2002

2002 Nebraska Swine Report

Duane E. Reese

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NEBRASKA SWINE REPORT

- Nutrition
- Genetics
- Reproduction
- Economics
- Housing
- Meats

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Prepared by the staff in Animal Science and cooperating Departments for use in Extension, Teaching and Research programs.

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Nebraska Swine Report Acknowledgments for 2002

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2002 Nebraska Swine Report

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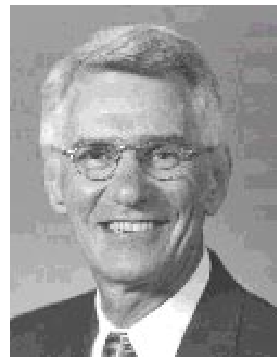


Austin J. Lewis

Austin J. Lewis retired from the Animal Science Department on September 30, 2001 after 25 years at the University of Nebraska. Dr. Lewis was born in Poole, Dorset, England. He received his B.S. (1967) in animal production from the University of Reading, England and his Ph.D. (1971) in applied biochemistry and nutrition from the University of Nottingham, England. He was a postdoctoral fellow at Iowa State University from 1971-74 and a research associate at the University of Nebraska from 1974-75 before going to the University of Alberta as an assistant professor in 1975. He came to Nebraska as an assistant professor in 1977, became an associate professor in 1980 and was given the status of professor in 1985. During the 1996-97 academic year, Dr. Lewis was granted a sabbatical leave to do research at the Babraham Research Institute Cambridge, England. His research has been in swine nutrition with emphasis on the amino acid nutrition of swine, and this has included investigations of the amino acid requirements of all classes of swine as well as the bioavailability of amino acids. Numerous scientific papers have been published based on this research. In 1987 he received the Gamma Sigma Delta Research Award from the Nebraska Chapter and in 1988 the Nutrition Research Award from the American Society of Animal Science. Dr. Lewis has taught undergraduate and graduate courses on animal nutrition and a graduate course on protein nutrition, as well as serving as an instructor for the Interdepartmental Nutrition Seminar. He has served as an advisor to several graduate students who were pursuing either a Master or Doctoral degree in swine nutrition, and as Chair of the Departmental Graduate Committee from 1998-2001. Dr. Lewis has contributed to the Journal of Animal Science as a member of the editorial board, as editor of the Nonruminant Nutrition section, and editor-in-chief in 1990-1993. He was a co-editor of the first and second editions of "Swine Nutrition" and also a co-editor of "Bioavailability of Nutrients for Animals." He has served as a member of the subcommittees responsible for the two most recent revisions of the "NRC Nutrient Requirements of Swine" and as a member of the Board on Agriculture, Committee on Animal Nutrition. Dr. Lewis will remain in Lincoln, where his wife, Nancy, is an Associate Professor in the Department of Nutritional Science and Dietetics. He will continue his affiliation with the Animal Science Department as professor emeritus.

Donald G. Levis resigned his position as professor of physiology after 23 years at the University of Nebraska to accept a position as coordinator of the Ohio Pork Industry Center at The Ohio State University. Dr. Levis was born in Chariton, Iowa. He received a B.S. degree (Agriculture) in 1971 from Northeast Missouri State University, an M.S. degree (Animal Science) in 1972 from Northwest Missouri State University and Ph.D. degree (Reproductive Physiology) in 1976 from South Dakota State. After completing his Ph.D., he moved to the Department of Animal Science at North Carolina State University where he was an assistant professor/extension swine specialist in Reproductive Physiology from 1976-78. In 1978 Dr. Levis moved to the University of Nebraska, South Central Research and Extension Center, as an Assistant Professor/Extension Swine Specialist. His research projects on neuroendocrinology of sexual behavior of boars was conducted at the United States Meat Animal Research Center. He became an associate professor in 1983. Don became a full professor in 1989 and moved to the Lincoln campus. During the 1991-92 academic year he spent a sabbatical in Australia conducting research in reproductive physiology at the Victorian Institute of Animal Science (Werribee, Victoria), and Western Australian Department of Agriculture (Perth, Western Australia). While at Nebraska his major job was to provide educational support in the subject matter area of swine reproductive physiology to pork producers and the University of Nebraska Agricultural Educators. During this time he come in contact with over 23,000 people in Nebraska and the United States. He is nationally and internationally known for designing the LEVIS Swine Breeding facility and his work with artificial insemination (A.I.) of pigs. His educational information on breeding facility design, A.I., and reproductive management of the breeding herd has gained state, national and international exposure through published articles and pork industry meetings. Dr. Levis has traveled to many foreign countries to present seminars and conduct farm visits. He published many extension articles on A.I. and reproductive management of pigs. He personally designed numerous swine breeding facilities for individual pork producers. During his tenure at Nebraska he received the Distinguished Extension Specialist Award from the University of Nebraska in 1988, the Dedicated Service to Pork Industry from the Nebraska Pork Producers Association in 1988, the Livestock Service Award from the University of Nebraska in 1989, Excellence in Team Programming from the University of Nebraska in 1991 and 1994, and in 1998 he received the Extension Award from the American Society of Animal Science. He has published many articles in trade journals, proceedings and other extension publications.

Donald G. Levis

Thomas Long resigned his position as assistant professor/swine extension specialist in January 2000 to accept a position with National Pig Development (NPD) in North Carolina.

Thomas Long

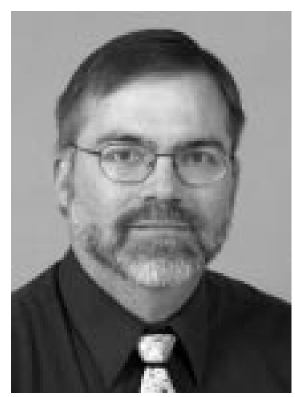
Dr. Long received his B.S. and M.S. degrees from the University of Illinois in 1975 and 1985, respectively. His Ph.D. degree was from the University of Nebraska in 1989. Prior to obtaining his M.S. degree, Dr. Long worked in the pork industry for seven years.

After receiving his Ph.D., he moved to Australia to work as coordinator of the Pig Genetics Program at the Animal Genetics and Breeding Unit, University of New England, Armidale, New South Wales. His responsibilities there included maintenance and implementation of PIGBLUP, a software system used for genetic evaluation of pigs. He also conducted extension activities with the Australian Pig Industry on a national scale and served as the genetic technical advisor to the pig branch of NSW Agriculture.

Dr. Long returned to the U.S. in 1994 to accept a position as assistant professor/swine specialist at the West Central Research and Extension Center at North Platte. His responsibilities included development and implementation of a research program in sow and litter management with emphasis on genetic x environmental interactions. He also provided leadership for swine management extension programming in the West Central and Panhandle districts as well as statewide leadership for programs in swine breeding.

Dr. Long is currently the director of genetics and research at NPD. His responsibilities include establishing the direction of breeding and selection programs within NPD as well as guiding research initiatives within this organization.

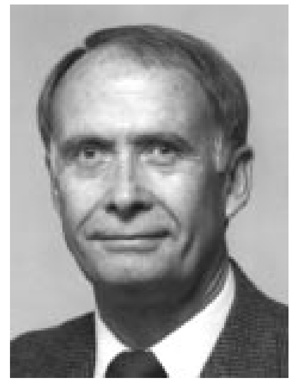
Robert W. Wills resigned his extension swine veterinarian position at the University of Nebraska in 2000 to accept a position in the College of Veterinary Medicine at Mississippi State University. Dr. Wills received his B.S. degree in 1978 from the University of Missouri, an M.S. degree in 1980 from the University of Tennessee - Knoxville, and his DVM in 1984 from the University of Missouri. In 1996 he received his Ph.D. from Iowa State University. Prior to starting this Ph.D. program, Dr. Wills worked as a private veterinarian/partner at the Fayette Veterinary Clinic in Iowa.



Robert W. Wills

Dr. Wills has written several articles for referred journals, most notably regarding the transmission of the PRRSV to swine. He has conducted many workshops and seminars in the United States and other countries. Dr. Wills also developed many educational aides and materials that are useful to pork producers. He was instrumental in increasing the number of pork producers in Nebraska who were certified Level III in the NPPC Pork Quality Assurance Program and for helping many to make a decision whether or not to adopt composting as a method of mortality disposal.

In his current position as an associate professor of Epidemiology, Dr. Wills conducts research projects with swine and poultry. He also teaches veterinary students about epidemiology, swine diseases, and the pork industry. His extension efforts are focused on using epidemiology to improve animal health and to promote food safety.



Larry Bitney

Larry Bitney, professor of agricultural economics, is retiring after 41 years of service to the University of Nebraska. Dr. Bitney is a native Nebraskan, born near Neligh. He received his B.S. degree in 1958 and his M.S. in 1965, both in agricultural economics from the University of Nebraska. He received his Ph.D. degree in agricultural economics from Oklahoma State University in 1969.

Dr. Bitney was hired as an assistant county extension agent in Dodge County in 1959 with primary responsibility for the Farm and Home Development Program, teaching families how to analyze their farm records. He moved to Lincoln in 1963, as an assistant extension economist in the Department of Agricultural Economics. In 1965 he became leader of NEBFARM, an electronic mail-in farm records and analysis program. After a two-year break at Oklahoma State University for his Ph.D. degree, he returned to the UNL Department of Agricultural Economics in 1968 as associate professor with an extension-research appointment. He was promoted to full professor in 1974. For two years beginning in 1982, Dr. Bitney held a 50 percent appointment with Extension Service-USDA in Washington D.C., providing national leadership in farm financial management programming. After a sabbatical leave with the MIAC Morocco project in Settat, Morocco in 1990/91, he served for two years as the campus coordinator for this USAID funded project.

Larry led or co-led the following educational programs: Managing for Tomorrow, Farm & Ranch Financial Counseling Service, Swine Enterprise Records and Analysis Program, and Decisions Now — Building Your Future. He supervises staff members who lead the Women in Agriculture programs, the UNL Beginning Farmer program, and the Returning to the Farm program. Dr. Bitney has been a member of the Pork Interest Group since its start in 1994. Pork Central originated from efforts of this group and was started in 1996 as a cooperative effort of Nebraska Cooperative Extension and the Nebraska Pork Producers Association. He has served as the fiscal manager of this program and as day-to-day supervisor of Al Prosch, the Pork Central coordinator.

Dr. Bitney worked with a graduate student, James Friesen, in 1989 on an economic analysis of three pseudorabies eradication alternatives for Nebraska. Results from this project, funded by the Nebraska Pork Producers Association, were used by state senators in drafting legislation for the Nebraska pseudorabies eradication program. He has conducted economic analysis of many technologies related to the swine industry. Most of these efforts have been to help producers make decisions on the adoption of the technology or practice. Results have typically appeared as co-authored articles in the *Nebraska Swine Report*.

Among the awards that Dr. Bitney has received are the UNL Distinguished Education Service Award, USDA Superior Service Award, Distinguished Extension Specialist Award, IANR Team Effort Award, and Excellence in Team Programming awards.

