 g/ton for 14 to 21 days prior to slaughter is a cost-effective strategy to optimize return while minimizing increases in feed cost per pound of gain. It should be understood that feeding ractopamine offers the most economic opportunity for producers who are limited in grow-finish space and are having difficulty in optimizing carcass weights. However, the shorter feeding durations fed in this study indicate feed cost per pound of gain is not affected by ractopamine supplementation due to the improvements in feed efficiency. Therefore, the shorter feeding durations are a more conservative economic approach for operations not constrained in finishing capacity. Operations with excess finishing capacity typically have a more conservative value for improvements in ADG, as finishing spaces are available to otherwise attain desired market weights. Understanding the biologic and economic dynamics of feeding ractopamine helps producers develop operationally dependant strategies concerning the cost-effective use of ractopamine.

Table 1. Effects of Ractopamine Dose (4.5, 9.0 g/ton) and Feeding Duration (7, 14, 21, or 28 days) on Pig Performance[a]

		Dose, g/ton												
		4.5 g/ton				9.0 g/ton								
		Feeding Duration, days									Probability ($P<$)			
Item	Control	7	14	21	28	7	14	21	28	SE	Dose	Dose × Duration	Linear Duration	Quadratic Duration
Start weight, lb	227.4	227.6	228.1	227.5	227.2	227.7	227.4	227.9	227.7	1.37	0.97	0.97	0.87	0.86
Sale weight, lb	264.8^{b}	268.8^{b,c}	274.4^{c,d}	274.9^{c,d}	274^{c,d}	275.6^{c,d}	277.7^{d}	276.1^{d}	277.6^{d}	2.86	0.07	0.8	0.26	0.38
ADG, lb	1.32^{b}	1.47^{b,c}	1.67^{c,d}	1.69^{c,d}	1.70^{c,d}	1.71^{c,d}	1.78^{d}	1.73^{c,d}	1.77^{d}	0.09	0.1	0.72	0.17	0.43
ADFI, lb	5.18^{b}	5.34^{b,c}	5.46^{b,c}	5.52^{c}	5.60^{c}	5.57^{c}	5.55^{c}	5.54^{c}	5.70^{c}	0.11	0.16	0.83	0.09	0.63
Feed Conversion	3.97^{b}	3.7^{b,c}	3.33^{c,d}	3.3^{c,d}	3.31^{c,d}	3.27^{c,d}	3.18d	3.23^{c,d}	3.22^{c,d}	0.17	0.13	0.71	0.23	0.35
Yield, %[f]	76.3^{b}	76.7^{b,c,d,e}	76.5^{b,c}	76.6^{b,c,d}	76.6^{b,c,d,e}	77.05^{c,d,e}	77.24^{d,e}	77.38^{e}	76.7^{b,c,d,e}	0.25	0.004	0.26	0.37	0.39
10th rib backfat, in[g]	0.62^{b,c,d}	0.65^{d}	0.61^{b,c,d}	0.60^{b,c}	0.59^{b,c}	0.64^{c,d}	0.62^{b,c,d}	0.59^{b,c}	0.57^{b}	0.02	0.7	0.77	0.005	0.7
Loin depth, in[g]	2.68^{c,d,e}	2.61^{b,c}	2.64^{c,d}	2.64^{c,d,e}	2.67^{c,d,e}	2.57^{b}	2.67^{c,d,e}	2.70^{e}	2.69^{d,e}	0.03	0.46	0.96	0.96	0.78
Lean, %[g]	56.6^{c,d,e}	56.2^{b,c}	56.6^{c,d,e}	56.6^{c,d,e}	56.8^{d,e}	55.9^{b}	56.5^{c}	57.01^{e}	57.06^{e}	0.21	0.37	0.38	0.0001	0.14

[a]A total of 45 pens (23 pigs/pen, 5 pens/treatment) of gilts were fed 4.5 or 9.0 g/ton ractopamine (Paylean^{TM}) for 7, 14, 21, or 28 days prior to slaughter, along with a control treatment without ractopamine.

[b,c,d,e]Means in the same row without a common superscript differ ($P<0.05$).

[f]Yield was calculated using live carcass pen-weights attained at the slaughter plant.

[g]Backfat, loin depth, and percent lean were adjusted to a common carcass weight.

Table 2. Economic Effects of Ractopamine Dose (4.5, 9.0 g/ton) and Feeding Duration (7, 14, 21, or 28 days)

		Dose, g/ton												
		4.5 g/ton				9.0 g/ton								
		Feeding Duration, days									Probability (*P*<)			
Item	Control	7	14	21	28	7	14	21	28	SE	Dose	Dose × Duration	Linear Duration	Quadratic Duration
Carcass weight, lb	200.7[a]	202.9[a,b]	208.6[b,c]	208.9[c]	208.5[b,c]	208.4[b,c]	210.5[c]	210.9[c]	211[c]	2.04	0.04	0.77	0.05	0.14
Grade Premium, $/CWT	6.32[a,b]	6.31[a,b]	6.33[a,b]	6.44[a,b]	6.50[a,b]	6.22[a]	6.52[a,b]	6.59[b]	6.56[b]	0.11	0.71	0.39	0.03	0.51
Revenue/hd[f], $	125.13[a]	126.55[a,b]	130.13[b,c]	130.52[c]	130.43[b,c]	129.73[b,c]	131.68[c]	132.08[c]	132.05[c]	1.36	0.03	0.89	0.02	0.12
Feed cost/hd, $	6.93[a]	7.42[a,b]	7.91[b,c]	8.42[c,d]	8.73[d]	7.95[b,c]	8.65[d]	9.13[d]	9.93[e]	0.23	0.01	0.56	0.01	0.93
Feed cost/hd over controls, $	-	0.49	0.99	1.49	1.81	1.03	1.72	2.20	3.01	.	.	.	.	.
Feed cost/lb of gain	0.187[a]	0.182[a,b]	0.173[a]	0.18[a,b]	0.186[a,b]	0.167[a]	0.175[a,b]	0.19[a,b]	0.20[b]	0.01	0.71	0.39	0.03	0.51
IOMFC/hd[h], $	118.20[a]	119.13[a,b]	122.21[b,c]	122.10[b,c]	121.71[a,b,c]	121.78[a,b,c]	123.03[c]	122.95[b,c]	122.11[b,c]	1.35	0.19	0.81	0.29	0.12
IOMFC/hd over controls, $	-	0.93	4.01	3.90	3.50	3.58	4.83	4.75	3.92	.	.	.	.	.

[a,b,c,d,e]Means in the same row without a common superscript differ ($P<0.05$).

[f]Revenue = Average pig revenue for each pen on test; with a $56.00 CWT base meat price on day of sale.

[g]Diet Cost: Control = $94/ton, 4.5 g/ton = $113/ton, 9.0 g/ton = $123/ton.

[h]IOMFC (Income Over Marginal Feed Costs) = Carcass value - feed costs incurred during trial.

EFFECTS OF INCREASING LYSINE:CALORIE RATIO IN PIGS GROWN IN A COMMERCIAL FINISHING ENVIRONMENT[1]

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

Summary

Seven experiments using 7,801 pigs (75 to 265 lb) were conducted to determine the biologic and economic effects of increasing dietary lysine in commercially reared grow-finish pigs. Each study was generally 28 d long and evaluated a different weight range of the grow-finish period for barrows (3 trials) and gilts (4 trials), respectively. All studies contained six dietary treatments of incrementally increasing lysine:calorie ratio. The primary response criteria measured were growth, carcass, and economic performance. Pigs fed high-energy diets in early finishing (< 150 lb) have only moderate biological responses to a wide range of dietary lysine. However, increasing dietary lysine levels in late finishing (>150 lb) has more quantitatively significant effects on growth and carcass performance. Due the magnitude of the biological responses observed, economic penalties for feeding below the lysine requirement were modest early and severe later in the grow-finish period. These studies indicate that income over marginal feed cost (IOMFC) is consistently optimized near the biological requirement for optimal growth and feed conversion. However, feed cost per pound of gain is consistently minimized below these biological requirements. Therefore, diet costs alone provide little value in developing cost effective feeding strategies. In addition, prediction equations to calculate the optimum lysine:calorie ratio based on body weight (BW, lb) were developed. The lysine:calorie ratio prediction equation is: lysine:calorie ratio, g total lysine/Mcal ME = -.006045 × BW + 3.694 for barrows and lysine:calorie ratio = -.00744 × BW + 4.004 for gilts.

Introduction

Understanding lysine requirements is an essential component to developing cost-effective grow-finish feeding strategies. Lysine requirements are commonly expressed as a lysine:calorie ratio (glysine/Mcal ME). Expressing lysine requirements relative to dietary energy content enables these requirements to be used across a broad range of feeding situations. Although grow-finish lysine requirements have been well studied, ongoing efforts are needed to better understand the biological needs of ever evolving high-lean genotypes in commercial environments. Because feed is such a large portion of the cost of production, it is equally necessary to gain an appreciation for the economic implications of either feeding below, at, or above the biological requirements at the different phases of the grow-finish period. The objective of these trials was

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

[2]Food Animal Health and Management Center.

to determine the biologic and economic effects of feeding increasing dietary lysine concentrations to pigs grown in a commercial finishing environment. Understanding these responses will illustrate both the biological lysine requirements and economic implications of increasing lysine:calorie ratio during the grow-finish period.

Procedures

A series of seven trials (3 barrow, 4 gilt) were conducted to determine the effects of increasing lysine:calorie ratio in barrows and gilts (PIC 337 × C22) grown in commercial finishing facilities. Each trial independently evaluated one phase (weight range) of the grow-finish period. Each trial had six dietary treatments of incrementally increasing lysine:calorie ratio. All diets were corn-soybean meal-based with 6% added choice white grease. The desired lysine:calorie ratio was obtained by replacing corn with soybean meal. No crystalline lysine was utilized to ensure lysine was the first limiting amino acid. All other nutrients were formulated to be non-limiting. An overview describing phases of growth evaluated, midpoint weight, trial duration, pigs per pen, and total pigs used in each trial is outlined in Table 1. Likewise, dietary treatments, calculated dietary analysis, and costs are illustrated in Tables 2 and 3 for the barrow and gilt trials, respectively. The lysine:calorie ratios discussed in this paper are expressed as total grams lysine:Mcal of ME. True ileal digestible lysine as a percent of diet is listed in Tables 2 and 3. A subsample of each diet was analyzed for lysine content and all values were within analytical variation of the calculated values.

Pigs were allotted to one of the six dietary treatments in a randomized completed block design with seven pens per treatment. Each pen was 10 × 18 ft with a 4-hole self-feeder and one cup waterer. Finishing facilities were total slatted, deep pitted, and double curtain-sided with a total of 48 pens per barn. Pig weights by pen and feed disappearance were measured throughout all trials. In trials not ending at slaughter (barrow Trials 1 and 2, gilt Trials 1, 2, and 3), five pigs per pen were individually identified, weighed, and scanned with real-time ultrasound to measure fat depth and loin eye area at the 10th rib. These five selected pigs were identified, weighed, and scanned at the beginning and at the end of the trial. The scanning data served to study the effects of dietary lysine on body compositional changes during the feeding period. In the trials terminating at slaughter (barrow Trial 3, gilt Trial 4), pen identity was maintained through slaughter. Maintaining pen identification enabled carcass data (carcass yield, fat and loin depth at the 10th rib, lean percentage, and grade premium) to be collected for each pen.

Gain, feed intake, feed conversion, feed cost per pound of gain, and income over marginal feed costs (IOMFC) were measured in each study. Income over marginal feed costs is defined as the value of the pigs weighed off-test less the feed costs incurred during the trial period. In the trials not terminating at slaughter, an average pig value was calculated by assessing value to the weight gain during trial period (at $42.50/CWT), and subsequently subtracting feed costs incurred during the trial period. In trials terminating at slaughter, an average pig value was calculated by using the calculated carcass weight and carcass grade premium data from each pen. Because there were no treatment differences in carcass yield, the trial mean carcass yield for all pens was applied to all pens off-test weights to attain a calculated carcass weight for each pen. The average feed cost per pig was then subtracted from the derived pig value to attain the IOMFC for each pen. Data were analyzed for linear and quadratic effects of increasing lysine:calorie ratio with pen being the experimental unit in all data analyses.

Results and Discussion

Barrow Trials: (Tables 4 to 6). In Trial 1 (95–155 lb barrows), ADG and F/G improved (quadratic, P<0.01, Table 4) with increasing lysine:calorie ratio. Gain was optimized at 2.89 g lysine/Mcal ME, while F/G was optimized at 3.23 g lysine/Mcal ME. Feed intake tended to be reduced (linear, *P*=0.06) as lysine:calorie ratio increased. This trend is due to the reduced intake observed at the highest level of lysine fed (3.91 g lysine/Mcal ME). This reduction in intake may be due to the level of soybean meal (42% of total diet) that was needed to meet this lysine:calorie ratio without the use of crystalline lysine. Fat deposition, as measured by a change in 10th rib backfat during the feeding period, was reduced (linear, *P*<0.0001) with increasing lysine:calorie ratio. The change in loin eye area (LEA) increased (quadratic, *P*<0.008) with increasing dietary lysine. However, only the lowest lysine:calorie ratio fed (2.21 g lysine/Mcal ME) had a different (*P*<0.05) change in LEA than all other treatments. Feed cost per pound of gain increased (quadratic, *P*<0.01) with increasing lysine:calorie ratio. However, numeric increases continued to occur through the highest lysine level fed. Income over feed costs improved (quadratic, *P*<0.005) with increasing dietary lysine. Income over feed cost was maximized at 2.89 g lysine/Mcal ME. These data indicate feeding barrows from 95 to 155 lb a 2.89 g lysine/Mcal ME diets adequately meets biological lysine requirements for growth and maximizes return over feed costs. However, feed cost per pound of gain was minimized while feeding below these biological requirements at 2.55 g lysine/Mcal of ME.