Comparison of Swine Performance When Fed Diets Containing Roundup Ready® Corn, Parental Line Corn, or Two Commercial Corns

Robert L. Fischer
Austin J. Lewis
Phillip S. Miller[1]

Summary and Implications

This experiment was conducted to evaluate growth performance and carcass quality measurements in growing-finishing pigs fed diets containing either Roundup Ready® corn expressing the CP4 EPSPS protein, the parental control corn, or two commercial sources of non-genetically modified corn. The experiment used 72 barrows and 72 gilts with an initial body weight of 50 lb. The pigs were allotted to a randomized complete block design with a 2 × 4 factorial arrangement of treatments (two sexes x four corn hybrids). The experiment continued until the average body weight was 255 lb, at which time all pigs were slaughtered. Real-time ultrasound measurements were taken on the final day of the experiment. Carcass quality measurements were made 24 hours postmortem. Average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (ADG/ADFI) were not affected by corn variety, but there was an effect of sex for all growth performance traits, with barrows having greater ($P < 0.001$) ADG and ADFI than gilts and gilts having better ($P < 0.001$) feed efficiency than barrows. Real-time ultrasound measurements were similar among corns, however a sex effect was detected for backfat (BF) depth, with gilts having less ($P < 0.001$) BF than barrows. There were no differences in carcass midline BF measurements among corns, but there was a significant difference between barrows and gilts, with gilts having less ($P < 0.05$) BF than barrows. Total body electrical conductivity measurements were not affected by corn, but hot carcass weight was greater ($P < 0.001$) in barrows than gilts. Also, primal percentage and percent carcass lean were greater ($P < 0.01$) in gilts than barrows. Longissimus muscle quality scores were similar among corns and between barrows and gilts, except for pH, which was greater ($P < 0.05$) in barrows than gilts. Analysis of longissimus muscle composition revealed no main effect of corn variety ($P > 0.05$) or effect of sex ($P > 0.05$) for protein, fat, and water percentages. Roundup Ready® corn (2.99%) differed ($P < 0.04$) from parental control corn (2.20%) but not commercial corns (3.08 and 3.06%) in longissimus fat content. In summary, there were no differences in growth performance or carcass measurements in growing-finishing pigs fed diets containing either Roundup Ready® corn, the parental control corn, or two commercial sources of non-genetically modified corn. Roundup Ready® corn can replace traditional corn in diets for growing-finishing pigs.

Introduction

Genetically modified crops offer producers a wide variety of agronomic benefits. The use of Roundup Ready® corn provides flexible and broad-spectrum, post-emergent weed control. Glyphosate, which is the active ingredient in the herbicide Roundup, is one of the most widely used herbicides in the world. Therefore, Roundup Ready® corn was developed to be tolerant to glyphosate. Previous experiments conducted with pigs and chickens have demonstrated that genetically modified corns are substantially equivalent to nontransgenic corn. Therefore, the objective of this study was to compare growth performance and carcass quality measurements in growing-finishing pigs fed diets containing either Roundup Ready® corn (CRR 0633), the parental control corn (RX 670), or two commercial sources of non-genetically modified corn (RX 760 and DK 647).

Procedures

Animals and Treatments

A total of 144 crossbred (PIC × Duroc× Hampshire) barrows and gilts with an initial BW of 50 lb were used. The pigs were allotted to a randomized complete block experiment with a 2×4 factorial arrangement of treatments. Blocks were based on initial weight and pen location within the building. There were two sexes (barrows and gilts) and four genetic corn lines (RX 740, DK 647, RX 670, and CRR 0633). Diets (Table 1) contained corn and soybean meal and were fortified with vitamins and minerals to meet or exceed the NRC (1998) requirements for 44- to 265-lb pigs. There were four diet phases during the experiment (Grower 1, Grower 2, Finisher 1, and Finisher 2).

(Continued on next page)

Table 1. Ingredient and calculated composition of diets, as-fed basis.

Ingredients, %	Dietary Phases			
	Grower 1	Grower 2	Finisher 1	Finisher 2
Corn[a]	68.07	74.21	78.11	81.79
Soybean meal (46.5% CP)	26.00	20.25	16.25	12.75
Tallow	3.00	3.00	3.00	3.00
Dicalcium phosphate	1.25	0.85	0.93	0.75
Limestone	0.40	0.40	0.40	0.40
Salt	0.30	0.30	0.30	0.30
Vitamin premix[b]	0.70	0.70	0.70	0.70
Trace mineral premix[c]	0.10	0.10	0.10	0.10
Antibiotic	0.13	0.13	0.13	0.13
Lysine•HCl	0.05	0.06	0.08	0.08
Calculated nutrient content				
Crude protein, %	18.10	15.80	14.30	12.10
Lysine, %	1.00	0.85	0.75	0.65
ME[d], Mcal/lb	1.56	1.57	1.57	1.57
Calcium, %	0.70	0.60	0.60	0.55
Phosphorus, %	0.60	0.50	0.50	0.45

[a]The only difference in the four diets within each dietary phase was the addition of the different genetic corn lines.
[b]Supplied per kilogram of diet: retinyl acetate, 3,088 IU; cholecalciferol, 386 IU; α-tocopherol acetate, 15 IU; menadione sodium bisulfite, 2.3 mg; riboflavin, 3.9 mg; d-pantothenic acid, 15.4 mg; niacin, 23.2 mg; choline, 77.2 mg; vitamin B_{12}, 15.4 µg.
[c]Supplied per kilogram of diet: Zn (as ZnO), 110 mg; Fe (as $FeSO_4$•H_2O), 110 mg; Mn (as MnO), 22 mg; Cu (as $CuSO_4$•5 H_2O), 11 mg; I (as $Ca(IO_3)$•H_2O), .22 mg; Se (as Na_2SeO_3), .3 mg.
[d]Metabolizable energy.

Each diet phase was 28 days, except Finisher 2, which was 19 days. This resulted in a total experimental period of 103 days.

The pigs were housed in a modified-open-front building with 24 pens (pen dimensions 4.95 ft × 15.84 ft), and each pen contained six barrows or gilts. Pigs had ad libitum access to feed and water throughout the experimental period. Pigs remained on the experiment until the average body weight of the pigs reached approximately 255 lb, at which time all pigs were removed from the experiment.

Data and Sample Collection

Pigs were weighed and feed intakes were measured biweekly to determine ADG, ADFI, and feed efficiency (ADG/ADFI). Real-time ultrasound measurements were taken at the end of the experiment by a certified technician, and tenth-rib backfat (BF) depth and longissimus muscle area (LMA) were recorded. At the termination of the experiment, pigs were shipped to SiouxPreme Packing Co. in Sioux Center, Iowa, where carcass characteristics were measured on individually identified pigs using total body electrical conductivity (TOBEC). At 24 hours postmortem, midline BF measurements (first rib, tenth rib, last rib, and last lumbar) and LMA traces at the tenth rib were collected on all the carcasses. Carcass quality tests were also performed at 24 hours postmortem. These tests were on the longissimus muscle at the tenth rib and included pH; firmness and marbling scores; and Minolta L*, a*, and b* values. A loin sample was collected from each carcass at the tenth rib and ten loin samples per treatment (five barrows and five gilts) were used to determine longissimus muscle chemical composition (protein, fat, and water).

Statistical Analysis

Data were analyzed as a randomized complete block design using PROC MIXED of SAS. The main effects in the statistical model were sex (barrows and gilts) and genetic corn line (RX 740, DK 647, RX 670, and CRR 0633). Also, the sex × corn line interaction was included in the statistical analysis. Contrasts were performed to compare the transgenic line with its parental control (CRR 0633 vs RX 670) and with the two commercial reference lines (CRR 0633 vs RX 740 and DK 647). In all analyses pen was the experimental unit.

Results

Growth Performance

Average daily gain, ADFI, and feed efficiency (ADG/ADFI) for the four diet phases and the entire experimental period are shown in Table 2. During the four diet phases, ADG, ADFI, and feed efficiency were not affected ($P \geq 0.30$) by corn variety. Average daily gain was greater (1.65, 2.27, 2.34, and 2.23 lb versus 1.57, 1.94, 2.12, and 2.07 lb; $P < 0.05$) in barrows than gilts during the four diet phases. Also, ADFI was greater (3.26, 5.42, 6.86, and 7.32 lb versus 3.09, 4.65, 5.84, and 6.42 lb; $P < 0.05$) in barrows than gilts during the four diet phases, respectively. During the Finisher 1 and 2 periods, gilts had better (0.36 and 0.32 versus 0.34 and 0.30; $P < 0.01$) feed efficiency than barrows, with no differences ($P \geq 0.53$) between barrows and gilts during the Grower 1 and 2 periods. Results of the overall experimental period indicate no differences ($P \geq 0.54$) among corn varieties for ADG, ADFI, and feed efficiency. However, overall ADG (2.12 versus 1.92 lb) and ADFI (5.58 versus 4.87 lb) were greater ($P > 0.001$) in barrows than gilts, and overall feed efficiency was better (0.39 versus 0.38; $P < 0.001$) in gilts than barrows.

Carcass Characteristics

Real-time ultrasound, carcass, and TOBEC measurements are summarized in Table 3. Ultrasound measurements of tenth-rib BF and LMA did not differ ($P \geq 0.38$) among corns, but tenth-rib BF was greater ($P < 0.001$) in barrows (0.91 in) than gilts (0.72 in). Carcass BF (first rib, tenth rib, last rib, and last lumbar) measurements were similar ($P \geq 0.43$)

Table 2. Growth performance of barrows and gilts.[a]

	Genetic Line					P-Value [b]				
Item	RX 740	DK 647	RX 670	CRR 0663	SEM	Trt	Sex	Trt × Sex	GMO vs P[c]	GMO vs Conv[d]
No. pens	6	6	6	6						
Initial wt., lb	49.79	49.79	49.74	49.70	0.075	NS	<0.001	NS	NS	NS
Final wt., lb	256.24	257.21	256.88	256.57	3.274	NS	<0.001	NS	NS	NS
Grower 1										
ADG, lb	1.58	1.65	1.58	1.60	0.029	NS	0.008	NS	NS	NS
ADFI, lb	3.14	3.24	3.14	3.20	0.051	NS	0.007	NS	NS	NS
ADG/ADFI	0.50	0.51	0.50	0.50	0.009	NS	NS	NS	NS	NS
Grower 2										
ADG, lb	2.11	2.11	2.11	2.08	0.031	NS	<0.001	NS	NS	NS
ADFI, lb	5.02	5.04	5.09	5.01	0.093	NS	<0.001	NS	NS	NS
ADG/ADFI	0.42	0.42	0.41	0.42	0.007	NS	NS	NS	NS	NS
Finisher 1										
ADG, lb	2.24	2.20	2.25	2.23	0.047	NS	0.001	NS	NS	NS
ADFI, lb	6.31	6.27	6.43	6.39	0.146	NS	<0.001	NS	NS	NS
ADG/ADFI	0.36	0.35	0.35	0.35	0.010	NS	<0.001	NS	NS	NS
Finisher 2										
ADG, lb	2.13	2.15	2.15	2.17	0.053	NS	0.012	NS	NS	NS
ADFI, lb	6.75	6.86	6.82	7.03	0.147	NS	<0.001	NS	NS	NS
ADG/ADFI	0.32	0.31	0.32	0.31	0.010	NS	0.001	NS	NS	NS
Overall										
ADG, lb	2.00	2.01	2.01	2.01	0.030	NS	<0.001	NS	NS	NS
ADFI, lb	5.18	5.22	5.24	5.27	0.094	NS	<0.001	NS	NS	NS
ADG/ADFI	0.39	0.39	0.38	0.38	0.006	NS	0.001	NS	NS	NS

[a]Two pigs removed from the data set.
[b]Trt = treatment; GMO = genetically modified organism; P = parental control line; Conv = conventional lines; and NS = nonsignificant effect, *P* > 0.10.
[c]Transgenic line (CRR 0633) comparison with parental control line (RX 670).
[d]Transgenic line (CRR 0633) comparison with conventional lines (RX 740 and DK 647).

among corns, but differences (1.80, 1.29, 1.44, and .99 in versus 1.81, 1.09, 1.30, and .83 in; $P < 0.05$) between barrows and gilts for all carcass BF measurements were detected with no differences ($P \geq 0.14$) in LMA. Total body electrical conductivity measurements for hot carcass weight (203 lb versus 188 lb; $P < 0.001$), shoulder weight (27.52 lb versus 26.81 lb; $P < 0.08$), and total lean (99.36 lb versus 96.98 lb; $P < 0.10$) were greater for barrows than gilts. However, gilts had a greater (39.97% versus 37.77%; $P < 0.0001$) percentage of primal weight in relation to hot carcass weight and a greater (51.50% versus 49.02%; $P < 0.01$) percentage of fat-free lean compared to barrows. The TOBEC measurements did not differ among corns ($P \geq 0.30$). Carcass fat-free lean gain calculated from TOBEC measurements was not affected by either sex or corn variety ($P \geq 0.14$).