In Trial 2 (150 to 205 lb barrows), ADG and F:G improved (linear, P<0.0001, Table 5) with increasing lysine:calorie ratio. Although gain improved at a steady rate through the highest lysine level fed (2.78 g lysine/Mcal ME), feed conversion was minimally improved beyond 2.53 g lysine/Mcal ME. Feed intake was not (P>0.15) affected by increasing lysine:calorie ratio. Fat deposition as measured by a change in fat depth during the feeding period was reduced (quadratic, *P*<0.008) with increasing lysine:calorie ratio. Reduction in fat deposition was not seen beyond 2.53 g lysine/Mcal of ME. Loin eye area tended to increase (quadratic, *P*<0.06) with increasing dietary lysine. The greatest change in LEA was observed as lysine:calorie ratio increased from 2.28 to 2.53 g lysine/Mcal ME, with little change thereafter. However, an increased change in LEA was not observed beyond 2.53 g lysine/Mcal ME. Increasing lysine:calorie ratio did not (*P*>0.46) affect feed cost per pound of gain due the magnitude of the linear improvements in feed conversion. However, IOMFC improved (linear, *P*<0.0001) with increasing dietary lysine. Although growth responses and subsequently income over marginal feed costs were improved linearly, improvements in feed efficiency and carcass composition were not significantly improved beyond 2.53 g lysine/Mcal ME. It seems probable that a combined optimal requirement for growth, feed efficiency, and carcass performance lies between 2.53 and 2.78 g lysine/Mcal ME. These data suggest that feeding barrows from 150 to 205 lb a 2.65 g lysine/Mcal ME diet provides an adequate blend of meeting biological requirements and optimizing return over marginal feed costs.

In Trial 3 (225 to 265 lb barrows), ADG and F/G improved (linear, *P*<0.03, Table 6) with increasing lysine:calorie ratio. Although the response in ADG to increasing lysine was linear, improvement was minimal beyond 2.0 g lysine/Mcal ME. Increasing lysine:calorie ratio did not affect (*P*>0.42) feed intake. Carcass yield was not affected (*P*>0.27) by dietary treatment. However, fat depth, loin depth, and lean percentage were improved (quadratic, *P*<0.0002) by increasing ly-

sine:calorie ratio. The improvement in backfat and percent lean was apparently optimized at 2.20 g lysine/Mcal ME. However, pigs fed the lowest level of lysine (1.40 g lysine/Mcal of ME) had similar backfat (P>0.05) as those fed the highest level (2.4 g lysine/ Mcal of ME). Loin depth was increased over all other treatments (P<0.05) in pigs fed 2.40 g lysine/Mcal ME. Although statistical improvements in grade premium were not evident (P>0.21), incremental numeric improvements were observed with increasing lysine:calorie ratio. Dietary lysine concentration did not affect (P>0.58) feed cost per pound of gain due to the linear improvements in feed conversion. Although IOMFC did not statistically improve (P=0.12) with increasing lysine:calorie ratio, step-wise numeric improvements in IOMFC were observed as dietary lysine increased. These numeric improvements were due to improved gain, feed conversion, as well as numeric improvements in lean premium. These data indicate feeding barrows from 225 to 265 lb a 2.20 g lysine/Mcal ME diet adequately meets biological requirements and optimizes IOMFC.

Gilt Trials: (Tables 7 to 10). In Trial 1 (75 to 135 lb gilts), ADG and F/G improved (quadratic, P<0.03, Table 7) with increasing lysine:calorie ratio. Gain and feed conversion were optimized at 3.23 g lysine/Mcal ME. Increasing lysine:calorie ratio from 2.55 to 4.25 g lysine/Mcal ME decreased (linear, P=0.05) ADFI from 4.30 to 4.18 lb/d. Fat deposition as measured by a change in fat depth during the feeding period was reduced (linear, P<0.0001) with increasing lysine:calorie ratio. Increasing lysine:calorie ratio did not affect (P>0.60) a change in LEA. Feed cost per pound of gain increased (quadratic, P<0.03) with increasing lysine:calorie ratio. However, step-wise numeric increases in feed cost per pound of gain were observed through 4.25 g lysine/Mcal ME. IOMFC improved (quadratic, P<0.02) with increasing dietary lysine, and was maximized at 3.23 g lysine/Mcal ME. These data indicate feeding gilts from 75 to 135 lb a 3.23 g lysine/Mcal ME diet adequately meets biological requirements and optimizes IOMFC. However, due to the relatively modest magnitude of the biological responses, feed cost per pound of gain numerically increased with lysine:calorie ratio.

In Trial 2 (130 to 190 lb gilts), ADG and F/G improved (quadratic, P<0.02, Table 8) with increasing lysine:calorie ratio. Feed and gain conversion were optimized at 2.80 g lysine/Mcal ME. Feed intake was not (P>0.11) affected by increasing lysine to calorie ratio. Fat deposition as measured by a change in fat depth during the feeding period was reduced (linear, P<0. 0002) with increasing lysine: calorie ratio. Increasing dietary lysine did not affect (P> 0.43) the change in LEA. Feed cost per pound of gain increased (quadratic, P<0.02) with increasing lysine:calorie ratio, with the largest increase occurring as the lysine:calorie ratio increased from 2.80 to 3.08 g lysine/Mcal ME. However, numeric increases in feed cost per pound of gain were observed through the highest dietary lysine diet fed. Income over feed costs improved (quadratic, P<0.002) with increasing dietary lysine and was maximized at the apparent biological requirement of 2.80 g lysine/Mcal ME. These data indicate feeding gilts from 130 to 190 lb a 2.80 g lysine/Mcal ME diet will meet biological requirements for optimizing growth and feed conversion, as well as maximize income over feed costs. However, feed cost per pound of gain was numerically reduced through the lowest dietary lysine level fed (1.96 g lysine/Mcal ME) in this study.

In Trial 3 (170 to 225 lb gilts), ADG and F/G improved (quadratic, P<0.003, Table 9) with increasing lysine:calorie ratio. Feed and gain conversion were optimized at 2.28 and 2.53 g lysine/Mcal ME respectively. Increas-

ing lysine:calorie ratio did not affect ($P>0.43$) feed intake. Change in fat depth at the 10th rib was reduced (linear, $P<0.0001$) and LEA tended to increase (quadratic, $P<0.10$) with increasing dietary lysine. The improvements in LEA were optimized at 2.53 g lysine/Mcal ME. Feed cost per pound of gain and IOMFC were improved (quadratic, $P<0.001$) as lysine:calorie ratio increased. Feed cost per pound of gain was optimized at 2.03 g lysine/Mcal ME, which again is below the biological lysine requirement. Income over feed cost improved (quadratic, $P<0.001$) with increasing dietary lysine and was optimized at 2.28 g lysine/Mcal ME. However, due to the more quantitatively significant effect dietary lysine is having on carcass composition in this phase of growth, the derived IOMFC value needs to be interpreted with caution. The standard IOMFC value illustrated does not account for differences in carcass lean at slaughter. When carcass lean values (Table 9) are calculated from the fat depth and LEA information and valued as if sold to slaughter, IOMFC improves in greater magnitude (linear, $P<0.0002$, quadratic, $P<0.06$) with increasing lysine:calorie ratio. These data illustrate the need to understand the quantitatively important effects that dietary lysine has on carcass composition during this phase of the growing period. These data indicate feeding gilts from 170 to 225 lb a 2.53 g lysine/Mcal ME diet adequately meets biological requirements and optimizes IOMFC when the implications on carcass lean are understood.

In Trial 4 (220 to 265 lb gilts), ADG improved (linear, $P<0.0001$) and F/G improved (quadratic, $P<0.04$) with increasing lysine:calorie ratio (Table 10). Although the response in gain was linear through the highest lysine level fed (2.40 g lysine/Mcal ME), quantitative improvement in gain was not observed above 2.20 g lysine/Mcal ME. Likewise, feed conversion was optimized at 2.20 g lysine/Mcal ME. Carcass yield was not affected ($P>0.18$) by increasing lysine:calorie ratio. Fat depth and lean percentage were improved (quadratic, $P<0.04$), as was loin depth with increasing lysine:calorie ratio. Numeric improvements in these carcass lean parameters were maximized in pigs fed 2.40 g lysine/Mcal ME. Grade premium also increased (linear, $P<0.02$) with increasing lysine:calorie ratio. Feed cost per pound of gain tended to be reduced (quadratic, $P=0.06$) as dietary lysine increased. Feed cost per pound of gain was equivocally low at 2.00 and 2.20 g lysine/Mcal ME. However, IOMFC increased (linear, $P<0.0001$) with increasing dietary lysine. These linear responses in IOMFC were due to improvements in growth performance and lean premium associated with increasing lysine:calorie ratio. However, numeric improvements in IOMFC were not observed above 2.20 g lysine/Mcal ME. These data suggest feeding gilts from 220 to 265 lb a 2.20 g lysine/Mcal of ME diet adequately meets biological requirements and optimizes IOMFC.

Prediction Equations. The determined optimum lysine:calorie ratios from both the barrow and gilt trials were plotted at the midpoint weight from each study. These data were utilized to develop regression equations to predict the optimum lysine:calorie feeding regimen based on body weight. Separate regression equations were developed for barrows and gilts. These curves describe the lysine:calorie ratio that best met the biological requirements for growth performance and optimized IOMFC for barrows and gilts used in this series of trials (Figure 1). In the barrow studies (midpoint weights 130 to 245 lb), the linear equation: lysine:calorie ratio, g total lysine/Mcal ME = -.006045 × BW + 3.694, describes the optimum lysine:calorie ratio observed. The linear equation: lysine:calorie ratio, g total lysine/Mcal ME = -.00744 × BW + 4.004, describes the optimum lysine:calorie ratio observed in the gilt studies (midpoint

weights = 105 to 243 lb). As expected, the optimum ratio declines with increasing body weight. These regressed optimum requirements also illustrate that the observed lysine requirements become more similar in the barrows and gilts as body weight increases.

These studies illustrate the biological and economical effects of increasing lysine:calorie ratio, and how the magnitude of the effects changes during the grow-finish period. In the trials with initial pig weights of less than 150 lb, the biologic and resulting economic effects were relatively modest in magnitude as compared to responses later in finishing. In these early finishing (<150 lb initial weight) trials, feed cost per pound of gain incrementally increased with lysine:calorie ratio. However, IOMFC was optimized when the biological requirements for growth were achieved. In late finishing (>150 lb initial weight), the biologic and economic responses to increasing lysine were more quantitatively significant. Feed cost per pound of gain was either not affected or reduced quadratically as lysine:calorie ratio increased. However, finishing feed cost per pound of gain was numerically minimized below the lysine:calorie ratio required for optimum biologic performance and IOMFC.

These studies indicate barrows and gilts (PIC 337 × C22) fed high fat diets in commercial facilities have a modest response to increasing dietary lysine in early finishing (<150 lb initial weight). However, penalties for feeding below the lysine requirement in late finishing (>150 lb initial weight) are severe due to the more quantitatively significant effects on gain, feed efficiency, and lean deposition. Contrary to being below the requirement, these studies suggest the penalties for being above the perceived requirement for optimal growth are minimal in late finishing. In the late finishing trials (>150 lb start weight), IMOFC tended to plateau or incrementally improve as lysine:calorie ratio increased beyond the requirement for optimal growth performance. These studies indicate feed cost per pound of gain is consistently minimized below the biological requirement for optimal growth performance and IOMFC. In summary, these studies illustrate the need to understand the dynamic biology and economic implications involved when making strategic nutritional decisions. Diet costs alone provide little value in developing cost effective feeding strategies.

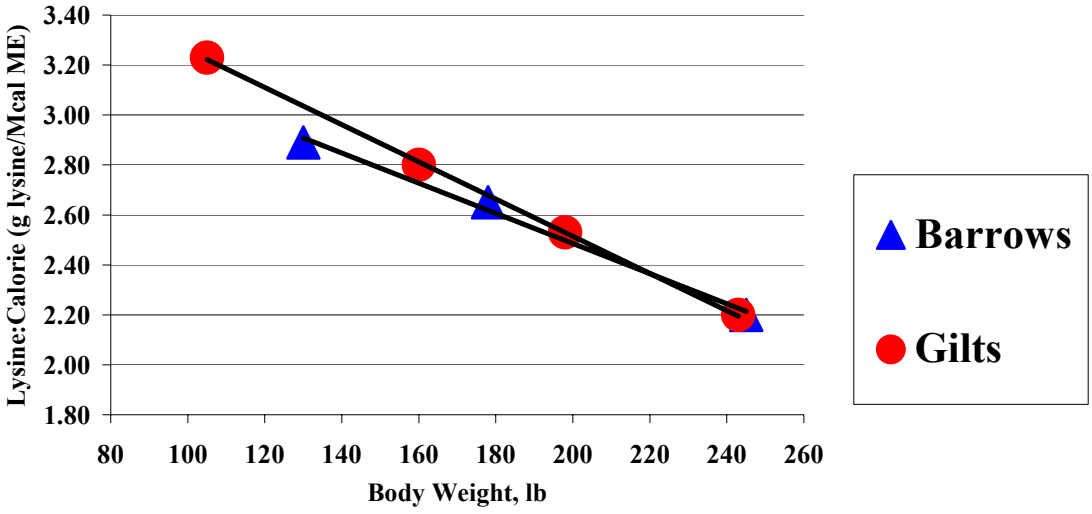

Figure 1. Predicted Optimal Lysine:Calorie Regimen for Pigs (PIC L337 × C22) Grown in Commercial Finishing Facilities[ab].

[a]A total of 7 trials (3 barrow, 4 gilt) were conducted using 7,801 pigs (PIC L337 × C22) to determine effects of increasing lysine:calorie ratio (g lysine/Mcal ME) in commercial finishing research facilities, and to subsequently derive prediction equations for an optimal lysine:calorie regimen for barrows and gilts respectively. [b]The lysine:calorie ratio prediction equation is: lysine:calorie ratio, g total lysine/Mcal ME = -.006045 × BW, lb + 3.694 for barrows and lysine:calorie ratio = -.00744 × BW, lb + 4.004 for gilts.

Table 1. Overview of Increasing Lysine: Calorie Ratio Studies[a]

	Weight Range, lb	Midpoint, lb	Duration, d	Pigs per pen, n	Pigs on test, n
Barrows					
Trial 1	95 to 155	130	28	26 to 28	1,166
Trial 2	150 to 205	178	27	25 to 28	1,147
Trial 3	225 to 265	245	21	22 to 24	968
Gilts					
Trial 1	75 to 135	105	28	28	1,176
Trial 2	130 to 190	160	28	27 to 28	1,163
Trial 3	170 to 225	198	28	27 to 28	1,160
Trial 4	220 to 265	243	25	21 to 25	1,021

[a]Studies were conducted to evaluate effects of increasing lysine: calorie ratio (g lysine/Mcal ME) in grow-finish pigs (PIC 337 × C22, n= 7,801) in a commercial finishing environment.

Table 2. Barrow Studies: Dietary Treatments, Formulated Composition, and Cost[a,b]

Item	Diet, Step-wise Lysine:Calorie Ratio					
Trial 1 (95 to 155 lb)						
Lysine:calorie, (g lysine/Mcal ME)	2.21	2.55	2.89	3.23	3.57	3.91
Total lysine, %	0.79	0.91	1.04	1.16	1.28	1.40
True digestible lysine, %	0.69	0.80	0.91	1.02	1.13	1.24
ME, kcal/lb	1624	1624	1624	1624	1623	1623
Diet cost/ton, $	118.10	121.71	125.37	129.02	133.39	137.04
Trial 2 (150 to 205 lb)						
Lysine:calorie, (g lysine/Mcal ME)	1.53	1.78	2.03	2.28	2.53	2.78
Total lysine, %	0.55	0.64	0.73	0.82	0.91	1.00

True digestible lysine, %	0.47	0.55	0.63	0.72	0.80	0.88
ME, kcal/lb	1631	1631	1631	1631	1631	1631
Diet cost/ton, $	109.57	112.26	114.94	117.65	120.33	123.04
Trial 3 (225 to 265 lb)						
Lysine:calorie, (g lysine/Mcal ME)	1.40	1.60	1.80	2.00	2.20	2.40
Total lysine, %	0.51	0.58	0.65	0.72	0.80	0.87
True digestible lysine, %	0.43	0.50	0.56	0.63	0.69	0.76
ME, kcal/lb	1640	1640	1640	1639	1639	1639
Diet cost/ton, $	107.29	109.48	111.55	113.75	115.91	118.07

[a]Increasing lysine: calorie ratios were achieved by replacing corn with soybean meal, as no crystalline lysine was used to ensure lysine was the first limiting amino acid.

[b]Diets costs were calculated with $ 1.85/bu corn and $150/ton, 46.5% soybean meal, along with a $12/ton manufacturing and delivery charge.

Table 3. Gilts Studies: Dietary Treatments, Formulated Composition, and Cost[a,b]

Item	Diet, Step-wise Lysine:Calorie Ratio					
Trial 1 (75 to 135 lb)						
Lysine:calorie, (g lysine/Mcal ME)	2.55	2.89	3.23	3.57	3.91	4.25
Total lysine, %	0.91	1.04	1.16	1.28	1.40	1.52
True digestible lysine, %	0.80	0.91	1.02	1.13	1.24	1.35
ME, kcal/lb	1624	1624	1624	1623	1623	1623
Diet cost/ton, $	121.71	125.37	129.02	133.39	137.04	141.03
Trial 2 (130 to 190 lb)						
Lysine:calorie, (g lysine/Mcal ME)	1.96	2.24	2.52	2.80	3.08	3.36
Total lysine, %	0.71	0.81	0.91	1.01	1.11	1.21
True digestible lysine, %	0.61	0.70	0.79	0.88	0.98	1.07
ME, kcal/lb	1628	1628	1628	1628	1628	1627
Diet cost/ton, $	114.92	117.91	120.93	123.91	127.27	130.65
Trial 3 (170 to 225 lb)						
Lysine:calorie, (g lysine/Mcal ME)	1.53	1.78	2.03	2.28	2.53	2.78
Total lysine, %	0.55	0.64	0.73	0.82	0.91	1.00
True digestible lysine, %	0.47	0.55	0.63	0.72	0.80	0.88
ME, kcal/lb	1631	1631	1631	1631	1631	1631
Diet cost/ton, $	109.57	112.26	114.94	117.65	120.33	123.04
Trial 4 (220 to 265 lb)						
Lysine:calorie, (g lysine/Mcal ME)	1.40	1.60	1.80	2.00	2.20	2.40
Total lysine, %	0.51	0.58	0.65	0.72	0.80	0.87
True digestible lysine, %	0.43	0.50	0.56	0.63	0.69	0.76
ME, kcal/lb	1640	1640	1640	1639	1639	1639
Diet cost/ton, $	107.29	109.48	111.55	113.75	115.91	118.07

[a]Increasing lysine:calorie ratios were achieved by replacing corn with soybean meal, as no crystalline lysine was use to ensure lysine was the first limiting amino acid.

[b]Diets costs were calculated with $ 1.85/bu corn and $150/ton, 46.5% soybean meal, along with a $12/ton manufacturing and delivery charge.

Table 4. Barrow Study, Trial 1, Effect of Lysine:Calorie Ratio on 95 to 155 lb Barrows[a]

	Lysine:Calorie (g lysine/Mcal ME)								
	2.21	2.55	2.89	3.23	3.57	3.91			
	Total Lysine, %							Probability (*P*<)	
Item	0.79	0.91	1.04	1.16	1.28	1.40	SE	Linear	Quadratic
Initial weight, lb	95.6	96.4	96.0	96.4	96.1	95.8	2.15	0.99	0.30
ADG, lb	2.01	2.14	2.19	2.13	2.12	2.08	0.05	0.50	0.007
ADFI, lb	4.56	4.60	4.65	4.50	4.55	4.42	0.09	0.06	0.14
Feed/gain	2.27	2.15	2.13	2.11	2.15	2.12	0.03	0.002	0.0086
Off-test weight, lb[b]	152.5	155.8	157.3	155.6	155.5	154.3	0.75	0.05	0.0001
10th rib fat depth change, mm[c]	4.8	3.9	4.1	3.3	3.4	2.5	0.24	0.0001	0.86
LEA change, cm^{2} [c]	7.7	8.7	8.5	9.0	8.8	8.5	0.29	0.03	0.008
Feed cost/lb of gain, $	0.134	0.131	0.133	0.136	0.143	0.146	0.002	0.0001	0.01
IOMFC, $/head[d]	16.41	17.61	17.86	17.22	16.77	16.29	0.46	0.27	0.005

[a]A total of 1166 barrows (PIC) housed at the rate of 26- 28 pigs/pen and 7 replications per treatment in the 28-day trial.

[b]Off-test weight = Start weight + (ADG * number of days of test); and adjusts all treatments to a common start weight.

[c]Change in fat depth and LEA = Difference in fat depth and LEA on the 5 animals/pen ultrasounded at the beginning and at the end of the feeding period. These differences in fat depth and LEA were adjusted to a common change in liveweight.

[d]IOMFC, Income over marginal feed costs, = Value of gain on a $42.50/CWT liveweight basis - feed costs during trial period.

Table 5. Barrow Study, Trial 2, Effect of Lysine:Calorie Ratio on 150 to 205 lb Barrows[a]

	Lysine:Calorie (g lysine/Mcal ME)								
	1.53	1.78	2.03	2.28	2.53	2.78			
	Total Lysine, %							Probability (*P*<)	
Item	0.55	0.64	0.73	0.82	0.91	1.00	SE	Linear	Quadratic
Initial weight, lb	151.2	153.5	153.8	152.4	152.0	152.6	3.91	0.92	0.27
ADG, lb	1.80	1.83	1.97	1.99	2.02	2.09	0.04	0.0001	0.51
ADFI, lb	5.02	5.08	5.10	5.19	5.04	5.18	0.07	0.15	0.66
Feed/gain	2.79	2.78	2.59	2.62	2.50	2.49	0.04	0.0001	0.34
Off-test weight, lb[b]	201.3	202.3	206.2	206.3	207.3	209.2	1.05	0.0001	0.02
10th rib fat depth change, mm[c]	5.0	4.7	3.7	3.9	3.5	4.2	0.29	0.003	0.008
LEA change, cm^2 [c]	7.6	8.0	8.5	9.3	9.7	8.6	0.45	0.006	0.06
Feed cost/lb of gain, $	0.153	0.156	0.149	0.154	0.150	0.153	0.002	0.46	0.47
IOMFC, $/head[d]	13.27	13.27	14.68	14.55	14.99	15.33	0.39	0.0001	0.50

[a]A total of 1147 barrows (PIC) housed at the rate of 25- 28 pigs/pen and 7 replications per treatment in the 27-day trial.

[b]Off-test weight = Start weight + (ADG * number of days of test); and adjusts all treatments to a common start weight.

[c]Change in fat depth and LEA = Difference in fat depth and LEA on the 5 animals/pen ultrasounded at the beginning and at the end of the feeding period. These differences in fat depth and LEA were adjusted to a common change in liveweight.

[d]IOMFC, Income over marginal feed costs, = Value of gain on a $42.50/CWT liveweight basis - feed costs during trial period.

Table 6. Barrow Study, Trial 3, Effect of Lysine:Calorie Ratio on 225 to 265 lb Barrows[a]

	Lysine:Calorie (g lysine/Mcal ME)								
	1.40	1.60	1.80	2.00	2.20	2.40			
	Total Lysine, %							Probability (*P*<)	
Item	0.51	0.58	0.65	0.72	0.80	0.87	SE	Linear	Quadratic
Initial weight, lb	226.5	226.8	227.0	227.0	226.9	226.8	3.20	0.77	0.67
ADG, lb	1.80	1.80	1.89	1.91	1.91	1.93	0.05	0.03	0.66
ADFI, lb	5.77	5.78	5.83	5.87	5.73	5.74	0.09	0.75	0.39
Feed/gain	3.21	3.22	3.09	3.08	3.00	2.97	0.05	0.0002	0.99
Off-test weight, lb[b]	264.7	264.7	266.5	266.9	267.0	267.4	0.44	0.0001	0.14
Carcass yield, %	76.16	76.06	76.18	76.26	75.41	76.11	0.24	0.27	0.96
10th rib backfat, in[c]	0.77	0.78	0.80	0.79	0.76	0.76	0.01	0.01	0.0001
Loin depth, in[c]	2.31	2.33	2.32	2.29	2.32	2.35	0.01	0.01	0.0002
Lean, %[c]	53.94	53.90	53.58	53.63	54.17	54.18	0.15	0.003	0.0001
Grade premium, $/CWT	2.96	2.97	2.81	2.88	3.10	3.19	0.17	0.26	0.21
Feed cost/lb of gain, $[d]	0.172	0.176	0.173	0.175	0.174	0.176	0.003	0.58	0.87
IOMFC, $/head[e]	106.64	106.66	106.98	107.09	107.60	107.81	1.40	0.12	0.78

[a]A total of 968 barrows (PIC) housed at the rate of 22- 24 pigs/pen and 7 replications per treatment in the 21-day trial.

[b]Off-test weight = Start weight + (ADG * number of days of test); and adjusts all treatments to a common start weight.

[c]10th-rib backfat, loin depth, and lean percent were all adjusted to a common carcass weight for statistical analysis.

[d]IOMFC, Income over marginal feed costs, = Carcass value - feed costs during trial period.

[e]Base meat price of $53.33 CWT, actual feed costs and lean premium, and carcass weights attained by applying the trial mean carcass yield (76.03%) to pen off-test weights were utilized in the IOMFC analysis.

Table 7. Gilt Study, Trial 1, Effect of Lysine:Calorie Ratio on 75 to 135 lb Gilts[a]

	Lysine:Calorie (g lysine/Mcal ME)								
	2.55	2.89	3.23	3.57	3.91	4.25			
	Total Lysine, %							Probability (*P*<)	
Item	0.91	1.04	1.16	1.28	1.40	1.52	SE	Linear	Quadratic
Initial weight, lb	77.26	77.39	77.24	77.33	77.33	77.69	1.76	0.46	0.60
ADG, lb	1.97	2.01	2.05	2.00	1.99	1.96	0.03	0.50	0.03
ADFI, lb	4.30	4.24	4.29	4.20	4.19	4.18	0.06	0.05	0.99
Feed/gain	2.18	2.11	2.09	2.11	2.11	2.14	0.03	0.35	0.03
Off-test weight, lb[b]	132.7	133.5	134.8	133.4	133.2	132.1	0.91	0.007	0.0001
10th rib fat depth change, mm[c]	2.5	2.5	2.3	2.1	1.9	1.5	0.21	0.0002	0.3
LEA change, cm^2 [c]	9.3	9.8	9.6	9.4	10.1	9.7	0.56	0.60	0.86
Feed cost/lb of gain, $	0.133	0.133	0.135	0.141	0.144	0.151	0.002	0.0001	0.03
IOMFC, $/head[d]	16.16	16.43	16.65	15.94	15.69	15.08	0.34	0.001	0.02

[a]A total of 1176 gilts (PIC) housed at the rate of 28 pigs/pen and 7 replications per treatment in the 28-day trial.