Longissimus Muscle Quality Scores and Composition

Longissimus muscle quality scores for pH; marbling and firmness; and Minolta L*, a*, and b* values were not affected ($P \geq 0.32$) by sex or corn line, except for pH which was greater ($P < 0.05$) in barrows (5.65) than gilts (5.60) (Table 4). Protein and water percentage of the longissimus muscle were similar ($P > 0.21$) between barrows and gilts and among corns. The longissimus muscle fat percentage was influenced by sex ($P = 0.07$) and corn variety ($P = 0.07$). The genetically modified corn (CRR 0633) vs parental (RX 670) comparison resulted in a difference ($P < 0.04$) in longissimus muscle fat percentage with pigs fed the parental corn (2.20%) having less fat than pigs fed the genetically modified corn (2.99%).

Discussion

The results indicate no significant differences among the corns for ADG, ADFI, or feed efficiency. However, in the present study, traditional sex differences between gilts and barrows were observed in growth performance. Recent experiments using barrows and gilts during the finishing period have shown that barrows have greater ADG and ADFI than gilts. However, in these same experiments, gilts had superior feed efficiency compared to barrows. Results of the current experiment support the results of previous experiments and indicate the same differences in ADG, ADFI, and feed efficiency between barrows and gilts.

Dietary treatment did not affect ultrasound and carcass measurements, however a difference in backfat

(Continued on next page)

Table 3. Ultrasound and carcass measurements.[a]

Item	Genetic Line				SEM	P-Value[b]				
	RX 740	DK 647	RX 670	CRR 0663		Trt	Sex	Trt × Sex	GMO vs P[c]	GMO vs Conv[d]
Ultrasound measurements										
Backfat, in	0.82	0.81	0.82	0.83	0.031	NS	<0.001	NS	NS	NS
LMA[e], in^2	7.25	7.43	7.58	7.51	0.136	NS	NS	NS	NS	NS
Carcass measurements[f]										
First rib, in	1.88	1.89	1.87	1.87	0.060	NS	0.037	NS	NS	NS
Tenth rib, in	1.18	1.17	1.17	1.21	0.029	NS	<0.001	NS	NS	NS
Last rib, in	1.42	1.35	1.33	1.38	0.041	NS	0.006	NS	NS	NS
Last lumbar, in	0.91	0.89	0.91	0.93	0.030	NS	<0.001	NS	NS	NS
LMA, in^2	8.57	8.77	9.08	8.77	0.313	NS	NS	NS	NS	NS
TOBEC measurements										
Hot carcass wt., lb	194.86	196.28	195.64	195.72	1.400	NS	0.001	NS	NS	NS
Ham wt., lb[h]	22.48	22.61	22.33	22.40	0.266	NS	NS	NS	NS	NS
Loin wt., lb[h]	25.87	26.76	26.18	26.35	0.322	NS	NS	NS	NS	NS
Shoulder wt., lb[h]	26.93	27.39	27.21	27.10	0.365	NS	0.077	NS	NS	NS
Primal percentage[hi]	38.68	39.04	38.87	38.88	0.372	NS	<0.001	NS	NS	NS
Total lean, lb[g]	93.85	93.41	93.02	92.77	1.315	NS	0.092	NS	NS	NS
Percent lean[g]	48.22	47.51	47.67	47.59	0.570	NS	0.001	NS	NS	NS
Lean gain, lb/d[j]	0.76	0.75	0.75	0.75	0.013	NS	NS	NS	NS	NS

[a]Ultrasound data set contains 142 pigs and the carcass data set contains 141 pigs.
[b]Trt = treatment; GMO = genetically modified organism; P = parental control line; Conv = conventional lines; and NS = nonsignificant effect, P > 0.10.
[c]Transgenic line (CRR 0633) comparison with parental control line (RX 670).
[d]Transgenic line (CRR 0633) comparison with conventional lines (RX 740 and DK 647).
[e]Longissimus muscle area.
[f]Backfat measurements were taken at the midline.
[g]Figured on a fat-free lean basis.
[h]Contains 5% fat.
[i]Primal percentage was calculated by taking the total weight of the primals (ham, loin, and shoulder) divided by the hot carcass weight.
[j]Lean gain calculation: Final fat-free lean – Initial fat-free lean[k]

[k]Initial fat-free equation: $\dfrac{.95 * [-3.95 + (.418 * \text{live weight, lb})]}{103\ \text{d}}$

Table 4. Longissimus muscle quality scores and composition.[a]

Item	Genetic Line				SEM	P-Value[b]				
	RX 740	DK 647	RX 670	CRR 0663		Trt	Sex	Trt × Sex	GMO vs P[c]	GMO vs Conv[d]
Longissimus muscle quality scores										
Marbling	2.00	2.00	2.03	2.00	0.014	NS	NS	NS	NS	NS
Firmness	2.08	1.93	2.22	2.08	0.096	NS	NS	NS	NS	NS
pH	5.63	5.63	5.60	5.64	0.016	NS	0.015	NS	NS	NS
Minolta L*	49.75	50.78	50.59	50.69	0.623	NS	NS	NS	NS	NS
Minolta a*	7.20	6.71	7.17	7.40	0.262	NS	NS	NS	NS	NS
Minolta b*	2.11	2.39	2.51	2.58	0.294	NS	NS	NS	NS	NS
Longissimus muscle composition, %										
Protein	23.74	23.48	23.78	23.51	0.216	NS	NS	NS	NS	NS
Fat	3.08	3.06	2.20	2.99	0.247	0.070	0.071	NS	0.039	NS
Water	72.31	72.40	72.71	72.53	0.262	NS	NS	NS	NS	NS

[a]Data set includes 141 pigs, two pigs were not slaughtered and one loin was lost at the slaughter facility.
[b]Trt = treatment; GMO = genetically modified organism; P = parental control line; Conv. = conventional lines; and NS = nonsignificant effect, P > 0.10.
[c]Transgenic line (CRR 0633) comparison with parental control line (RX 670).
[d]Transgenic line (CRR 0633) comparison with conventional lines (RX 740 and DK 647).

depth between barrows and gilts was detected, with no difference in longissimus muscle area. The difference in backfat depth between barrows and gilts is supported by the results of previous experiments, however in these experiments gilts had greater longissimus muscle area than barrows, which is in contrast to the results of the present experiment. The similar longissimus muscle area estimate for barrows and gilts may be a result of feeding the barrows and gilts the same lysine concentration throughout the four-phase growing-finishing experiment. Previous research has shown that gilts require higher dietary concentrations of lysine compared to barrows to maximize growth performance and carcass leanness. The significant effect of sex on hot carcass weight is a result of terminating the experiment on a constant time basis resulting in a significant difference in final weight between barrows and gilts.

Total body electrical conductivity measurements of the ham, loin, and shoulder weights were similar among corns, but the weight of the shoulder was significantly different between barrows and gilts. This increase in shoulder weight of the barrows is a result of the greater slaughter weight of barrows (267 lb) versus gilts (247 lb). However, the TOBEC estimation of primal weights is similar to the wholesale primal weights reported in previous experiments. In the present experiment, the combined weight of the primals (ham, loin, and shoulder) as a percentage of the hot carcass weight was greater in gilts than barrows. Similarly, researchers have reported that when barrows and gilts are fed to a similar end weight, the primal percentage is greater in gilts than in barrows. Previous studies have shown that gilts produce carcasses with a greater percentage of lean compared to barrows at similar end weights. The percentage of fat-free lean was greater in gilts than barrows in the present experiment. This observation is supported by the decrease in backfat measurements and a greater primal percentage in gilts than barrows.

Longissimus muscle pH is strongly related to pork quality. The pH value is highly correlated to the quality traits of color and water holding capacity as well as various eating quality traits, such as tenderness. In the present study, corn variety did not affect pH, but there was a significant effect of sex on the pH value with longissimus muscles from barrows having a greater pH value than those from gilts. Most previous studies have indicated that 24-hours postmortem pH measurements are similar between barrows and gilts. Although, a significant effect of sex on pH was detected, the pH values were similar to previous experiments and the pH is within the normal range for measurements taken 24 hours postmortem. The subjective measurements of marbling and firmness of the longissimus muscle were similar among corns and between barrows and gilts. The marbling and firmness values in the present study were numerically similar to those of previous experiments where pigs were fed a corn-soybean meal diet.

The different corns and sexes resulted in minimal influence on longissimus muscle color scores (Minolta L*, a*, and b*). The Minolta L* values, which measure the lightness (0-100) of the sample, were within a normal range of 42 to 50 and were in agreement with other experiments. Although, Minolta a* and b* values, which measure the amount of red (+a*) or green (-a*) and the amount of yellow (+b*) or blue (-b*) in a meat sample, were not affected by corn or sex, the numerical values of the present study were lower than those of previously reported experiments.

The percentages of protein and water in longissimus muscle in the present experiment were not affected by corn variety or sex ($P > 0.05$). Also, the percentages of protein, fat, and water in longissimus muscle are similar to the percentages reported in other experiments. There was a trend toward differences in longissimus muscle fat percentage due to sex ($P = 0.07$) and corn variety ($P = 0.07$). Barrows (3.08%) had a greater fat percentage than gilts (2.59%). This observation is consistent with the greater backfat measurements and lesser fat-free lean percentage in barrows than gilts. Although the main effect of corn on longissimus muscle fat was not significant at the $P < 0.05$ level, individual contrasts indicated less fat ($P < 0.04$) in the parental control group (2.20%) than the Roundup Ready® group (2.99%). However, the Roundup Ready® group did not differ ($P < 0.80$) from the two commercial varieties (3.08% and 3.06%).

Compositional analyses have been conducted to measure proximate (protein, fat, ash, carbohydrate, and moisture), acid detergent fiber, neutral detergent fiber, amino acid, fatty acid, calcium, and phosphorus contents of Roundup Ready® corn line.

Results from the compositional analyses showed that the amounts of proximate components, fiber, phosphorus, amino acids, and fatty acids in the Roundup Ready® corn were comparable to those in the grain of the control line and were within published literature ranges. Because Roundup Ready® corn has been shown to be similar in composition to that of traditional corn, it is not surprising that in the present experiment no differences were detected among corns for growth performance; ultrasound and carcass measurements; and longissimus muscle quality measurements.

Conclusion

This experiment demonstrates that the feeding value of Roundup Ready® corn (CRR 0633) is equivalent to that of conventional corns (RX 740 and DK 647). Therefore, Roundup Ready® corn can be used in swine diets with no detrimental effects on growth performance or carcass characteristics.

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Niacin and Vitamin B_{12} Requirements of Weanling Pigs

Sara S. Blodgett
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Summary and Implications

An experiment was conducted to assess the responsiveness of weanling pigs to increased dietary concentrations of niacin and vitamin B_{12}. The purpose of the experiment was to determine if the niacin and vitamin B_{12} requirements of nursery pigs are greater than the NRC (1998) recommendations for 11 to 22 lb pigs. Pigs (initial weight 9.4 lb) were fed one of four diets for a total of 35 days: 1) Negative control, common nursery diet with no added niacin or vitamin B_{12}; 2) Niacin, common nursery diet with 22.7 mg/lb added niacin; 3) B_{12}, common nursery diet with 36.3 μg/lb added vitamin B_{12}; and 4) Positive control, common nursery diet with 22.7 mg/lb added niacin and 36.3 μg/lb added vitamin B_{12}. Pigs and feeders were weighed weekly to determine average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (ADG/ADFI). Pigs were visually scored to assess any potential niacin and vitamin B_{12} deficiencies on days 14, 21, 28, and 35. No niacin $\times$ vitamin B_{12} interactions were observed. During Phase I, pigs fed supplemental niacin had a greater ADFI ($P < 0.01$) than pigs fed supplemental vitamin B_{12}. During Phase II, pigs fed supplemental vitamin B_{12} had the greatest ADG ($P < 0.001$) and ADFI ($P < 0.01$). Overall, the pigs fed supplemental vitamin B_{12} had greater ADG ($P < 0.001$), ADFI ($P < 0.01$), and ADG/ADFI ($P < 0.05$) than pigs fed supplemental niacin. There were no differences among groups for visual assessment of B vitamin deficiencies. Based on these results, the niacin requirement of 10 to 40 lb pigs is not greater than 4.5 μg/lb of diet and the vitamin B_{12} requirement is greater than 3.1 μg/lb.

Introduction

The B-vitamins have received little attention since the 1950s and 1960s. In the past 40 to 50 years, leaner pigs have been developed, which may increase their B-vitamin requirements due to increased protein accretion. Vitamins are important to consider when formulating diets, especially the water-soluble vitamins because the body cannot synthesize these vitamins and there is little storage in the body.

Niacin and vitamin B_{12} are the only two B-vitamins that are significantly limiting (below the NRC requirement) in a common nursery diet. There are conflicting data regarding current niacin research. Research at Iowa State University reported that niacin supplementation up to 13.6 mg/lb did not alter average daily gain (ADG), average daily feed intake (ADFI), feed efficiency (ADG/ADFI), protein accretion, or fat accretion of high-lean segregated early weaned pigs. Kansas State reported that adding niacin to nursery diets improved ADG and ADFI day 0 to 8 after weaning with the greatest response observed at 25 mg/lb of diet.

Vitamin B_{12} functions include: purine and pyrimidine synthesis, transfer of methyl groups, formation of proteins from amino acids, and carbohydrate and fat metabolism. The most important function of B_{12} is in the metabolism of nucleic acids and proteins.

The major function of niacin is as a coenzyme, primarily as nicotinamide adenine dinucleotide (NAD) and nicotinamide adenine dinucleotide phosphate (NADP). Enzymes containing NAD and NADP are important links in a series of reactions associated with carbohydrate, protein, and lipid metabolism.

The objective of this study was to determine the responsiveness of weanling pigs to niacin and vitamin B_{12} supplementation. Our hypothesis was that pigs fed diets containing supplemental niacin or vitamin B_{12} would have greater ADG and improved feed efficiency than pigs fed a negative control diet.

Materials and Methods

Pigs were weighed and allotted, based on initial weight and litter of origin, to one of four treatments using a randomized complete block design. Treatments were arranged in a 2 $\times$ 2 factorial. Ninety-six pigs were allotted to 16 pens. There were four replications per treatment and six pigs per pen. Pigs were weaned at 14 to 16 days of age with an average initial weight of 9.4 lb. The duration of the trial was 35 days (Phase I was from day 0 to 14 and Phase II was from day 15 to 35). The average final weight was 38.2 lb.

Pigs and feeders were weighed every seven days to determine ADG, ADFI, and ADG/ADFI. Pigs were scored to determine whether there were any visual B-vitamin deficiencies. Two individuals examined the pigs on days 14, 21, 28, and 35 using a scale of 1 to 5 (1 having extensive deficiency signs and 5 having no deficiency signs). This assessment was based on physical appearances, such as skin and hair coat characteristics.

The four diets (Table 1) were: 1) Negative control, common nursery diet with no added niacin or vitamin B_{12};

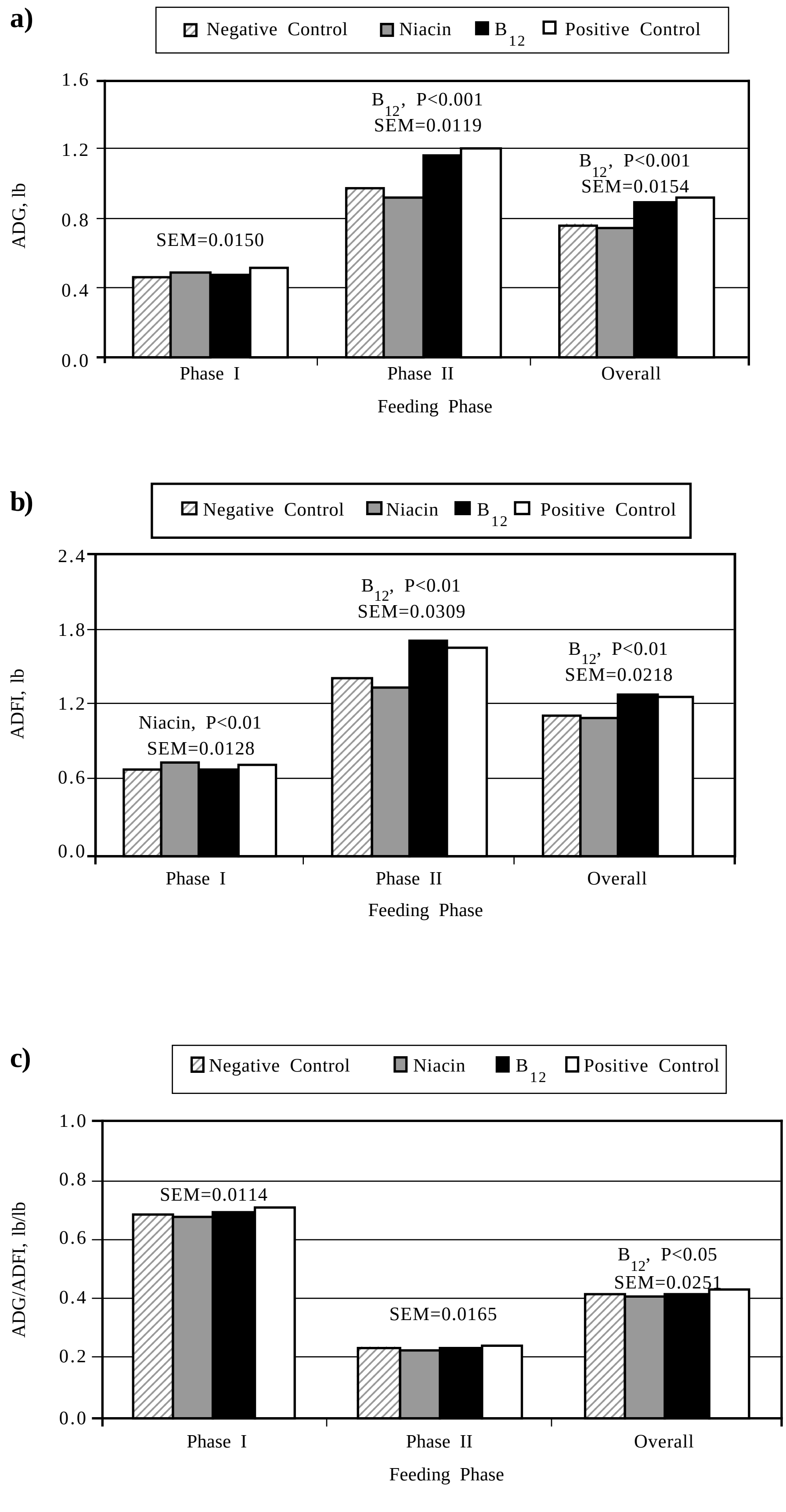

Figure 1. The response of a) average daily gain (ADG), b) average daily feed intake (ADFI), and c) ADG/ADFI in weanling pigs. SEM = standard error of the mean.

2) Niacin, common nursery diet with 22.7 mg/lb added niacin; 3) B_{12}, common nursery diet with 36.3 µg/lb added vitamin B_{12}; and 4) Positive control, common nursery diet with 22.7 mg/lb added niacin and 36.3 µg/lb added vitamin B_{12}. All phase-I diets were formulated to contain 22% CP, 1.5% total lysine, 0.31% total tryptophan, 0.9% Ca, and 0.78% P. Phase-II diets were similar to diets used in Phase I, except diets were formulated to contain 21% CP, 1.4% total lysine, 0.29% total tryptophan, 0.86% Ca, and 0.74% P.

Pigs were housed in pens 6.3 ft $\times$ 3.4 ft that had plastic-coated wire flooring, one nipple waterer, and one four-hole stainless steel feeder. Pigs had ad libitum access to feed and water throughout the experiment. Heat lamps and comfort boards were provided during Phase I of the trial. The relative humidity (ranging between 50% and 60%) and room temperature (maintained at 78°F) were monitored continuously using a temperature and humidity recorder.

Results and Discussion

Average daily gain, ADFI, ADG/ADFI are shown in Figures 1a, b, and c, respectively. No niacin $\times$ vitamin B_{12} interactions were observed. Average daily gain was greater ($P < 0.001$) during Phase II and overall ($P < 0.001$) for the pigs fed supplemental vitamin B_{12}. During Phase I, pigs receiving the niacin diet had a greater ($P < 0.01$) ADFI than pigs fed the vitamin B_{12} diet. However, pigs fed the vitamin B_{12} diet had a greater ADFI during Phase II ($P < 0.01$) and overall ($P < 0.01$). There were no differences in feed efficiency except during the overall experimental period, when the pigs fed vitamin B_{12} had a greater ADG/ADFI ($P < 0.05$).

Scores for each group are shown in Figure 2. Essentially no B-vitamin deficiencies were observed throughout the five-week study, and there were no differences among treatment groups.

The vitamin B_{12} content of the negative control and vitamin B_{12} supplemented diets were calculated to be 3.1 and 39.4 µg/lb, respectively, and the

(Continued on next page)

Table 1. Composition of experimental diets, as fed basis.