[b]Off-test weight = Start weight + (ADG * number of days of test); and adjusts all treatments to a common start weight.

[c]Change in fat depth and LEA = Difference in fat depth and LEA on the 5 animals/pen ultrasounded at the beginning and at the end of the feeding period. These differences in fat depth and LEA were adjusted to a common change in liveweight.

[d]IOMFC, Income over marginal feed costs, = Value of gain on a $42.50/CWT liveweight basis - feed costs during trial period.

Table 8. Gilt Study, Trial 2, Effect of Lysine:Calorie Ratio on 130 to 190 lb Gilts[a]

	Lysine:Calorie (g lysine/Mcal ME)								
	1.96	2.24	2.52	2.80	3.08	3.36			
	Total Lysine, %							Probability (*P*<)	
Item	0.71	0.81	0.91	1.01	1.11	1.21	SE	Linear	Quadratic
Initial weight, lb	132.1	131.4	131.7	131.3	131.8	131.9	1.84	0.89	0.17
ADG, lb	2.02	2.07	2.12	2.15	2.10	2.06	0.03	0.09	0.001
ADFI, lb	5.09	5.09	5.21	5.12	5.24	5.10	0.05	0.32	0.11
Feed/gain	2.52	2.48	2.46	2.39	2.50	2.47	0.03	0.27	0.02
Off-test weight, lb[b]	188.1	189.4	190.9	191.8	190.3	189.4	0.42	0.0001	0.0001
10th rib fat depth change, mm[c]	4.0	3.3	3.3	3.3	2.9	2.9	0.23	0.0002	0.34
LEA change, cm^2 [c]	9.3	9.6	9.9	9.5	9.6	9.5	0.38	0.78	0.43
Feed cost/lb of gain, $	0.145	0.146	0.149	0.148	0.159	0.161	0.002	0.0001	0.02
IOMFC, $/head[d]	15.83	16.12	16.38	16.64	15.60	15.25	0.29	0.06	0.002

[a]A total of 1163 gilts (PIC) housed at the rate of 27-28 pigs/pen and 7 replications per treatment in the 28-day trial.

[b]Off-test weight = Start weight + (ADG * number of days of test); and adjusts all treatments to a common start weight.

[c]Change in fat depth and LEA = Difference in fat depth and LEA on the 5 animals/pen ultrasounded at the beginning and at the end of the feeding period. These differences in fat depth and LEA were adjusted to a common change in liveweight.

[d]IOMFC, Income over marginal feed costs, = Value of gain on a $42.50/CWT liveweight basis - feed costs during trial period.

Table 9. Gilt Study, Trial 3, Effect of Lysine:Calorie Ratio on 170 to 225 lb Gilts[a]

	Lysine:Calorie (g lysine/Mcal ME)								
	1.53	1.78	2.03	2.28	2.53	2.78			
	Total Lysine, %							Probability (*P*<)	
Item	0.55	0.64	0.73	0.82	0.91	1.00	SE	Linear	Quadratic
Initial weight, lb	172.3	173.0	172.7	173.0	172.9	172.5	2.53	0.93	0.65
ADG, lb	1.78	1.79	1.98	2.02	2.01	1.98	0.04	0.0001	0.003
ADFI, lb	5.60	5.62	5.62	5.61	5.54	5.56	0.09	0.43	0.73
Feed/gain	3.15	3.14	2.84	2.78	2.75	2.82	0.04	0.0001	0.0003
Off-test weight, lb[b]	222.6	222.9	228.3	229.3	229.0	228.1	0.65	0.0001	0.0001
10th rib fat depth change, mm[c]	4.7	4.1	3.1	3.4	3.6	2.6	0.28	0.0001	0.27
LEA change, cm^2 [c]	5.4	6.5	7.7	7.2	9.3	8.4	0.47	0.0001	0.10
Lean, %[d]	53.0	53.5	54.7	53.6	54.5	55.3	0.37	0.0001	0.93
Feed cost / lb of gain, $	0.173	0.176	0.163	0.164	0.166	0.173	0.003	0.16	0.001
IOMFC, $/head[e]	12.57	12.49	14.57	14.82	14.61	13.94	0.39	0.0001	0.001
IOMFC with lean, $/head[f]	83.3	84.03	87.34	86.46	87.25	87.16	1.29	0.0002	0.06

[a]A total of 1160 gilts (PIC) housed at the rate of 27 - 28 pigs/pen and 7 replications per treatment in the 28-day trial.

[b]Off-test weight = Start weight + (ADG * number of days of test); and adjusts all treatments to a common start weight.

[c]Change in fat depth and LEA = Difference in fat depth and LEA on the 5 animals/pen ultrasounded at the beginning and at the end of the feeding period. These differences in fat depth and LEA were adjusted to a common change in liveweight. Calculated lean percentage from established equations (National Pork Board) from ultrasound fat depth and LEA data.

[d]IOMFC, Income over marginal feed costs, = Value of gain on a $42.50/CWT liveweight basis - feed costs during trial period.

[e]Projected carcass value (as if pigs were sold to slaughter at the off-test weight) - feed costs during trial period.

[f]Assigns an average carcass value to each pen using calculated lean percentage, packer lean payment grid (John Morrell & Company), and a standard carcass yield (75%) to the pen off-test weights, with a base meat price of $53.33 / CWT.

Table 10. Gilt Study, Trial 4, Effect of Lysine:Calorie Ratio on 220 to 265 lb Gilts[a]

	Lysine:Calorie (g lysine/Mcal ME)								
	1.40	1.60	1.80	2.00	2.20	2.40			
	Total Lysine, %							Probability (*P*<)	
Item	0.51	0.58	0.65	0.72	0.80	0.87	SE	Linear	Quadratic
Initial weight, lb	221.6	221.5	222.4	222.2	222.2	221.8	3.28	0.73	0.60
ADG, lb	1.59	1.6	1.69	1.85	1.94	1.94	0.04	0.0001	0.90
ADFI, lb	5.36	5.26	5.14	5.29	5.45	5.43	0.09	0.15	0.05
Feed/gain	3.37	3.32	3.05	2.87	2.81	2.81	0.06	0.0001	0.04
Off-test weight, lb[b]	262.2	262.3	264.5	268.4	270.8	270.8	0.60	0.0001	0.99
Carcass yield, %	75.4	76.0	76.3	76.2	75.7	76.2	0.30	0.28	0.25
10th rib backfat, in[c]	0.71	0.69	0.72	0.69	0.68	0.67	0.009	0.0001	0.003
Loin depth, in[c]	2.21	2.25	2.25	2.29	2.30	2.31	0.015	0.0001	0.07
Lean, %[c]	54.7	55.1	54.6	55.2	55.3	55.5	0.16	0.0001	0.04
Grade premium, $/CWT	3.52	3.76	3.48	3.8	3.83	4.02	0.16	0.02	0.51
Feed cost/lb of gain, $	0.181	0.182	0.170	0.163	0.163	0.166	0.003	0.0001	0.06
IOMFC, $/head[d,e]	105.66	106.19	107.46	108.87	109.64	109.64	1.57	0.0001	0.47

[a]A total of 1021 gilts (PIC) housed at the rate of 21- 25 pigs/pen and 7 replications per treatment in the 25-day trial.

[b]Off-test weight = Start weight + (ADG * number of days of test); and adjusts all treatments to a common start weight.

[c]10th-rib backfat, loin depth, and lean percent were all adjusted to a common carcass weight for statistical analysis.

[d]IOMFC, Income over marginal feed costs, = Carcass value - feed costs during trial period.

[e]Base meat price of $53.33 CWT, actual feed costs and lean premium, and carcass weights attained by applying the trial mean carcass yield (75.94%) to pen off-test weights were utilized in the IOMFC analysis.

PHOSPHORUS REQUIREMENTS OF GROW-FINISH PIGS RAISED IN A COMMERCIAL ENVIRONMENT[1]

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

Summary

We conducted three experiments to identify available phosphorus (aP) requirements of pigs reared in commercial facilities. In a pilot study (Exp. 1), 600 gilts (PIC, initially 95.2 lb) were randomly allotted to a low or high dietary P regimen in a 98-d study. Pigs were phase-fed six diets from 95 to 106, 106 to 150, 150 to 183, 183 to 212, 212 to 245, and 245 to 267 lb. Corresponding aP concentrations were: 0.30, 0.28, 0.27, 0.27, 0.24, and 0.19% (low) and 0.37, 0.33, 0.30, 0.28, 0.27, and 0.26% (high).

No differences were observed (P > 0.10) in ADG and overall F/G was greater (P<0.07) for pigs fed the low aP regimen. In Exp. 2, 1,260 gilts (initially 74.5 lb) were randomly allotted to one of five dietary treatments in a 26-d study. Experimental diets contained 0.18, 0.22, 0.25, 0.29, or 0.32% aP, corresponding to 0.5, 0.6, 0.7, 0.8, or 0.9 g aP/Mcal ME. There were 28 pigs per pen and 9 pens per treatment. From d 0 to 14, increasing aP tended to increase (linear, P<0.03) ADG and F/G (quadratic, P<0.05) with the greatest response observed as aP increased from 0.18 to 0.22%. However, from d 0 to 26, no differences were observed for any growth traits (P>0.12). Pooled bending moment of the femur, 6th rib, and 3rd and 4th metatarsals increased with increasing aP (linear, P<0.01). Ash content of the rib and metatarsals numerically increased (P>0.10) with increasing aP. In Exp. 3, 1,236 gilts (initially 195.1 lb) were randomly allotted to one of five dietary treatments in a 28-d study. Experimental diets contained 0.05, 0.10, 0.14, 0.19, 0.23% aP, equivalent to 0.152, 0.277, 0.402, 0.527, or 0.652 g aP/Mcal ME. From d 0 to 14, increasing aP increased (linear, P<0.01) ADG and F/G. However, from d 0 to 28 increasing aP had no effect (P>0.17) on growth performance. Increasing aP increased (linear, P<0.05) bone ash and bending moment of the 3rd and 4th metacarpals. In commercial facilities, 74 to 121 lb pigs require approximately 0.22% aP to maximize ADG and F/G, whereas 195 to 240 lb pigs require approximately 0.19% aP. However, bone bending moment and ash continued to increase with increasing aP. These values correspond to 0.60 and 0.527 g aP/Mcal ME and 3.24 and 4.07 g/d of aP intake. Our results suggest percentage aP requirement estimates are similar to NRC (1998); however, because of the low feed intake of pigs in commercial facilities our study shows a lower requirement estimate on a g/d basis.

(Key Words: Grow-Finish Pigs, Phosphorus, Growth Performance.)

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[2]Food Animal Health and Management Center.

Introduction

Most states in the U.S. regulate swine waste application based on N concentration but more are changing to P-based regulations. Because of the ratio between N and P in swine waste and their rate of uptake by most plants, P concentration can be first limiting for waste application if soil P accumulation is not permitted. Therefore, re-evaluation of P requirements of swine is an important step in minimizing its excretion.

Differences in feed intake have been observed between university and commercial environments. Therefore, expressing requirement estimates on a percentage basis could lead to nutrient deficiencies. The purpose of these experiments was to estimate the available P (aP) requirements of pigs reared in commercial facilities.

Procedures

General. All three trials were conducted at a commercial research facility in southwestern Minnesota. Each pen contained one 4-hole dry self-feeder and one cup-waterer to allow ad libitum access to feed and water. Pen weights and feed disappearance were measured approximately every 14 days to calculate ADG, ADFI, and F/G. Prior to starting experimental diets, pigs were fed a diet containing 0.40% aP in Exp. 1 and 2, and 0.27% aP in Exp. 3. All diets were formulated using NRC (1998) nutrient composition values for the respective ingredients.

Experiment 1. A total of 600 gilts with an initial weight of 95.2 lb were blocked by weight and randomly allotted to one of two dietary treatments in a 98-d pilot study. Within each treatment, pigs were phase-fed six diets from 95 to 106, 106 to 150, 150 to 183, 183 to 212, 212 to 245, and 245 to 267 lb. Corresponding aP concentrations were 0.30, 0.28, 0.27, 0.27, 0.24, and 0.19% for pigs fed the low aP regimen (low) or 0.37, 0.33, 0.30, 0.28, 0.27, and 0.26% aP in the high aP regimen (high; Table 1). There were 25 pigs per pen and 12 pens per treatment. A constant Ca:P ratio of 1.1:1 was maintained in all diets. The range of values used represented recommendations similar to those proposed by swine breeding stock companies and nutritionists for commercial production in the United States. Our objective with this pilot study was to obtain an aP estimate from which we could more efficiently conduct titration studies.