Ingredient, %	Phase I				Phase II			
	NC[a]	Niacin	Vitamin B_{12}	PC[a]	NC[a]	Niacin	Vitamin B_{12}	PC[a]
Corn	31.81	31.81	31.81	31.81	43.07	43.07	43.07	43.07
SBM, 46.5% CP	10.62	10.62	10.62	10.62	32.75	32.75	32.75	32.75
Soy protein concentrate	6.25	6.25	6.25	6.25	——-	——	——	——
Whey	30.00	30.00	30.00	30.00	15.00	15.00	15.00	15.00
Blood cells	——	——	——	——	2.00	2.00	2.00	2.00
Animal plasma	8.00	8.00	8.00	8.00	——	——	——	——
Lactose	4.00	4.00	4.00	4.00	——	——	——	——
Corn oil	5.00	5.00	5.00	5.00	3.00	3.00	3.00	3.00
Limestone	0.69	0.69	0.69	0.69	0.30	0.30	0.30	0.30
Dicalcium phosphate	1.28	1.28	1.28	1.28	1.60	1.60	1.60	1.60
Salt	0.30	0.30	0.30	0.30	0.53	0.53	0.53	0.53
Vitamin mix[b]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral[c]	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
L-Lysine•HCl	0.15	0.15	0.15	0.15	——	——	——	——
DL-Methionine	0.11	0.11	0.11	0.11	0.06	0.06	0.06	0.06
Mecadox	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ZnO	0.40	0.40	0.40	0.40	0.30	0.30	0.30	0.30
Vitamin B_{12}, µg/lb	——	——	36.30	36.30	——	——	36.30	36.30
Niacin, mg/lb	——	22.70	——	22.70	——	22.70	——	22.70

[a]NC = Negative control and PC = Positive control
[b]Supplied per kilogram of diet: retinyl acetate, 3,088 IU; cholecalciferol, 386 IU; alpha-tocopherol acetate, 15 IU; menadione sodium bisulfite, 2.3 mg; riboflavin, 3.9 mg; d-pantothenic acid, 15.4 mg; choline, 77.2 mg.
[c]Supplied per kilogram of diet: Zn (as ZnO), 110 mg; Fe (as FeSO4•H2O), 110 mg; Mn (as MnO), 22 mg; Cu (as CuSO4•5 H2O), 11 mg; I (as Ca(IO3)•H2O), 0.22 mg; Se (as Na2SeO3), 0.3 mg.

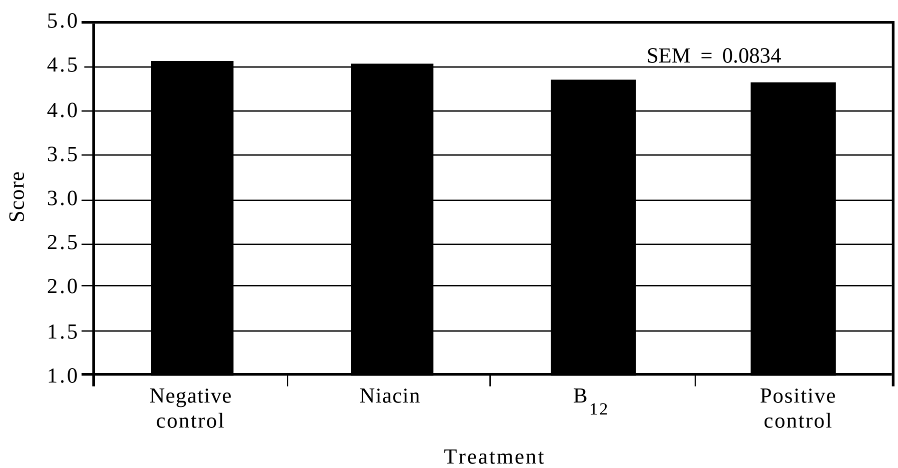

Figure 2. Visual assessment of deficiency signs. Data based on a scale of 1 to 5, with 1 having extensive deficiency signs and 5 having no deficiency signs. SEM = standard error of the mean.

NRC requirement is 7.9µg/lb. Thus, as expected, supplementation with vitamin B_{12} improved growth performance. Almost all of the growth response was observed in Phase II with no response in Phase I. Sows' milk has a high content of vitamin B_{12} and perhaps the pigs had sufficient stores of vitamin B_{12} at weaning to carry them through the first two weeks post weaning without additional supplementation.

The niacin content of the negative control and niacin-supplemented diets were calculated to be 4.5 and 27.2 mg/lb, respectively. This compares to the NRC requirement of 6.8 mg/lb for pigs with an initial weight similar to those used in this experiment. Therefore, we anticipated an improvement in growth performance when niacin was supplemented.

Several factors may have affected niacin intake and contributed to a lack (except for ADFI in Phase I) of response to added niacin. Coprophagy may have contributed to the available niacin intakes because the negative control pigs had access to feces of positive control or niacin-fed pigs in adjoining pens. The amount of available niacin in corn was assumed negligible; however, true niacin availability may be greater and the total niacin contributed by corn could be significantly greater than anticipated. Additionally, tryptophan can be converted to niacin (35 mg tryptophan to 1 mg niacin).

Conclusion

Based on these results, the niacin requirement of 10 to 40 lb pigs is not greater than 4.5 mg/lb of diet and the vitamin B_{12} requirement is greater than 3.1 mg/lb. Further research is needed to define more precisely and to describe the factors controlling the vitamin B_{12} requirement of young pigs.

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Phytase Sources in Pelleted Diets

Michael C. Brumm[1]

Summary and Implications

An experiment was conducted to determine whether there were differences in performance between two commercial sources of phytase when added to corn and soybean meal-based diets prior to pelleting. Pelleted diets investigated for growing-finishing barrows of high-lean-gain-potential included: 1) University of Nebraska recommended formulations; 2) diets formulated to contain 0.1% less available phosphorus than recommended; 3) diets formulated with 500 FYT/kg added phytase from Ronozyme-P®; 4) diets formulated with 750 FYT/kg added phytase from Ronozyme-P®; 5) diets formulated with 500 FTU/kg added phytase from Natuphos®; and 6) diets formulated with 750 FTU/kg added phytase from Natuphos®. Temperature of the pellets for all diets as they exited the die ranged from 150 to 160°F. Pigs fed diets formulated to contain 0.1% less available phosphorus than recommended had slower ($P < 0.05$) growth, slower daily lean gain, poorer feed conversion, and decreased bone ash and bone breaking strength than pigs fed the University recommended diets. Phytase recovery following pelleting ranged from 74% to 100%. There was no effect of phytase level or source on daily gain, daily feed, carcass lean, daily lean gain, bone ash or bone breaking strength. Pigs fed diets formulated with Ronozyme-P® had improved ($P < 0.05$) feed conversion compared with pigs fed Natuphos® as the phytase source. These results suggest that phytase is an effective replacement for dicalcium phosphate in swine diets, and that under the conditions of this experiment, phytase can be added to pelleted diets prior to the pelleting process.

Introduction

The recent proposal by the United States Environmental Protection Agency to regulate land application of animal manures based on phosphorus has

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Table 1. Experimental diet composition, 45 to 130 pound body weight

	45 to 80 lb						80 to 130 lb					
Item	UNL[a]	NEG[a]	R500[a]	R750[a]	N500[a]	N750[a]	UNL	NEG	R500	R750	N500	N750
Ingredient, lb/ton												
Corn	1149	1153	1152.6	1152.4	1152.9	1152.85	1261	1265	1264.6	1264.4	1264.9	1264.85
Soybean meal, 44% CP	550	550	550	550	550	550	445	445	445	445	445	445
Wheat midds	200	200	200	200	200	200	200	200	200	200	200	200
Choice white grease	50	50	50	50	50	50	50	50	50	50	50	50
Dicalcium phosphate, 18.5% P	19	8	8	8	8	8	12	1	1	1	1	1
Calcium carbonate	19	26	26	26	26	26	19	26	26	26	26	26
L-lysine	3	3	3	3	3	3	3	3	3	3	3	3
Salt	6	6	6	6	6	6	6	6	6	6	6	6
Vit/TM mix	4	4	4	4	4	4	4	4	4	4	4	4
Ronozyme-P®[b]			0.4	0.6					0.4	0.6		
Natuphos®[c]					0.1	0.15					0.1	0.15
Calculated composition												
ME, kcal/lb	1521	1524	1524	1524	1524	1524	1531	1535	1535	1535	1535	1535
Lysine, %	1.13	1.14	1.14	1.14	1.14	1.14	0.99	0.99	0.99	0.99	0.99	0.99
Calcium, %	0.69	0.71	0.71	0.71	0.71	0.71	0.61	0.63	0.63	0.63	0.63	0.63
Phosphorus, %	0.59	0.49	0.49	0.49	0.49	0.49	0.50	0.40	0.40	0.40	0.40	0.40
Available phosphorous, %	0.29	0.19	0.19	0.19	0.19	0.19	0.22	0.12	0.12	0.12	0.12	0.12
Analyzed composition												
Lysine, %[d]	1.24	1.22	1.20	1.20	1.22	1.19	1.09	1.05	1.05	1.06	1.03	0.97
Calcium, %[d]	1.35	0.91	0.71	0.76	0.64	0.62	0.74	0.59	0.78	0.67	0.86	0.81
Phosphorus, %[d]	0.58	0.56	0.53	0.53	0.48	0.46	0.55	0.48	0.46	0.50	0.42	0.41
Total phytase activity, units/kg[e]												
Prepelleting	289	311	920	1160	993	1315	232	273	851	1112	936	1282
Postpelleting	172	209	683	838	787	1012	140	215	671	1113	772	1008

[a]UNL = University of Nebraska recommended; NEG = UNL formulated to 0.1% lower available P; R500 = 500 FYT/kg phytase from Ronozyme-P®; R750 = 750 FYT/kg phytase from Ronozyme-P®; N500 = 500 FTU/kg phytase from Natuphos®; N750 = 750 FTU/kg phytase from Natuphos®.
[b]Ronozyme-P® CT, Roche Vitamins, Inc., Parsippany, NJ 07054.
[c]Natuphos® 10000 G, BASF, Inc., Mt. Olive, NJ 07828.
[d]Ward Laboratories, Kearney, NE 68848.
[e]Roche Vitamins, Inc. Parsippany, NJ 07054.

Table 2. Experimental diet composition, 130 pound bodyweight to slaughter.

	130 to 190 lb						190 lb to slaughter					
Item	UNL[a]	NEG[a]	R500[a]	R750[a]	N500[a]	N750[a]	UNL	NEG	R500	R750	N500	N750
Ingredient, lb/ton												
Corn	1418	1425	1424.6	1424.4	1424.9	1424.85	1540	1544	1543.6	1543.4	1543.9	1543.85
Soybean meal, 44% CP	290	287	287	287	287	287	171	170	170	170	170	170
Wheat midds	200	200	200	200	200	200	200	200	200	200	200	200
Choice white grease	50	50	50	50	50	50	50	50	50	50	50	50
Dicalcium phosphate, 18.5% P	10	0	0	0	0	0	8	0	0	0	0	0
Calcium carbonate	19	25	25	25	25	25	18	23	23	23	23	23
L-lysine	3	3	3	3	3	3	3	3	3	3	3	3
Salt	6	6	6	6	6	6	6	6	6	6	6	6
Vit/TM mix	4	4	4	4	4	4	4	4	4	4	4	4
Ronozyme-P®[b]			0.4	0.6					0.4	0.6		
Natuphos®[c]					0.1	0.15					0.1	0.15
Calculated composition												
ME, kcal/lb	1541	1544	1544	1544	1544	1544	1549	1551	1551	1551	1551	1551
Lysine, %	0.78	0.78	0.78	0.78	0.78	0.78	0.62	0.62	0.62	0.62	0.62	0.62
Calcium, %	0.56	0.57	0.57	0.57	0.57	0.57	0.50	0.52	0.52	0.52	0.52	0.52
Phosphorus, %	0.45	0.36	0.36	0.36	0.36	0.36	0.41	0.34	0.34	0.34	0.34	0.34
Total available phosphorous, %	0.19	0.10	0.10	0.10	0.10	0.10	0.16	0.09	0.09	0.09	0.09	0.09
Analyzed composition												
Lysine, %[d]	0.82	0.82	0.81	0.76	0.80	0.80	0.64	0.61	0.65	0.67	0.69	0.69
Calcium, %[d]	0.64	0.63	0.64	0.71	0.70	0.70	0.74	0.60	0.69	0.65	0.59	0.56
Phosphorus, %[d]	0.46	0.36	0.36	0.37	0.37	0.35	0.43	0.31	0.34	0.34	0.34	0.32
Phytase activity, FTU/kg[e]												
Prepelleting	227	303	817	1084	840	1185	255	280	802	1073	764	1152
Postpelleting	155	184	640	912	719	918	222	216	758	840	754	938

[a]UNL = University of Nebraska recommended; NEG = UNL formulated to 0.1% lower available P; R500 = 500 FYT/kg phytase from Ronozyme-P®; R750 = 750 FYT/kg phytase from Ronozyme-P®; N500 = 500 FTU/kg phytase from Natuphos®; N750 = 750 FTU/kg phytase from Natuphos®.
[b]Ronozyme-P® CT, Roche Vitamins, Inc., Parsippany, NJ 07054.
[c]Natuphos® 10000 G, BASF, Inc., Mt. Olive, NJ 07828.
[d]Ward Laboratories, Kearney, NE 68848.
[e]Roche Vitamins, Inc. Parsippany, NJ 07054.

intensified the interest of pork producers in the use of phytase in swine diets. Phytase has reduced phosphorus excretion by growing-finishing pigs 25-35% when used in corn-soybean meal based swine diets as a replacement for inorganic phosphorus. A limit to the use of phytase has been the inability to include phytase in pelleted diets prior to the pelleting process due to losses in enzyme activity associated with the heat of pelleting. The only method available to add phytase to pelleted diets was to spray phytase on the cooled pellet, involving expensive equipment and time.