Experiment 2. A total of 1,260 gilts with an initial weight of 74.5 lb were blocked by weight and randomly allotted to one of five dietary treatments in a 26-d experiment. The corn-soybean meal-based diets contained 6% added fat and were formulated to 1.25% total lysine. Treatments consisted of five levels of aP; 0.18, 0.22, 0.25, 0.29, or 0.32%, which correspond to 0.5, 0.6, 0.7, 0.8, or 0.9 g of aP/Mcal ME, (Table 2). There were 28 pigs per pen and 9 pens per treatment. A constant Ca:P ratio of 1.1:1 was maintained in all diets by varying the amounts of monocalcium phosphate and limestone to attain the desired levels of Ca and P.

At the conclusion of Exp. 2, one pig from each pen was randomly selected and humanely euthanized. The right 5th, 6th, and 7th ribs and the right rear leg were collected, labeled, placed in plastic bags, and stored in a cooler filled with ice for transport to Kansas State University for bone analysis.

Experiment 3. A total of 1,260 gilts with an initial weight of 195.1 lb were blocked by weight and randomly allotted to one of five dietary treatments in a 28-d experiment. Pigs were fed diets with either 0.05, 0.10, 0.14, 0.19, or 0.23% aP, which correspond to 0.152, 0.277, 0.402, 0.527, or 0.652 g aP/Mcal (Table 3). There were 28 pigs per pen and 9 pens

per treatment. A constant Ca:P ratio of 1.1:1 was maintained for all diets, while varying the amounts of monocalcium phosphate and limestone to attain the desired levels of Ca and P in the diets.

At the conclusion of Exp. 3, two pigs from each pen where randomly selected, tattooed, and shipped to a commercial meat packing facility for slaughter (Sioux-Preme, Sioux Center, IA). After pigs were processed, the lower third of the front right leg was removed, labeled, and placed in a plastic bag and stored in a cooler on ice for transport to Kansas State University for bone analysis.

Bone Analysis. Bones were cleaned of adhering tissue then tested for mechanical properties with force applied by an Instron Universal Testing Machine. Following mechanical tests bones were cut in half, measured for dimensions, then placed in petroleum ether for 7 d, and dried for 12 h at 105^{o}C three times to determine the absolute dry, fat free weight. Bones were then ashed at 600^{o}C for 24 h to determine percentage ash. Ash is expressed as a percentage of dried, fat free bone weight.

Treatments for all three trials were arranged in a randomized complete block design. Analysis of variance was conducted on all data using the PROC MIXED procedure of SAS, while repeated measure methods were used for bone data analysis.

Results and Discussion

In Exp. 1, over the entire 98-d experiment, no differences were observed (P>0.10) for ADG or ADFI, but pigs fed the low aP regimen tended (P<0.07) to have better F/G than those fed the high aP regimen. These results suggest that the aP levels in the high regimen were above those necessary for maximum growth.

Using this data, we then established a range of aP concentrations to evaluate in the subsequent experiments, which used 74 to 121 and 195 to 240 lb pigs. We expanded our response criteria to include bone mechanical properties because typically aP requirements to maximize bone strength are greater than those required to maximize growth.

In Exp. 2, from d 0 to 14, increasing aP tended to increase (linear, P<0.03) ADG and F/G (quadratic, P<0.05). The greatest improvement in both ADG and F/G was observed as aP increased from 0.18 to 0.22%. This corresponded with aP intakes of 2.70 and 3.21 g/d. However, from d 14 to 26 and for the overall study, no differences were observed (P>0.10) in ADG, ADFI, or F/G. Although not different (P>0.10) numerical trends similar to those observed from d 0 to 14 were observed for overall ADG and F/G as aP increased from 0.18 to 0.22% or 2.75 to 3.24 g/d.

The aP requirement based on the growth data observed in our study (0.22%) is very similar to that suggested by NRC for 44 to 110 lb pigs (0.23%). However, because of differences in ADFI between our study and that projected by NRC, our results suggest a lower aP requirement estimate on a g/d basis compared to NRC (1998, 3.24 vs 4.27 g/d). Our findings correspond to a requirement of 0.60 g aP/Mcal ME, compared to 0.71 g aP/Mcal ME calculated from NRC.

There were no bone × treatment interactions. Rib and femur bending moment increased (quadratic P<0.03, and linear P<0.01, respectively) with increasing aP. However, increasing aP had no effect (P>0.10) on metatarsal bending moment (Table 6). Percentage ash increased (linear, P<0.01) with increasing aP in the 4th metatarsal, but not in the 3rd metatarsal or rib. Femurs were only evaluated for bending moment. Based on the repeated

measures analysis, the main effect of dietary aP was significant, with increasing aP increasing (linear, P<0.007) bending moment, but bone ash was not affected.

These results suggest that 0.22% aP or 0.60 g aP/Mcal ME is adequate to maintain growth and bone strength in pigs from 74 to 121 lb. The 3.21 g/d aP intake observed in our study is similar to other studies, but the percentage of the diet necessary to achieve this intake in our study was higher.

In Exp. 3, from d 0 to 14 increasing aP increased (linear, P<0.01) ADG and F/G (Table 7). Although the response in ADG to increasing aP was linear, the greatest ADG was observed in pigs fed 0.19% aP. Average daily feed intake tended to increase (quadratic, P<0.09), with the greatest increase observed as aP increased from 0.05 to 0.10% aP. This corresponds to an increase from 0.96 to 2.00 g/d aP intake. From d 14 to 28 and 0 to 28, no differences (P > 0.17) were observed for ADG, ADFI, or F/G. For bone properties, no bone × treatment interactions were observed, bending moment increased (linear, P < 0.003) with increasing aP in the 3rd but not the 4th metacarpal (Table 8). Repeated measures analysis of both bones indicated a linear increase (P<0.04) with increasing aP. Bone ash increased (linear, P<0.01) in both metacarpals; this relationship was also evident with repeated measures analysis.

Some nutritionists suggest, and universities trials have shown, that no inorganic P is needed during the last phase of production; however, this has caused known problems such as vertebral breakage during stunning in some production systems and higher incidence of broken limbs in finishing barns. The results of Exp. 3 suggest that some added inorganic P (in diets without added phytase) is necessary in corn-soybean meal-based finishing diets for pigs from 195 to 240 lb raised in commercial facilities. Therefore, it appears that at least 0.19% aP or 0.527 g aP/Mcal ME is adequate for maintaining growth and bone strength in pigs from 195 to 240 lb.

In conclusion P requirements of commercially reared pigs are similar to the NRC suggestion when expressed on a dietary percentage basis, but because of decreased feed intake, the grams per day requirements in our studies were less. These estimates are slightly lower than current estimates and may help decrease phosphorus excretion in commercial swine operations.

Table 1. Diet Composition[a] (Exp. 1, as-fed basis)

	Low regimen, aP %[b]						High regimen, aP %[b]					
Phase:	1	2	3	4	5	6	1	2	3	4	5	6
Ingredient, %	0.30	0.28	0.27	0.27	0.24	0.19	0.37	0.33	0.30	0.28	0.27	0.26
Corn	62.26	67.14	71.10	73.53	75.44	76.85	61.86	66.88	70.95	73.45	75.33	76.48
Soybean meal (46.5 %)	29.08	24.26	20.40	17.99	16.21	15.05	29.12	24.29	20.41	17.99	16.22	15.08
Choice white grease	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Monocalcium P, 21% P	1.08	1.03	1.01	1.01	0.90	0.64	1.43	1.26	1.13	1.07	1.00	0.98
Limestone	0.84	0.88	0.83	0.81	0.85	0.86	0.86	0.88	0.85	0.83	0.85	0.86
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.09	0.08	0.06	0.06	0.05	0.05	0.09	0.08	0.06	0.06	0.05	0.05
Trace mineral premix	0.15	0.13	0.10	0.10	0.05	0.05	0.15	0.13	0.10	0.10	0.05	0.05
L-lysine HCl	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Calculated composition												
Lysine, %	1.18	1.04	0.93	0.86	0.81	0.78	1.18	1.04	0.93	0.86	0.81	0.78
ME, kcal/kg	3,590	3,594	3,599	3,601	3,606	3,615	3,578	3,586	3,594	3,598	3,602	3,603
Ca, %	0.64	0.62	0.59	0.58	0.57	0.52	0.71	0.67	0.62	0.59	0.59	0.58
Total P, %	0.60	0.57	0.55	0.54	0.51	0.45	0.67	0.62	0.58	0.55	0.53	0.52
g aP/ Mcal ME	0.83	0.78	0.76	0.75	0.68	0.52	1.03	0.92	0.83	0.78	0.74	0.72
Analyzed values,%												
Ca	0.68	0.59	0.54	0.52	0.57	0.56	0.68	0.64	0.70	0.60	0.49	0.60
P	0.60	0.52	0.51	0.48	0.46	0.42	0.60	0.58	0.55	0.53	0.43	0.51

[a]Diet composition was calculated using NRC (1998) values for ingredient composition.

[b]Diets were phase-fed: 1 = 95 to 106, 2 = 106 to 150, 3 = 150 to 183, 4 = 183 to 212, 5 = 212 to 245, and 6 = 245 to 267 lb.

Table 2. Diet Composition[a] (Exp. 2, as-fed basis)

	Available P, %				
Ingredient, %	0.18	0.22	0.25	0.29	0.32
Corn	59.93	59.56	59.18	58.81	58.43
Soybean meal, 46.5 CP%	31.98	32.01	32.05	32.08	32.11
Choice white grease	6.00	6.15	6.30	6.45	6.60
Monocalcium P, 21% P	0.51	0.68	0.85	1.02	1.20
Limestone	0.85	0.87	0.89	0.91	0.93
Salt	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.08	0.08	0.08	0.08	0.08
Trace mineral premix	0.15	0.15	0.15	0.15	0.15
L-lysine HCl	0.15	0.15	0.15	0.15	0.15
Calculated composition					
Lysine, %	1.25	1.25	1.25	1.25	1.25
ME, kcal/kg	3601	3601	3601	3601	3601
CP, %	20.13	20.11	20.09	20.08	20.06
Ca, %	0.54	0.58	0.62	0.66	0.70
P, %	0.49	0.53	0.57	0.60	0.64
g aP / Mcal ME	0.50	0.60	0.70	0.80	0.90
Analyzed values, %					
Ca	0.53	0.53	0.56	0.59	0.67
P	0.45	0.46	0.50	0.55	0.57

[a]Diet composition was calculated using NRC (1998) composition values for ingredients.

Table 3. Diet Composition[a] (Exp. 3, as-fed basis)

	Available P, %				
Ingredient, %	0.05	0.10	0.14	0.19	0.23
Corn	75.68	75.68	75.68	75.68	75.68
Soybean meal, 46.5 CP%	15.90	15.90	15.90	15.90	15.90
Choice white grease	6.00	6.00	6.00	6.00	6.00
Monocalcium P, 21% P	0.00	0.21	0.43	0.64	0.86
Limestone	0.73	0.76	0.78	0.81	0.83
Salt	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.08	0.08	0.08	0.08	0.08
Trace mineral premix	0.15	0.15	0.15	0.15	0.15
Sand	0.96	0.72	0.48	0.24	0.00
L-lysine HCl	0.15	0.15	0.15	0.15	0.15
Calculated composition					
Lysine, %	0.80	0.80	0.80	0.80	0.80
ME, Mcal/kg	3,596	3,596	3,596	3,596	3,596
Ca, %	0.35	0.40	0.45	0.50	0.55
P, %	0.32	0.37	0.41	0.46	0.50
g aP / Mcal ME	0.152	0.277	0.402	0.527	0.652
Analyzed values %					
Ca	0.36	0.42	0.43	0.55	0.49
P	0.30	0.35	0.37	0.40	0.45

[a]Diet composition was calculated using NRC (1998) composition values for ingredients.

Table 4. Effects of Dietary P Regimen on Pig Growth Performance, Exp. 1[a]

Item	Low aP[b]	High aP[b]	SEM	P-value
Overall, d 0 to 98				
ADG, lb	1.76	1.76	0.01	0.81
ADFI, lb	4.66	4.73	0.05	0.20
Feed/gain	2.65	2.69	0.02	0.07

[a]A total of 600 gilts, initially, 95.2 lb were used. Values represent the means of 25 pigs per pen and 12 pens per treatment.

[b]Diets were fed according to feed budget, with weights of 95 to 106, 106 to 150, 150 to 183,183 to 212, 212 to 245, and 245 to 267 lb for each regimen. Available P was 0.30, 0.28, 0.27, 0.27, 0.24, and 0.19% for pigs fed the low aP regimen or 0.37, 0.33, 0.30, 0.28, 0.27, and 0.26% aP in the high aP regimen.

Table 5. Effects of Increasing Available P on Pig Growth Performance, Exp. 2[a]

	Available P,%					P-value		
Item	0.18	0.22	0.25	0.29	0.32	Linear	Quadratic	SEM
Day 0 to 14								
ADG, lb	1.75	1.85	1.82	1.88	1.85	0.03	0.13	0.03
ADFI, lb	3.31	3.22	3.25	3.19	3.28	0.67	0.24	0.06
Feed/gain	1.90	1.74	1.79	1.70	1.78	0.06	0.05	0.05
aP intake, g/d[b]	2.70	3.21	3.69	4.20	4.76	< 0.01	0.62	0.07
Day 14 to 26								
ADG, lb	1.94	1.95	1.96	1.96	1.95	0.89	0.70	0.04
ADFI, lb	3.41	3.41	3.45	3.51	3.46	0.46	0.79	0.08
Feed/gain	1.77	1.75	1.76	1.79	1.78	0.71	0.88	0.05
aP intake, g/d[b]	2.79	3.41	3.91	4.62	5.02	< 0.01	0.51	0.09
Day 0 to 26								
ADG, lb	1.84	1.90	1.88	1.92	1.89	0.12	0.19	0.03
ADFI, lb	3.36	3.31	3.34	3.34	3.36	0.81	0.63	0.06
Feed/gain	1.83	1.74	1.77	1.74	1.78	0.38	0.19	0.04
aP intake, g/d[b]	2.75	3.24	3.81	4.35	4.91	< 0.01	0.89	0.07

[a]A total of 1,260 gilts, initially 74.5 lb were used. Values represent the means of 25 pigs per pen and 9 pens per treatment.