Recently, additional sources of phytase have become available. This has renewed interest in the possibility of adding phytase to pelleted diets prior to the pelleting process. The purpose of the following experiment was to compare the effect of two commercial sources of phytase in pelleted diets on pig performance.

Methods

The experiment was conducted at the University of Nebraska's Haskell Ag Lab at Concord. At arrival, 288 crossbred barrows (Thunderbird Genetics, Wecota, SD) were weighed, ear tagged, and assigned to the following treatments:

1) University of Nebraska recommended diets (**UNL**);
2) UNL formulated to contain 0.1% less available phosphorus (**NEG**);
3) NEG formulated with 500 FYT/kg Ronozyme-P® (**R500**);
4) NEG formulated with 750 FYT/kg Ronozyme-P® (**R750**);
5) NEG formulated with 500 FTU/kg Natuphos® (**N500**); and
6) NEG formulated with 750 FTU/kg Natuphos® (**N750**).

Diets (Tables 1 and 2) were pelleted by a commercial feed mill. The phytase product from both manufacturers was preblended with ground corn before mixing to assure a uniform mix. Temperature of the pellets as they exited the pellet die ranged from 150 to 160° F. Conditioning temperatures prior to pelleting were 140 to 150° F. The pellet size was 0.172 inch.

The lysine sequence was 1.13% from 45 to 80 lb body weight, 0.99% from 80 to 130 lb, 0.78% from 130 to 190 lb, and 0.62% from 190 lb to slaughter. Diets were switched on the week the average weight of individual pens was

Table 3. Main effects of experimental treatments on pig performance and carcass characteristics.

	Treatments[a]							*P* Values				
	UNL	NEG	R500	R750	N500	N750	SEM	UNL vs NEG	UNL vs 500	UNL vs 750	500 vs 750	Ronozyme-P® vs Natuphos®
No. pens	4	4	4	4	4	4						
Pig wt., lb												
Initial	45.3	44.9	45.2	45.1	45.0	45.3	0.3	0.311	0.576	0.683	0.851	0.914
Final	244.9	241.3	247.0	250.4	244.4	247.4	2.0	0.235	0.734	0.124	0.134	0.190
Daily gain, lb/d	1.95	1.78	1.93	1.96	1.91	1.95	0.03	0.005	0.469	0.930	0.326	0.617
Daily feed, lb/d	5.42	5.13	5.38	5.44	5.43	5.52	0.09	0.039	0.872	0.584	0.391	0.453
Feed/gain	2.78	2.89	2.78	2.78	2.85	2.83	0.04	0.013	0.275	0.436	0.684	0.037
Dressing %	74.5	74.8	74.8	74.8	74.3	74.5	0.5	0.742	0.993	0.892	0.860	0.443
Carcass % lean[b]	47.3	46.8	47.1	47.2	47.4	47.1	0.5	0.449	0.907	0.776	0.836	0.894
Daily lean gain, lb/d[b]	0.696	0.614	0.688	0.703	0.687	0.683	0.017	0.014	0.720	0.888	0.789	0.569
Bone ash, %[c]	61.54	59.47	61.13	60.45	61.35	60.40	0.31	0.005	0.411	0.039	0.094	0.744
Bone strength, kg/cm^2[c]	243.7	186.2	218.4	253.7	240.9	225.8	8.1	<0.001	0.117	0.523	0.227	0.380

[a]UNL = University of Nebraska recommended; NEG = UNL formulated to 0.1% lower available P; R500 = 500 FYT/kg phytase from Ronozyme-P®; R750 = 750 FYT/kg phytase from Ronozyme-P®; N500 = 500 FTU/kg phytase from Natuphos®; N750 = 750 FTU/kg phytase from Natuphos®.
[b]Containing 5% fat.
[c]Metacarpal from front left foot of two pigs per pen.

at or above the target weight. The 1.13% lysine diets contained 100 g/ton Tylan. The remaining diets contained 40 g/ton Tylan. All diets within a given lysine sequence were mixed on the same day.

Pigs were housed in two mechanically ventilated, partially slatted facilities. There were two replications of each treatment in each facility. Within each facility, the pens measured 6 ft x 15 ft and had 12 pigs/pen (7.5 ft^2/pig). There was one three-hole stainless feeder and one nipple drinker in each pen. Pen size was not adjusted in the event of pig death or removal.

At arrival, pigs were vaccinated for erysipelas, *M. hyopneumonia,* and *S suis*. All pigs that died during the experiment were examined for cause of death by a consulting veterinarian.

Pigs were weighed individually every 14 days. Individual pigs were removed for slaughter on the week they weighed 240 pounds or greater. Carcass lean was determined by TOBEC on individually identified pigs by employees of SiouxPreme Packing Co., Sioux Center, Iowa.

At the time of first shipment to slaughter, the left front foot from the two heaviest pigs in each pen was collected at the slaughter plant and frozen. The frozen feet were sent to Dr. Merlin Lindeman at the University of Kentucky for determination of metacarpal bone breaking strength and bone ash.

The pen of pigs was the experimental unit. The following contrasts were used to separate treatment means:

- UNL vs NEG - This examined whether a phosphorus deficiency was created.
- UNL vs 500 - This examined if there was a response to 500 units of phytase/kg regardless of phytase source.
- UNL vs 750 -This examined if there was a response to 750 units of phytase/kg regardless of phytase source.
- 500 vs 750 - This examined whether the response to phytase varied with the level added to the diet.
- R vs N - This examined whether there was a difference due to phytase source.

Results and Discussion

A phytase unit is defined as the amount of phytase which liberates one micromole of inorganic phosphorus per minute from an excess of sodium phytate at 37^o C and pH 5.5. Natuphos® phytase units are presented as FTU and Ronozyme-P® as FYT. Both abbreviations are derived from fytase, the Dutch name for phytase. Different abbreviations are used to define each source since the two phytase sources originate from different microorganisms. However, all laboratory assays are reported as FTU to simplify reporting.

The laboratory analysis of the diet samples is given in Tables 1 and 2. The 155-300 units/kg phytase activity reported for the UNL and NEG diets is the result of the phytase activity contributed by the wheat midds. The experimental treatments of 500 and 750 phytase units/kg were additions to the basal diet and the phytase activity for the phytase containing diets is within normal ranges when the activity contributed by wheat midds is accounted for.

Phytase stability was defined as the percentage of phytase in the pellet versus the phytase in the meal prior to pelleting. The relatively cool pelleting temperature of 150-160^o F versus a more customary 180^{o}F exit temperature, resulted in very good phytase stability for both commercial sources of phytase. Averaged across all levels of lysine, stability ranged from 79% for the N750 diets to 87% for the N500 diets. Stability for the phytase associated with wheat midds averaged 69% for the UNL diet

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and 71% for the NEG diet.

The main effects of the experimental diets on pig performance are in Table 3. Decreasing the available phosphorus from the recommended levels (NEG vs UNL) resulted in a reduction ($P < 0.05$) in daily gain, daily feed intake, and daily lean gain. It also resulted in a poorer feed conversion efficiency.

The addition of phytase at 500 and 750 units/kg to the NEG diet resulted in performance that was similar to pigs fed the UNL diets. There were no differences in performance or carcass characteristics between sources of phytase in this study except for feed conversion efficiency. Pigs fed Ronozyme-P® as the phytase source had a better feed conversion efficiency than pigs fed Natuphos® (2.78 vs 2.84; $P = 0.037$).

Bone strength and bone ash were lower ($P < 0.01$) for pigs fed a diet 0.1% lower in available P than the University of Nebraska recommendation (NEG vs UNL). While bone ash decreased slightly for the 750 versus 500 phytase units/kg treatment for both sources of phytase, there was no effect of phytase level on bone breaking strength, a more sensitive indicator of dietary adequacy.

Conclusion

These results are in agreement with the large body of data supporting the effectiveness of phytase in swine diets as a replacement for inorganic phosphorus sources such as dicalcium phosphate. They also suggest that at relatively cool pelleting temperatures, phytase losses are not as great as previously thought, meaning phytase use to reduce phosphorus in swine manure may be another economic option for producers who use pelleted feeds. Finally, both sources of phytase were effective in improving performance compared to the negative treatment. However, Ronozyme-P® fed pigs had better feed conversion, regardless of level of addition. In this study, there was no benefit from adding 750 FTU/kg versus the lower level of 500 FTU/kg.

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Managing Swine Dietary Phosphorus to Meet Manure Management Goals

Michael C. Brumm
Charles A. Shapiro
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Summary and Implications

A demonstration was carried out for 15 months at a 1,200-head growing-finishing facility in Holt County, Neb. The purpose was to document the impact of diet formulation on phosphorus excretion and the associated land area needed to utilize the phosphorus in the accumulated manure. The demonstration facility had four 300-head rooms. Prior to the demonstration, pigs in all rooms were fed diets formulated to contain 0.55-0.57% total phosphorus for all phases of growth. For the demonstration, two rooms were fed diets formulated to the University of Nebraska recommended levels for available phosphorus. The other two rooms were fed diets formulated to have the same amounts of all nutrients except phosphorus as the University of Nebraska diets using reduced amounts of dicalcium phosphate and phytase. Analysis of feces samples taken twice per month for the first 11 months, and monthly thereafter, indicated a 34% reduction in phosphate in the excreted feces of growing-finishing pigs fed diets containing phytase. Based on the phosphorus needs for 180 bu/acre corn, the switch from the previous diets containing 0.55 to 0.57% total phosphorus to diets formulated with decreasing amounts of phosphorus according to the University of Nebraska recommendations resulted in 49 fewer acres needed per year for land application of the manure. Formulating the diets according to the University of Nebraska recommendations and utilizing phytase and reduced amounts of dicalcium phosphate resulted in an additional reduction of 65 acres per year. In this demonstration, phytase was effective in reducing phosphorus excretion by growing-finishing pigs, even in diets formulated according to the University of Nebraska recommendations. Phytase use, combined with the reduction in estimated phosphorus excretion when switching from the previous nutrition program of 0.55 to 0.57% total phosphorus to decreasing amounts of phosphorus according to the University of Nebraska recommendations, resulted in an estimated 114 fewer acres needed per year for application of the accumulated manure at agronomic rates.