[b]Values represent the calculated dietary aP values multiplied by the ADFI.

Table 6. Effects of Increasing Available P on Bone Properties, Exp. 2[a]

	Available P,%					P-value		
Item	0.18	0.22	0.25	0.29	0.32	Linear	Quadratic	SEM
Metatarsal 3								
Bending moment, kg-cm	36.1	27.8	24.0	28.2	32.8	0.77	0.18	6.60
Ash, %	49.1	52.1	50.1	50.3	49.8	0.97	0.51	1.90
Metatarsal 4								
Bending moment, kg-cm	36.7	31.8	37.2	37.1	32.2	0.82	0.76	4.69
Ash, %	46.3	49.5	48.1	48.4	49.8	0.01	0.40	0 .64
Rib								
Bending moment, kg-cm	18.7	25.5	24. 8	27.7	27. 6	0.001	0.03	1.24
Ash, %	47.1	48.1	48.3	48.8	48.3	0.16	0.64	0 .92
Femur								
Bending moment, kg-cm	289.1	338.2	319.1	339.4	338.1	0.01	0.17	11.78
Main effects of bone[b]								
Bending moment, kg-cm	96.1	105. 8	101. 3	108. 1	107. 7	0.007	0.35	3.07
Ash, %[c]	47.5	49.9	48.8	49.2	49.5	0.24	0.40	0.90

[a]One pig from each pen was randomly selected for harvest of bones. Values represent the mean of 9 observations per treatment.

[b]Values represent means of bones combined by treatment using repeated measures analysis of SAS.

[c]Percent ash was not conduct on femurs. Values represent the main effects of metatarsals and rib.

Table 7. Effects of Increasing Available P on Finishing Pig Growth Performance, Exp. 3[a]

	Available P, %					P-value		
Item	0.05	0.10	0.14	0.19	0.23	Linear	Quadratic	SEM
Day 0 to 14								
ADG, lb	1.37	1.51	1.52	1.62	1.56	0.008	0.14	0.06
ADFI, lb	4.23	4.42	4.42	4.48	4.33	0.44	0. 09	0.10
Feed/gain	3.13	2.96	2.94	2.79	2.78	0.01	0.59	0.10
aP intake g/d[b]	0.96	2.00	2.81	3.86	4.51	< 0.01	0.01	0.05
Day 14 to 28								
ADG, lb	1.68	1.63	1.68	1.67	1.68	0.89	0.82	0.09
ADFI, lb	4.96	4.82	5.03	4.94	5.03	0.49	0.73	0.12
Feed/gain	3.08	3.01	3.01	2.99	3.08	0.97	0.59	0.14
aP intake g/d[b]	1.12	2.19	3.19	4.26	5.25	< 0.01	0.78	0.08
Day 0 to 28								
ADG, lb	1.54	1.57	1.60	1.64	1.63	0.17	0.63	0.06
ADFI, lb	4.62	4.64	4.75	4.72	4.70	0.34	0.52	0.08
Feed/gain	3.06	2.96	2.96	2.88	2.92	0.18	0.53	0.08
aP intake g/d[b]	1.05	2.10	3.01	4.07	4.91	< 0.01	0.11	0.05

[a]A total of 1,236 gilts, initially 195.1 lb were used. Values represent the means of 28 pigs per pen and nine pens per treatment.

[b]Values represent the calculated dietary aP values multiplied by the ADFI.

Table 8. Effects of Increasing Available P on Finishing Pig Bone Properties, Exp. 3[a]

	Available P,%					P-value		
Item	0.05	0.10	0.14	0.19	0.23	Linear	Quadratic	SEM
Metacarpal 3								
Bending moment, kg-cm	100.2	110.3	118.4	112. 9	120.0	0.003	0.24	4.36
Ash %	50.1	50.7	51.9	52.0	52.1	0.001	0.14	0.36
Metacarpal 4								
Bending moment, kg-cm	92.8	95.3	92.6	97.3	95.5	0.59	0.93	4.34
Ash %	51.2	51.6	51.8	52.7	53.3	0.001	0.48	0.52
Main effects of bone[b]								
Bending moment, kg-cm	96.5	103.3	105.5	105.1	107.7	0.04	0.41	3.50
Ash %	50.6	51.2	51.9	52.3	52.7	0.001	0.65	0.40

[a]Two pigs were randomly selected from each pen for harvest of bones, values represent the mean of nine observations per treatment.

[b]Values represent means combined Metacarpal 3 and 4 using repeated measures analysis of SAS.

EFFECTS OF INCREASING CA:P RATIO IN DIETS CONTAINING PHYTASE ON GROWTH PERFORMANCE OF GROW-FINISH PIGS

S. M. Hanni, M. D. Tokach, J. L. Nelssen, R. D. Goodband, S. S. Dritz[1], M. R. Barker, C. N. Groesbeck, T. P. Keegan, K. R. Lawrence, M. G. Young, and B. W. James

Summary

We used 144 growing-finishing pigs (72 barrows and 72 gilts; initially 85 lb) to determine the effects of calcium to total phosphorus (Ca:P) ratio on growth performance. Pigs were housed in an environmentally regulated finishing building with two pigs per pen and nine pens per sex per treatment in a randomized complete block design. Pigs were blocked by initial weight and sex, and then allotted to one of four dietary treatments. The dietary treatments were corn-soybean meal-based diets fed in three phases. In each phase, diets consisted of a 1:1; 1.25:1; 1.5:1, and 2:1 Ca:P ratio. Diets were formulated to contain 0.44%, 0.39%, and 0.34% phosphorus from 70 to 130, 130 to 190, and 190 to 250 lb, respectively. All diets contained 0.05% phytase, providing 300 FTU/kg of feed. For the overall experiment, increasing Ca:P ratio decreased ADG (quadratic $P<0.03$) and ADFI (linear $P<0.05$). However, the greatest decrease in ADG and ADFI was observed when Ca:P increased from 1.5:1 to 2:1. Feed to gain was not affected by Ca:P ratio. These results suggest that in growing-finishing diets containing 300 FTU/kg phytase, a Ca:P ratio greater then 1.5:1 will decrease ADG and ADFI.

(Key Words: Calcium, Phosphorus, Phytase, Finishing Pigs.)

Introduction

Calcium and phosphorus are essential for proper skeletal development and maintenance. Phosphorus is organically bound in cereal grains to phytate and has poor availability to pigs. However, the bioavailability of phytate phosphorus from cereal grains is increased with the addition of phytase. This reduces the level of dietary phosphorus in a diet, which results in reduced amounts of phosphorus excreted. As the Ca:P ratio widens, there is a decrease in phosphorus absorption, which results in poorer growth performance. However, as we decrease the phosphorus level and maintain a narrow Ca:P ratio, calcium levels can fall below estimated requirements of NRC (1998). Therefore, the objective of this experiment was to determine the effect of increasing calcium to total phosphorus ratio in diets containing phytase on growth performance in growing finishing pigs.

Procedures

One hundred forty-four pigs (72 barrows and 72 gilts; PIC 327 × C22) averaging 85 lb were used in this experiment. Pigs were housed in an environmentally regulated finishing building with two pigs per pen and nine pens (5 × 5 ft) per sex per treatment (nine pens of barrows and nine pens of gilts) in a ran-

[1]Food Animal Health and Management Center.

domized complete block design. Pigs were blocked by initial weight and sex, and then randomly allotted to one of the four experimental treatments. Feed and water were provided ad libitum.

The four dietary treatments consisted of calcium to total phosphorus ratios of 1:1; 1.25:1; 1.5:1, and 2:1. Soybean meal, vitamin premixes, antibiotic, Natuphos 600, monocalcium phosphate, trace mineral premix, and limestone were analyzed for percentage calcium and phosphorus. These values were then used in diet formulation. Diets were fed in meal form in three phases; phase one and two were 28 days and phase 3 was 19 days. These corresponded to approximately 70 to 130 lb, 130 to 190 lb, and 190 to 250 lb, respectively. The same Ca:P ratios were used in each phase. Diets were formulated to contain 1.10%, 0.90%, and 0.75% total dietary lysine, and 0.45%, 0.40%, and 0.35% total available phosphorus for phase 1, 2, and 3, respectively. Natuphos was added to all of the diets to provide 300 FTU/kg in order to achieve available phosphorus equivalence values of 0.22%, 0.19%, and 0.15% for phase 1, 2, and 3, respectively.

Individual pig weights and feed disappearance were measured every 14 d to calculate ADG, ADFI, and F/G. At the end of the study, pigs were marked with an individual tattoo to allow for individual carcass data to be collected at marketing. All pigs were sent to Sioux Preme Packing Co, Sioux Center, IA for individual carcass data collection (i.e., carcass weight, fat and loin measurements). The experiment was conducted from May to August, 2002.

Results and Discussion

From d 0 to 28, increasing Ca:P ratio decreased ADG (linear $P<0.0006$) and worsened F/G (linear $P<0.008$), but did not affect ($P<0.18$) ADFI. Although responses were linear for both ADG and F/G, the greatest change in performance was observed when Ca:P ratios increased from 1.5:1 to 2:1. From d 28 to 57, increasing Ca:P ratio decreased ADG (quadratic $P<0.002$) and ADFI (linear $P<0.03$), but F/G was not affected ($P<0.76$). Again, as with phase I, the greatest change in performance was observed when Ca:P ratio increased from 1.5:1 to 2:1. From day 57 to 76, no differences in growth performance were observed; however, pigs fed the 2:1 Ca:P ratio had a numerically lower ADG.

For the overall experiment, increasing the Ca:P ratio decreased ADG (quadratic $P<0.03$) and ADFI (linear, $P<0.05$). Similar to the response in both phase 1 and 2, the greatest changes occurred when the Ca:P ratio increased from 1.5:1 to 2:1. Even though F/G was not affected ($P<0.21$), as the Ca:P ratio increased from 1.5:1 to 2:1, F/G was numerically reduced.

Increasing the Ca:P ratio decreased carcass weight (quadratic $P<0.03$). Once again the greatest changes taking place when the Ca:P ratio was increased from 1.5:1 to 2:1. There were no differences for carcass yield, backfat depth, loin eye area, and fat free lean index (FFLI).

In summary, these results suggest that calcium to total phosphorus should not be greater than a 1.5:1 ratio in a corn-soybean meal-based diet containing 300 FTU/kg phytase for growing finishing pigs to avoid limiting growth performance.

Table 1. Diet Composition for Phase 1, 2, and 3

Ingredient, %	Phase 1	Phase 2	Phase 3
Corn	70.65	78.20	83.90
Soybean meal 46.5%	26.45	19.15	13.70
Monocalcium phosphate, 21%P	0.40	0.25	0.10
Limestone	0.44 - 1.60	0.46 - 1.48	0.48 - 1.38
Salt	0.35	0.35	0.35
Vitamin premix	0.15	0.15	0.15
Trace mineral premix	0.15	0.15	0.15
Tylan 40	0.05	0.05	0.05
Sand	1.17 - 0.005	1.04 - 0.02	0.93 - 0.03
Lysine HCL	0.15	0.15	0.15
Natuphos 600	0.05	0.05	0.05
Calculated Analysis			
Lysine, %	1.10	0.90	0.75
Protein, %	18.30	15.50	13.50
Me, Kcal/lb	1497	1502	1508
Ca, %	0.44 - 0.88	0.39 – 0.77	0.34 - 0.68
P, %	0.44	0.39	0.34

Table 2. Influence of Ca:P Ratio on Growth Performance[d]

	Calcium : Phosphorus Ratio					Contrast *P*<	
Item	1:1	1.25:1	1.5:1	2:1	SED	Linear	Quadratic
Day 0 to 28							
ADG	2.23[a]	2.14[a]	2.20[a]	2.04[b]	0.05	<0.01	0.44
ADFI	5.08	4.91	5.00	4.92	0.10	0.18	0.56
Feed/gain	2.28[a]	2.29[a]	2.28[a]	2.40[b]	0.05	<0.01	0.15
Day 28 to 57							
ADG	1.93[a,c]	2.01[a,b]	2.03[b]	1.86[c]	0.05	0.76	<0.01
ADFI	5.81	5.79	5.81	5.51	0.15	0.03	0.27
Feed/gain	3.01	2.89	2.85	2.96	0.09	0.76	0.08
Day 57 to 76							
ADG	1.56	1.52	1.55	1.44	0.08	0.11	0.64
ADFI	5.65	5.66	5.86	5.46	0.21	0.40	0.15
Feed/gain	3.65	3.74	3.86	3.84	0.16	0.23	0.44
Overall							
ADG	1.95[a]	1.94[a]	1.97[a]	1.83[b]	0.04	0.01	0.03
ADFI	5.49[a]	5.43[ab]	5.52[a]	5.27[cb]	0.11	0.05	0.25
Feed/gain	2.81	2.80	2.80	2.89	0.07	0.21	0.34
Packing Plant Data							
Carcass wt.	169.40[a]	170.24[a]	172.25[a]	157.47[b]	4.25	<0.01	0.03
Yield, %	72.75	72.92	73.20	72.59	0.38	0.65	0.15
Backfat, in.	0.86	0.90	0.93	0.83	0.06	0.58	0.12
Loin eye area	7.37	7.55	7.53	7.11	0.28	0.26	0.18
FFLI, %	52.88	53.64	52.85	53.77	0.89	0.46	0.84

USING HEART GIRTH TO DETERMINE WEIGHT IN FINISHING PIGS[1]

C. N. Groesbeck, R. D. Goodband, J. M. DeRouchey, M. D. Tokach, S. S. Dritz[2], J. L. Nelssen, K. R. Lawrence, and M. G. Young

Summary

Heart girth and body weight were measured on 100 growing-finishing pigs (50 to 273 lb) at the KSU Swine Teaching and Research Center. Heart girth, in inches, was measured using a cloth measuring tape. The tape was placed directly behind the front legs and then wrapped around the heart girth and read directly behind the shoulders. Heart girth was strongly correlated (R^2=0 .98) with body weight, with the following regression equation: pig weight = 10.1709 × Heart girth - 205.7492. The 95% confidence interval shows the projected weight to be ±10 lb of the actual weight of the pig. To validate our equation we weighed and measured heart girth on 40 pigs from a commercial breeding farm and a group of 165 pigs at the 2002 Swine Classic Youth Exposition. At the commercial breeding farm, the actual measured body weights fit within the 95% confidence interval from their projected weights, based on the regression equation. The average residual (difference between predicted and actual weight) of the 40 pigs was -0.70 lb with a range of ± 4 lb. The actual weights of pigs at the Swine Classic averaged 16 lb greater than their predicted body weights with a range of ±8.5 lb. The actual weights failed to fall within the 95% confidence interval for the developed regression equation. This was probably due to shrink during transportation to the show and limited feed and water. Heart girth as a means of determining body weight is a viable device for 4-Hers and producers, but it is important to use only on pigs with continuous access to feed and water.

Introduction

Many people in 4-H as well as producers may not have access to an accurate scale to weigh their pigs. Heart girth can be a tool used by 4-Hers and producers to estimate body weight and track progress of growth for their pigs. Using heart girth to measure weight may also help if a producer or individual only has a few pigs that need to be weighed by reducing the amount of time it takes to put up and tear down a scale and reduce transportation of the pigs. The objective of our study was to develop a regression equation to determine pig weight based on heart girth and validate its accuracy.

Procedure

Heart girth and weight were measured on 100 randomly selected pigs at the KSU swine teaching and research facilities. All pigs had ad libitum access to feed and water. Weights of pigs measured for heart girth ranged from 50 to 273 lb. The heart girth was measured with a cloth measuring tape in inches. The tape was placed snuggly around the heart girth of the pigs, directly behind the front legs, and carefully read directly behind the pigs shoul-

[1]Appreciation is expressed to Craig Good for his cooperation with part of the study.

[2]Food Animal Health and Management Center.

ders. However, it is important that the pig is measured when its head is down or even with its body. When a pig raises its head, this increases its heart girth. The pig needs to be standing still when the measurement is taken. A confined pig is the easiest to tape as its movement is restricted. In addition, an extremely muddy pig may also affect the result of the taping procedure.

Results and Discussion

A correlation between heart girth and weight (R^2 =0.98) was obtained (Figure 1) and a regression equation (pig weight = 10.1709 × heart girth -205.7492) was developed. The 95% confidence interval for the equation is ± 10 lb. The regression equation was tested on two populations of pigs, which consisted of 40 pigs from a commercial breeding farm and 165 pigs from the Swine Classic. All weights of the pigs from the commercial breeding farm fit well within the 95% confidence interval from their projected weights (Figure 2). The average residual (difference between predicted and actual weight) of the 40 pigs was -0.70 lb with a range of ±4 lb. The projected weights of pigs at the Swine Classic showed much greater variation and were less accurate than the pigs from the commercial farm. The actual weights of pigs at the Swine Classic averaged 16 lb greater than their predicted body weights with a range of ±8.5 lb. The regression equation greatly underestimated the weights of the Swine Classic pigs. This was probably due to shrink during transportation to the show from limited feed and water, travel, or stress.

There are a few problems that may occur when measuring pigs. Pigs move around and have a tendency to lift their head which leads to more variation in the weight measurement accuracy. A confined pig is simplest to measure with the cloth tape. We suggest taking three separate heart girth measurements and using the average. A 1-inch inaccuracy will result in an inaccuracy of 10 lb. Averaging three measurements should more accurately represent true girth measurement. The pigs also should be on continuous feed and water to insure accuracy of results. Heart girth measuring can be very useful to 4-Hers and producers for approximating pig weight.

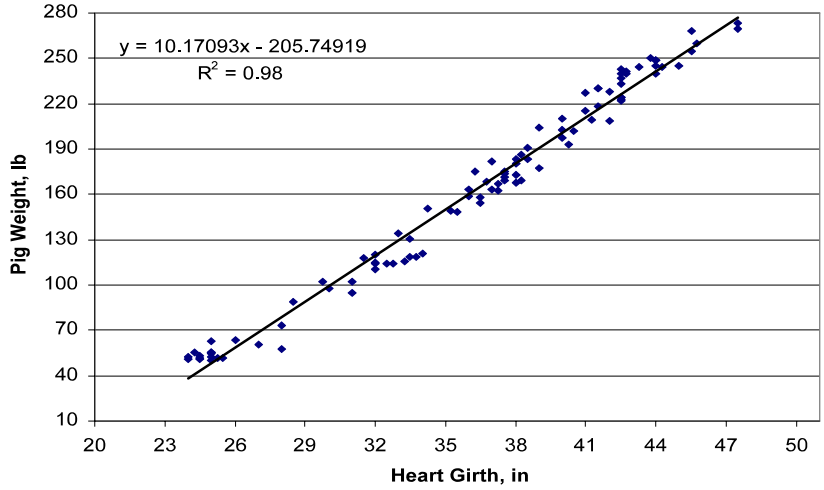

Figure 1. Heart Girth and Weight Measurements of 100 Pigs from KSU Swine Teaching and Research Center.

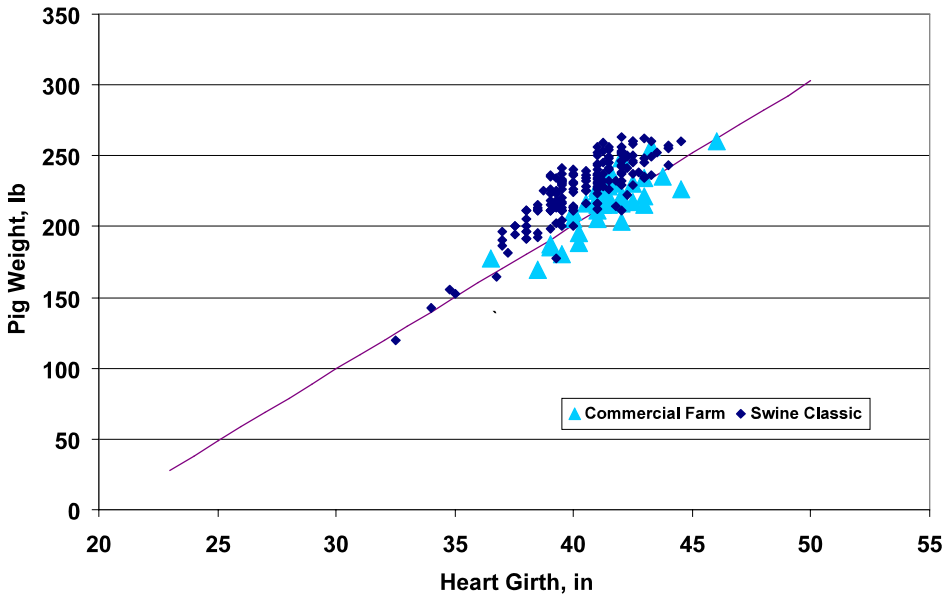

Figure 2. Heart Girth and Weight Measurements of 165 Swine Classic Pigs and 40 Commercial Farm Pigs. The average residual (difference between predicted and actual weight) of the 40 pigs was -0.70 lb with a range of ±4 lb. The actual weights of pigs at the Swine Classic averaged 16 lb greater than their predicted body weights with a range of ±8.5 lb.

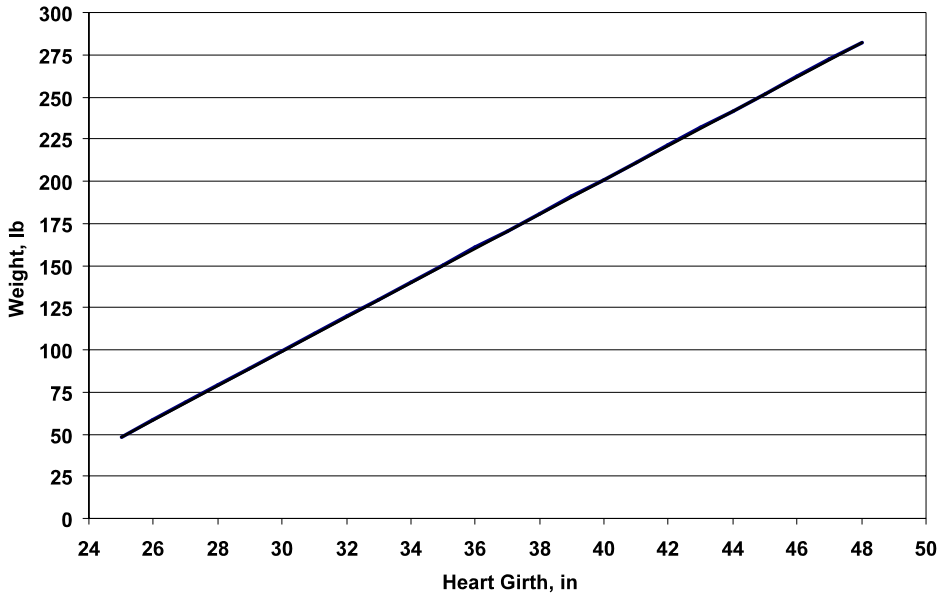

Figure 3. The Relationship Between Heart Girth and Weight Generated to Predict Body Weight of Pigs. This chart can be used to estimate weight based on heart girth.

MEASURING EMISSION RATES OF PARTICULATE MATTER FROM FAN VENTILATED SWINE BARNS [1]

B. Z. Predicala[2], R. G. Maghirang[2]

Summary

Methods for measuring concentrations and emission rates of particulate matter (PM) from mechanically ventilated livestock buildings were evaluated in a laboratory facility and in a swine-finishing barn. Concentrations of PM were measured inside the room (room sampling) and at the exhaust duct (exhaust sampling). Concentrations at the exhaust duct were determined using high-volume traverse downstream of the exhaust fan, low-volume traverse downstream of the fan, and fixed sampling upstream and downstream of the fan. The traverse methods, which served as the reference, were conducted under isokinetic conditions; fixed sampling was done under both isokinetic and sub-isokinetic conditions. Compared to the traverse method, both room sampling and exhaust sampling under sub-isokinetic conditions overestimated PM concentrations. Fixed sampling under isokinetic conditions, on the other hand, did not differ significantly (P>0.05) from the high-volume traverse method. Thus, isokinetic fixed sampling can be an alternative to the more expensive and time-consuming high-volume PM traverse method to measure PM concentrations and emission rates at the exhaust.

(Key Words: Air Quality, Dust, Emission, Measurement.)

Introduction

Emissions of particulate matter (PM), odors, and gases from animal production systems are rapidly becoming an important concern for livestock producers. Numerous complaints of adverse effects on the quality of life of residents in communities near large animal facilities have been reported. Measurement of emission rates of specific airborne pollutants from animal buildings is an important step towards developing a thorough understanding of the issues and in finding cost-effective solutions.

Previous studies have used different methods of determining air pollutant emission rates from livestock buildings. Most methods were based on the product of the air pollutant concentration at the exhaust and the ventilation rate. However, the sampling locations for measuring pollutant concentration varied. Some studies sampled inside the exhaust duct while others measured concentrations at a distance upstream of the duct. Still others measured outside the building in the discharge plume of the exhaust fans. Methods for measuring the ventilation rate also varied. Some studies used fan-wheel anemometers, others used tracer gases, while some relied on the performance curves of the ventilation fans. This wide variability in emission measurement

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[2]Department of Biological and Agricultural Engineering.

protocols precludes meaningful comparison of results from various studies and hinders the compilation of an emission inventory, from which a reliable emission factor can be derived.

This study was conducted to develop and evaluate simple methods for measuring PM emission rates from livestock buildings. Specifically, different techniques for measuring the emission rates from mechanically ventilated swine buildings were compared. The influence of isokineticity and sampling location on the measured emission rate was investigated in an in-house laboratory facility and in an actual swine barn.

Procedures

Laboratory experiments. Three air sampling methods were investigated in a test chamber (Figure 1), which was 12 ft long, 8 ft high, and 24 ft wide. The chamber had a PM generation system that has been used in previous air quality studies. A variable speed fan (diameter = 24 in.) provided the desired airflow rate, which ranged from 3800 to 4200 ft^3/min. Outside air entered through a sidewall inlet (11 × 47-in. opening) with a baffle at an angle of 45°. The fan had a fiberglass housing typical of ventilation exhaust fans in swine buildings. A 74-in.-long round extension duct (25-in. diameter) was added at the exhaust side of the fan. The downstream sampling plane for the fixed samplers was 48 in. from the fan while the PM traverse was at a plane 56 in. from the fan. The upstream sampling plane was located 22 in. before the fan, which was approximately 3.5 in. upstream of the wall plane.