Introduction

Nitrate contamination of groundwater was first detected in Holt County, Neb. in the mid-1960s. From 1976 to 1990, nitrate-N concentrations increased in 90 percent of the wells sampled by the Natural Resource Districts (NRD) in the county. As a consequence of the concerns associated with this increase, the Holt County Groundwater Education Project was initiated in 1995.

The Holt County Manure Management Education Project, a spin-off from the Groundwater Education Project, is a three-year effort funded by an EPA-319 grant with cooperation among

UNL Cooperative Extension, UNL Conservation and Survey Division, USDA-NRCS, the Lower Niobrara NRD, and the Upper Elkhorn NRD. The goal of the project is to educate producers on cropping and manure best management practices to protect water resources from contamination. The project centers around demonstrating best management practices that are cost effective and that can be used in existing production facilities.

Best management practices include whole-farm nutrient planning when animal manures are spread on irrigated crop land. Whereas nitrogen management was the primary goal of the funded demonstration effort, large amounts of phosphorus are also present in beef and swine manures. A typical analysis of swine slurry has a phosphorus content, expressed as P_2O_5, that is as high or higher than the available nitrogen content, expressed as ammonium-N (Table 1).

Table 2 lists the average nutrient removal by crops. Applying high rates of swine slurry to meet the nitrogen needs of crops such as corn results in the over-application of phosphorus and potassium relative to the crop needs. With the US Environmental Protection Agency proposing to regulate Animal Feeding Operations based in part on the phosphorus content of the collected and land applied manures, a demonstration site was identified to examine the role of dietary manipulation of phosphorus on the phosphorus content of swine manure.

Table 1. Typical nutrient content of liquid swine manure.[a]

	% Dry matter	NH_4-N	Organic-N	P_2O_5	K_2O
		- - - - - - lb/1000 gal - - - - - -			
Deep pit	5	17	10	19	15
		- - - - - - lb/acre-inch - - - - - -			
Anaerobic lagoon	0.25	50	29	17	86

[a]USDA-SCS Agricultural Waste Management Field Book (1992). Due to extreme variability, manure analysis is recommended for each situation.

Table 2. Average nutrient removal by crops.[a]

Crop	N content	P_2O_5 content	K_2O content
	- - - - - - - - lb/bu grain - - - - - - - -		
Corn grain	0.90	0.39	0.22
Soybean	3.76	0.82	1.20
Grain sorghum	0.90	0.38	0.21
Oats	0.38	0.24	0.15
Wheat	1.36	0.50	0.27
	- - - - - - - - lb/ton forage - - - - - - - -		
Alfalfa hay	57.2	11.8	55.1
Corn silage	8.6	3.2	7.7

[a]University of Nebraska NebGuide 97-1334.

Table 3. University of Nebraska dietary recommendations for total and available phosphorus in corn-soybean meal diets.[a]

Pig body wt., lb:	45-80	80-130	130-190	190-market
Total P, %[b]	0.58	0.51	0.47	0.43
Available P,%	0.29	0.22	0.19	0.16

[a]*Nebraska and South Dakota Swine Nutrition Guide* EC95-273.
[b]Assumes corn and soybean meal based diet formulations.

Methods

The demonstration site was a 1,200-head, 4-room, fully slatted finishing facility with pull-plug gutters to an outside concrete manure storage tank. Pigs typically enter the facility at 45-55 lb and are sold for slaughter weighing 255-265 lb. The finishing facility is located on a corner of an irrigated quarter section (160 acres) in Holt County. The manure management goal of the producer is to use the center pivot irrigated portion of the quarter section (132 acres) for manure utilization by a cropping system of continuous corn.

Prior to the demonstration, the producer was feeding diets formulated using corn, soybean meal and a base mix containing 7.8% phosphorus. When the base mix was added to the corn-soybean meal diets at the recommended rate of 55 lbs/ton, the complete diets for pigs from 45 pounds to market weight contained 0.55% to 0.57% total phosphorus and 0.27% to 0.28% available phosphorus.

This type of dietary formulation is quite common in the pork industry. Based on an estimated 1.5 gal of manure per pig space per day and the values in Tables 1 and 2, the producer needed an estimated 300 acres each year to utilize the phosphorus in the manure when harvesting 180 bu/acre in a continuous irrigated corn cropping system.

In contrast to the phosphorus content of the diets formulated with the base mix, the current University of Nebraska recommendations for total and available phosphorus in corn-soybean meal diets are given in Table 3. Including 55 lb of the base mix in the diet met the phosphorus needs of 45-lb pigs, but provided excess phosphorus for all other stages of growth.

Because the goal of the demonstration was to reduce the amount of

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Table 4. Holt County demonstration diets.

Ingredient, lb	Pig body wt., lb:	45-80		80-130		130-190		190-market	
	Phytase:	No	Yes	No	Yes	No	Yes	No	Yes
Corn		1338	1347	1415	1424	1528	1537	1680	1689
Soybean meal (46.5% CP)		590	590	520	520	410	410	260	260
Fat		20	20	20	20	20	20	20	20
Dicalcium phosphate		22	9	16	3	14	1	13	0
Limestone		18	20	17	19	16	18	15	17
Salt		6	6	6	6	6	6	6	6
Vitamin/trace mineral mix		5	5	5	5	5	5	5	5
L-lysine		1	1	1	1	1	1	1	1
Phytase[a]		0	2	0	2	0	2	0	2
		2000	2000	2000	2000	2000	2000	2000	2000
Calculated composition									
Lysine, %		1.07	1.07	0.98	0.98	0.83	0.83	0.64	0.64
Ca, %		0.72	0.60	0.62	0.50	0.56	0.44	0.51	0.39
Total P, %		0.59	0.48	0.53	0.41	0.48	0.37	0.45	0.33
Avail P, %		0.29	0.17	0.23	0.11	0.20	0.08	0.18	0.06

[a]Natuphos, BASF Corp, Mt Olive, NJ 07828. According to the manufactures recommendations, when added at 500 FTU/kg, the product provided .12% available P and Ca in cereal grain based diets.

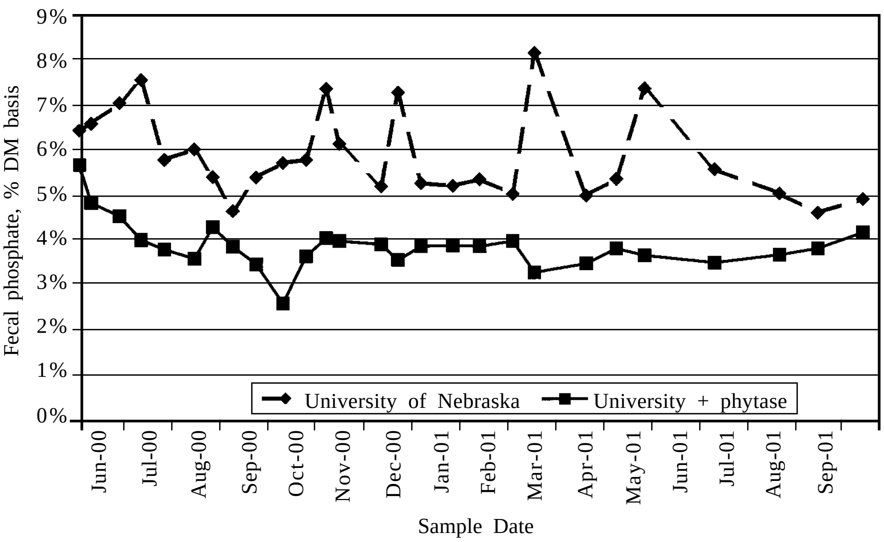

Figure 1. Impact of phytase on fecal phosphate, Holt County Demonstration Project.

total phosphorus in the manure, pigs in two of the four rooms were fed diets formulated with limestone, dicalcium phosphate, salt and a vitamin-trace mineral premix according to the University of Nebraska recommendations (Table 4). Pigs in the other two rooms were fed diets formulated to the available phosphorus requirement utilizing phytase. In this demonstration, phytase was added at 500 FTU/kg of diet and replaced up to 13 lb of dicalcium phosphate per ton of diet.

Phytase increases the availability of phytate-phosphorus in corn and soybean meal so lesser amounts of inorganic phosphorus are needed in diets. This results in a decrease in the amount of phosphorus excreted in the manure.

Results and discussion

Manure was sampled by taking grab samples of feces on top of the slats twice per month in each of the four rooms from mid-June 2000 through mid-May 2001, and monthly thereafter. Samples were sent to a commercial laboratory for analysis. Results of the manure sampling are shown in Figure 1. The inclusion of phytase in the diets reduced fecal phosphorus excretion an average of 34% for the demonstration period compared to diets formulated to the University of Nebraska recommendations without phytase.

To calculate the impact of the dietary changes implemented at the demonstration site, a two-step analysis was conducted. For the analysis, it was assumed there was no difference in performance between the producer's previous base mix formulated diets, the University of Nebraska recommended diets and the recommended diets formulated with phytase. Assuming a 2.98 feed:gain ratio, 2.7 turns or groups of pigs per year, and 1,200 pigs per turn, changing from diets formulated with the 55 lb base mix to diets formulated according to the University of Nebraska recommendations resulted in a total estimated reduction in phosphorus entering the facility in the feed of 1,484 pounds per year. Adding phytase to the University of Nebraska recommended diets resulted in a further estimated reduction in phosphorus in the feed of 1,976 lb per year.

If it is assumed that all diets met the growing pigs requirements for digestible phosphorus, the reductions in phosphorus in the feed translate directly into reductions in the amount of phosphorus excreted in the manure. Thus, changing from formulating diets with a 55 lb inclusion of a base mix containing 7.8% phosphorus to formulating diets according to the University of Nebraska recommendations and using phytase to enhance phosphorus availability resulted in 3,460 fewer pounds of phosphorus in the manure yearly. Using a conversion factor of 2.3 to convert elemental phosphorus to P_2O_5, the change in diet formulations results in a total reduction of 7,958 lb of phosphate per year.

If the long term phosphate need for irrigated corn at this site is 70 lb/acre (180 bu/acre x 0.39 lb P_2O_5/bu), the change from the 55 lb inclusion product to the University of Nebraska recommended diets represented 49 fewer acres needed per year for utilization of the phosphorus in the manure. Adding phytase to the University of Nebraska recommended diets represented an additional 65 fewer acres. In summary, converting from a nutrition program using a 55 lb inclusion rate base mix containing 7.8% phosphorus to a program using the University of Nebraska recommendations and phytase resulted in 114 fewer acres needed per year for proper utilization of the phosphorus in the manure at this site.

Conclusion

While the producer was unable to achieve the goal of applying all the manure from the demonstration facility on land under one center pivot system (132 acres), altering the phosphorus sources in growing-finishing diets from a 55 lb inclusion rate of a base mix containing 7.8% phosphorus to diets formulated for decreasing amounts of phosphorus using dicalcium phosphate and phytase resulted in a major reduction in the amount of crop land needed to properly utilize the phosphorus in the manure. Based on the estimated original cropping acres needed for continuous irrigated corn and the reductions in phosphorus associated with the dietary changes demonstrated, the new land base needed is estimated to be 186 acres if the phytase containing diets are fed to all pigs in the facility, down considerably from the original 300 acre estimate. The 34% reduction in phosphorus content in the feces for the phytase fed pigs versus pigs fed University of Nebraska recommended diets formulated with dicalcium phosphate is similar to reductions reported in the scientific literature.