Particulate matter sampling methods. Three air sampling methods were considered: low-volume PM traverse under isokinetic conditions, fixed sampling at specific locations within the duct cross-section, and high-volume PM traverse under isokinetic conditions. The low-volume PM traverse used a sampling head with 0.55-in. probe inlet diameter and a 1.46-in. filter assembly. The sampling head was attached to a flowmeter with a flow control mechanism and a vacuum pump. During sampling, the sampling head was positioned at selected locations (Fig. 1) within the sampling plane, facing the airstream. At each location, the sampling flow rate was adjusted to achieve isokinetic condition and the sampler was operated for 4.0 min before moving to the next location. Isokinetic condition was achieved by varying the air sampling flow rate to match the air velocity at the inlet plane of the sampler with the airstream velocity outside the sampler. The required sampling flow rates for isokinetic sampling were determined by conducting an air velocity traverse at the sampling plane prior to PM sampling.

The fixed sampling method used 0.55-in. samplers and IOM samplers. The 0.55-in. sampler was similar to that in the low-volume traverse method while the IOM sampler was an inhalable PM sampler operated under either isokinetic condition or at the recommended flow rate of 0.071 ft^3/min (sub-isokinetic sampling for this study). An air velocity traverse was also conducted prior to sampling to determine the required isokinetic sampling flow rate.

The high-volume sampler, which was considered as the reference sampler for this study, was assembled based on specifications in test methods for high-volume sampling for low concentrations of PM from stationary sources (ASTM D4536-95 and US EPA CTM-003). The sampling train consisted of a 2-in. diameter probe, an 8 × 10-in. filter holder, a flow nozzle, and a variable-speed vacuum motor. Similar to the low-volume PM traverse, PM was also extracted isokinetically at specified sampling locations within the sampling plane.

After sampling, the probe and the front part of the filter holder were rinsed with acetone (about 75-100 mL) to collect the PM deposited on the probe and filter holder walls. The acetone was allowed to evaporate and the mass of the residual PM was added to that of the PM collected on the filter. The sampling duration at each traverse point (approximately 3.0 min) was determined from preliminary tests such that the total PM mass collected was at least 100 mg as specified in ASTM D4536-95.

All laboratory tests were replicated three times. For each test, one IOM sampler, operated sub-isokinetically at 0.071 ft^3/min, was installed at an additional upstream sampling location to determine the effect of anisokineticity on the measured PM concentrations.

All collection filters were type AE, binder-free glass fiber filters. Filters were conditioned in a constant humidity container (77°F, 50% relative humidity) for 24 h prior to weighing both before and after sampling. All filters were weighed in an electronic microbalance with a sensitivity of 0.01 mg.

The air velocity traverse was conducted at the sampling plane using a pitot tube and a micromanometer with an accuracy of ±0.002-in. water guage. The traverse points (Fig. 1) were selected based on the guidelines specified in US EPA Method 1. For a round duct with a diameter of 25 in., the sampling points for a 12-point velocity traverse were located along two perpendicular diametrical lines at distances of 1.1, 3.7, and 7.3 in. from the duct wall.

For each velocity traverse point, the air velocity was calculated from the velocity pressure reading obtained from the pitot tube. The isokinetic sampling flow rate for each point was calculated as the product of the velocity and the area of the inlet opening of the sampler. The ambient air conditions were monitored with a psychrometer to determine the air density. The ambient air temperature during the laboratory tests ranged from 77 to 82°F, with relative humidity between 19 and 46%.

The average air velocity at the traverse plane was calculated from the velocity pressure readings from all traverse points. The fan ventilation rate was calculated as the product of the average air velocity and the cross-sectional area of the duct.

Field test. The 0.55-in. samplers and the high-volume traverse method were used to measure the PM emission rate from a swine-finishing barn. The barn was 112 ft long, 40 ft wide, and 8 ft high, with 80 pens arranged in four rows over fully-slatted floors. Each pen (5.3 × 5.3 ft) had a feeder and drinker and held two pigs during the study. Outside air entered through 21 sidewall inlets (21-in. wide each) distributed along the two sidewalls, passed through two underfloor pits running longitudinally under the pens, and exhausted by three 24-in. exhaust fans at one end of the building. The outside air temperature ranged from 37 to 53°F during the study, and only 8 - 10 of the inlets were used with baffle vertical opening adjusted to about 3 to 4 in. The temperature inside the barn ranged from 66 to 76°F. All measurements were done on the minimum ventilation fan.

The same extension duct, downstream sampling locations and sampling procedures used in the laboratory were used in the field tests. The mean airflow rate through the fan was 3900 ft^3/min, ranging from 3600 to 4100 ft^3/min. Preliminary tests indicated that a sampling duration of 12 min at each sampling location was necessary to obtain the required target catch of at least 100 mg from the PM traverse. Two fixed samplers were operated isokinetically with a mean flow rate of 1.79 ft^3/min. Another sampler was ran anisokineti-

cally at a mean flow rate of 0.91 ft^3/min while the required flow rate for isokinetic sampling was 1.66 ft^3/min. The fixed samplers were operated simultaneously with the PM traverse, which lasted for about 150 to 190 min. Duplicate IOM samplers were installed at the center of the barn to monitor the corresponding room PM concentrations during the emission test. These IOM samplers were operated at the recommended flow rate of 0.071 ft^3/min for 4 to 5 hours.

Data analysis. The PM concentration was calculated by dividing the PM collected by the total air volume sampled. The total air volume was obtained from the product of the sampler's average sampling flow rate and the total time that the sampler was operated. The emission rate was the product of the calculated PM concentration and the fan ventilation rate obtained from the velocity traverse. Because the ventilation rate for each test was the same for the methods being compared, only the PM concentrations were used in the analysis. The measured PM concentrations, C_a, were normalized by dividing each with the concentration from the corresponding PM traverse, C_r.

Results and Discussion

Laboratory tests. The mean normalized PM concentrations measured by the different methods in the laboratory and the mean PM concentrations from the PM traverse are summarized in Table 1. Room PM concentrations were considerably higher than the PM concentration at the exhaust (Tests 1-3). The disparity between the room average and exhaust PM concentrations can be due to the imperfect mixing within the room, which would result in spatial variability in PM concentrations. As such, to estimate PM emission rates from mechanically ventilated buildings, sampling should be conducted at the exhaust.

The IOM sampler, when operated at its rated sampling flow rate and under sub-isokinetic conditions, overestimated PM concentration by more than 2.4 times that of the reference sampler (Tests 1-3). This could be attributed to oversampling of the large airborne particles due to the mismatch in the velocity between the airstream that entered the sampler inlet and the airstream outside the sampler. The unequal velocities would result in the divergence of the airstream approaching the sampler inlet; consequently, large particles that should not have entered the sampler were projected into the sampler due to their momentum.

The upstream and downstream 0.55-in. fixed samplers (Test 3), when operated isokinetically, did not differ significantly ($P>0.05$) in PM concentration. While they underestimated the PM concentrations indicated by the reference method by 12% and 9%, respectively (Test 3), the differences were not significant ($P>0.05$).

Field test. The mean PM concentration at the center of the swine barn was 2.08 mg/m^3 (range of 1.26 to 2.81 mg/m^3). This concentration was significantly ($P<0.05$) higher than the mean concentration measured at the exhaust airstream (1.12 mg/m^3), reinforcing the need to measure the PM concentration at the exhaust when determining PM emission rates.

The mean PM concentrations measured with the high-volume PM traverse and the downstream isokinetic 0.55-in fixed samplers did not differ significantly ($P>0.05$), with only a 3% difference. The PM concentration measured by the anisokinetic 0.55-in. sampler downstream of the fan was significantly ($P<0.05$) higher than that obtained by the reference method.

The PM emission rates from the exhaust fan considered were calculated from the PM concentrations measured by the high-volume traverse method and the airflow rates measured by velocity traverse. The fan PM emission rate had a mean of 7.4 g/h, ranging from 6.9 to 8.3 g/h. Expressing the emission rate based on a livestock unit (500-kg liveweight), the rate ranged from 415 to 733 mg/h per 500 kg, with a mean of 526 mg/h per 500 kg. The total PM emission rate from the swine barn was approximately 1.25 - 1.33 times higher than the fan PM emission rate because of the emissions from the other two exhaust fans. The calculated PM emission rates were comparable to those obtained in similar type of swine buildings in northern Europe in which inhalable PM emission rates ranged from 418 to 895 mg/h per 500 kg with a mean of 612 mg/h per 500 kg

From the observations made in this study, it appears that isokinetic fixed sampling at the exhaust could be an alternative method for accurate measurement of PM emission rates from mechanically ventilated swine buildings. This method is less expensive and easier to implement than the high-volume PM traverse method. This information can be useful in the development of standard protocols for measurement of PM emission rates from mechanically ventilated livestock buildings.

Table 1. Normalized PM Concentrations (mean C_a/C_r ± SD) Measured Using the Different Methods. Measured PM concentrations (C_a) were normalized using concentration obtained from the reference method (C_r)

Test #	Room (IOM sampler)	Sampling Location				Reference Method Concentration, C_r (mg/m^3)[c]
		Upstream of Exhaust Fan		Downstream of Exhaust Fan		
		Isokinetic[b] (IOM or 0.55-in. sampler)	Anisokinetic (IOM sampler)	Isokinetic (0.55-in. sampler)	Anisokinetic (0.55-in.] sampler)	
Laboratory Tests (3 replicates)						
1	4.78[a] ± 0.63	0.93[a] ± 0.01	2.53[a] ± 0.24	-	-	8.30 ± 1.68
2	2.26 ± 0.87	1.00 ± 0.02	3.85[a] ± 0.45	-	-	7.11 ± 0.32
3	4.20 ± 1.55	0.88 ± 0.06	2.39[a] ± 0.22	0.91 ± 0.04	-	6.00 ± 2.05
Field Test (5 replicates)						
4	1.85[a] ± 0.45	-	-	1.03 ± 0.13	1.37[a] ± 0.30	1.12 ± 0.07

[a]Indicates significant difference ($P<0.05$) with respect to PM traverse.

[b]Tests 1 and 2 used the IOM sampler while Test 3 used the 0.55-in. sampler.

[c]The high-volume PM traverse was the reference method for Tests 1, 3, and 4; the low-volume PM traverse was the reference for Test 2.

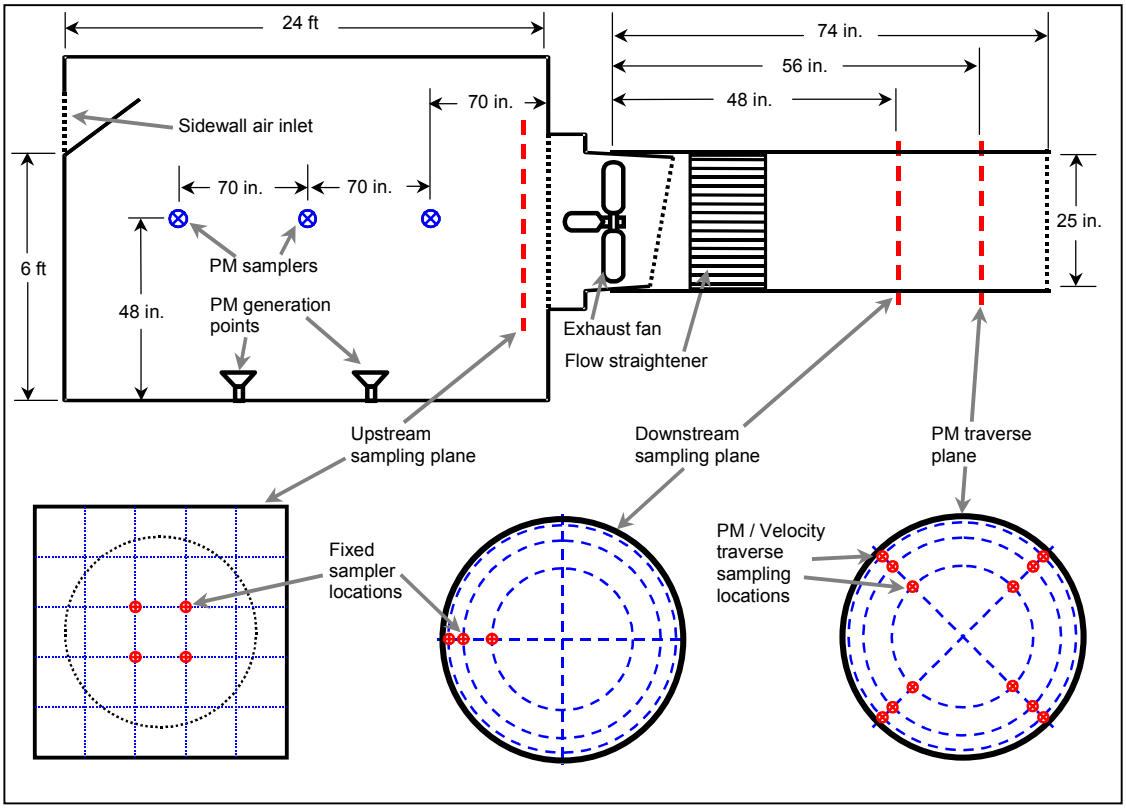

Figure 1. Schematic Diagram of the In-house Laboratory Set-Up Showing the Location of the Sampling Planes and the Sampling Locations Within Each Plane (not drawn to scale).

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