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Update on the Economics of Feeding Ractopamine (Paylean™) to Finishing Pigs

Duane E. Reese
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Summary and Implications

Ractopamine is a feed additive that improves feed efficiency, daily gain, and carcass merit in finishing pigs. An economic feasibility analysis on the feeding of 4.5 and 9.0 g/ton ractopamine to finishing pigs fed a 1% lysine, corn-soybean meal diet for an average of 29 days before slaughter was conducted. The analysis was performed in two stages: 1) an economic benefit for ractopamine was calculated from revenues due to improved feed efficiency, daily gain and carcass yield (dressing percent), and 2) the amount of a carcass lean premium needed per pig to recover the added cost of feeding ractopamine was calculated for each dietary level of ractopamine. One pound of Paylean™, containing 9 grams of ractopamine per pound, cost $28 and live slaughter pig prices were $34, $42, and $50/cwt. In 10/12 of our evaluations, the cost of feeding ractopamine cannot be justified economically through improved feed efficiency, daily gain, and carcass yield alone (corn =$2.00/bu; soybean meal = $200/ton). A producer would need to earn carcass lean premiums ranging from $0.23 to $1.78/pig in order to recover the cost of feeding ractopamine. However, we projected a potential profit of $0.55 and $1.50/pig from feeding 9 g/ton ractopamine when live slaughter price was $42 and $50/cwt, respectively, and when ractopamine-fed pigs were allowed to reach a heavier body weight at slaughter. We conclude that a consistent carcass lean premium is necessary sometimes to justify feeding ractopamine economically and that it can improve profitability of pork production.

Introduction

Ractopamine (Paylean™; Elanco Animal Health) was approved by the Food & Drug Administration (FDA) in 1999 for increased rate of gain, improved feed efficiency, and increased carcass leanness in finishing pigs fed a complete diet containing at least 16% crude protein (0.82% lysine) from 150 to 240 lb. The additive can be included in a finisher diet at 4.5 to 18.0 g/ton.

In the 2001 Nebraska Swine report we estimated the value of feeding ractopamine to finishing pigs. We concluded that a consistent carcass premium was necessary to justify feeding ractopamine economically. That conclusion was reached based on pig performance data generated during the late 1980's and early 1990's. Improvements have been made in the genetic merit of pigs since then that could affect the response to ractopamine. In

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Table 1. Effect of ractopamine (4.5 g/ton) on finisher pig performance.[a,b]

	Ractopamine, g/ton	
Item	0	4.5
No. pens	33	61
No. pigs	300	331
Daily gain, lb	2.17	2.35
Daily feed, lb	6.36	6.19
Feed/gain	2.97	2.65
Hot carcass weight, lb	200	202
Yield, %	74.7	74.5
Lean, %	56.4	56.8

[a]Means from Cook et al., 2001; Herr et al., 2001; and Main et al. 2001 weighted according to the number of pens/treatment.
[b]1.04% lysine diet; 29.2-day feeding period.

Table 2. Effect of ractopamine (9.0 g/ton) on finisher pig performance.[a,b]

	Ractopamine, g/ton	
Item	0	9.0
No. pens	39	97
No. pigs	357	668
Daily gain, lb	2.24	2.49
Daily feed, lb	6.59	6.34
Feed/gain	2.96	2.55
Hot carcass wt., lb	200	207
Yield, %	74.3	75.4
Lean, %	54.9	55.8

[a]Means from Cook et al., 2001; Herr et al., 2001; Main et al., 2001; and Boyd et al., 2001 weighted according to the number of pens/treatment.
[b]1.02% lysine diet; 28.8-day feeding period.

addition, researchers have recently investigated the response of ractopamine in diets containing more than 16% crude protein and when it is fed for less time before slaughter than in previous trials. Therefore, we believe a re-evaluation of the economic feasibility of feeding ractopamine to finishing pigs is warranted.

Performance Results

Pig performance results were obtained from 4 abstracts given at the American Society of Animal Science meetings in 2001. Data from the 4 abstracts were combined to produce one data set for pigs fed 4.5 or 9.0 g/ton ractopamine (Tables 1 and 2). Means for each response variable were weighted according to the number of pens of pigs per treatment.

Total dietary lysine provided to pigs fed ractopamine ranged from 0.9 to 1.14%. The average level of lysine provided to pigs fed ractopamine was 1.03%. Slaughter weight for pigs fed ractopamine ranged from 245 to 288 lb. The duration of ractopamine feeding varied between 21 and 32 days before slaughter and all carcass data were collected at commercial slaughter plants. Fat-O-Meater® technology was used to collect carcass measurements on 80% of the pigs represented in Tables 1 and 2 while the AutoFOM® was used to access 20% of the pigs.

Daily gain and feed efficiency increased by 8 and 11 %, respectively, when pigs were fed diets containing 4.5 g/ton ractopamine (Table 1). Hot carcass weight for pigs fed 4.5 g/ton ractopamine was 2 lb heavier, yield (dressing percent) was unchanged, and lean percent was improved by 0.4% units compared to the control. Providing 9 g/ton ractopamine improved daily gain and feed efficiency by 11 and 14%, respectively (Table 2). Hot carcass weight was increased by 7 lb, yield by 1.1% units, and lean percent by 0.9% units. These observations support previous data showing that pigs fed 9.0 g/ton ractopamine perform better than those fed 4.5 g/ton.

Method for Estimating Value

Costs

Corn-soybean meal diets containing 0.72 and 1.03% lysine were formulated. We assumed a 0.72% lysine diet would be fed to finishing pigs provided no ractopamine; that allowed us to calculate the cost of additional amino acids provided to pigs fed ractopamine. Because ractopamine reduces feed intake and increases lean gain, dietary amino acid level should be increased. All the diets contained 44% crude protein soybean meal as the sole source of supplemental protein and the same level of energy, amino acids, vitamins and minerals. Diets were formulated to contain 0, 4.5 and 9.0 g/ton of ractopamine. Ractopamine ($28/lb of premix or $3.11/g of active ingredient) replaced corn in the diet. Corn and soybean meal were priced at $2.00/bu and $200/ton, respectively. Feed efficiency and daily gain would not be expected to improve by feeding a diet containing more than 0.72% lysine to finishing pigs used in the studies summarized for this report, thus all the additional ingredient expense for providing ractopamine fed pigs a higher lysine diet was assigned to them.

Some producers have reported a higher death loss among pigs fed ractopamine while they are transported to market. However, no transport deaths have been reported in the scientific literature. We included a transport death cost of $0.45/pig in our analysis, a figure estimated by researchers from Cape Fear Consulting in Warsaw, NC based on field trials where 4.5 and 9.0 g/ton ractopamine was evaluated.

Revenues

The responses for feed efficiency shown in Tables 1 and were applied to the diet containing ractopamine to estimate revenue from improved feed efficiency. The revenue realized from improved feed conversion was attributed to ractopamine. (Note: The control diet for calculating the revenue contained 0.72% lysine.)

We modeled two scenarios to estimate revenue from improved daily gain by feeding ractopamine. In the first scenario we assumed pens would be "topped out" (TO) twice then the entire facility would be emptied. Therefore, pig slaughter weight would remain constant after ractopamine was introduced, except for pigs in the last shipment to market. They would weigh more when fed ractopamine, but we did not consider that in our analysis. Instead we assumed the faster growth rate due to feeding ractopamine would be manifest in fewer days to market. That could result in some savings in interest, utilities, and repair costs. This was credited at the rate of $0.05 per pig per day. The TO scenario is meant for producers who believe they are producing the heaviest market hogs their packer will accept given the time they have to feed them.

In the second scenario, we assumed pigs provided ractopamine were fed on a time constant basis (TC), i.e., they were fed for the same number of days before going to market as before ractopamine was introduced. Faster daily gain would be manifest in heavier pigs sold. The extra live weight sold was valued at $42/cwt. The TC scenario is meant for producers who are short on feeding days and can market heavier pigs without additional sort loss.

Revenue from increased carcass yield was calculated assuming a carcass price of $56.75/cwt of carcass.

Because of the large variation in genetics, production systems, and differences in packer buying grids and how carcasses are evaluated, it is difficult to develop estimates of the benefit a producer would receive in carcass lean premiums. The approach we have taken is presented in Tables 3 and 4. Costs and revenues for feeding ractopamine are itemized for feeding 4.5 (Table 3) and 9.0 g/ton ractopamine (Table 4) for TO and TC production scenarios. In the event that the additional costs exceeded the additional revenues, we calculated the amount of a carcass lean premium required to breakeven.

Table 3. Costs (-) and revenues (+) from feeding ractopamine (4.5 g/ton) in different production scenarios.[a]

	Top out		Time constant	
	$/pig		$/pig	
Item	Amount	Cumulative	Amount	Cumulative
Ractopamine	-1.17	-1.17	-1.26	-1.26
Extra amino acids	-1.44	-2.61	-1.44	-2.70
Transport deaths	-0.45	-3.06	-0.45	-3.15
Gain	+0.11	-2.95	+2.06	-1.09
Yield	+0.00	-2.95	+0.00	-1.09
Feed/gain	+1.17	-1.78	+0.42	-0.67
Required lean premium[b]	+1.78	0.00	+0.67	0.00
Net		0.00		0.00

[a]Top out = pens are topped out twice then facility emptied; Time constant = pigs are fed ractopamine for the same number of days before going to market as before it was introduced.
[b]Premium required to cover costs of feeding ractopamine after considering revenues from gain, carcass yield, and feed efficiency.

Table 4. Costs (-) and revenues (+) from feeding ractopamine (9.0 g/ton) in different production scenarios.[a]

	Top out		Time constant	
	$/pig		$/pig	
Item	Amount	Cumulative	Amount	Cumulative
Ractopamine	-2.30	-2.30	-2.54	-2.54
Extra amino acids	-1.47	-3.77	-1.47	-4.01
Transport deaths	-0.45	-4.22	-0.45	-4.46
Gain	+0.14	-4.08	+2.85	-1.61
Yield	+1.68	-2.40	+1.72	+0.11
Feed/gain	+1.54	-0.86	+0.53	+0.64
Required lean premium[b]	+0.86	0.00		0.00
Net		0.00		+0.64

[a]Top out = pens are topped out twice then facility emptied; Time constant = pigs are fed ractopamine for the same number of days before going to market as before it was introduced.
[b]Premium required to cover costs of feeding ractopamine after considering revenues from gain, carcass yield, and feed efficiency.

Results and Discussion

Feeding 4.5 g/ton ractopamine in a TO production scenario would require a carcass lean premium of $1.78/pig to breakeven (Table 3). In contrast, feeding 9.0 g/ton ractopamine in a TC production scenario did not require a carcass lean premium to breakeven (Table 4). Instead we projected a net profit of $0.64/pig; any lean premium earned would further increase net profit. Lean premiums were required to breakeven feeding 4.5 g/ton ractopamine in a TC production scenario ($0.67/pig) and 9.0 g/ton in a TO scenario ($0.86/pig). Our results indicate that a producer using a TO production scenario is more dependent on his/her pigs earning a lean premium than one who uses a TC scenario. In the TC scenario, the improvement in daily gain is valued more than it is in the TO scenario.

Considering that the method we used to calculate revenues from improved daily gain significantly affected the requirement for a lean premium, we also modeled the economics of feeding ractopamine at slaughter prices of $34 and $50/cwt (Figures 1 and 2). The amount of a lean premium required when feeding 4.5 g/ton ractopamine in a TO production scenario was not affected by slaughter price (Figure 1), because slaughter weight is constant and carcass yield was not affected by ractopamine. However, in a TC production situation, the amount of lean premium required to break even decreased as slaughter price increased. Feeding 9.0 g/ton ractopamine, resulted in a smaller lean premium required for the TO production scenario as slaughter price increased, because of increasing revenues from carcass yield. In contrast, no lean premium was required when feeding 9.0 g/ton ractopamine in

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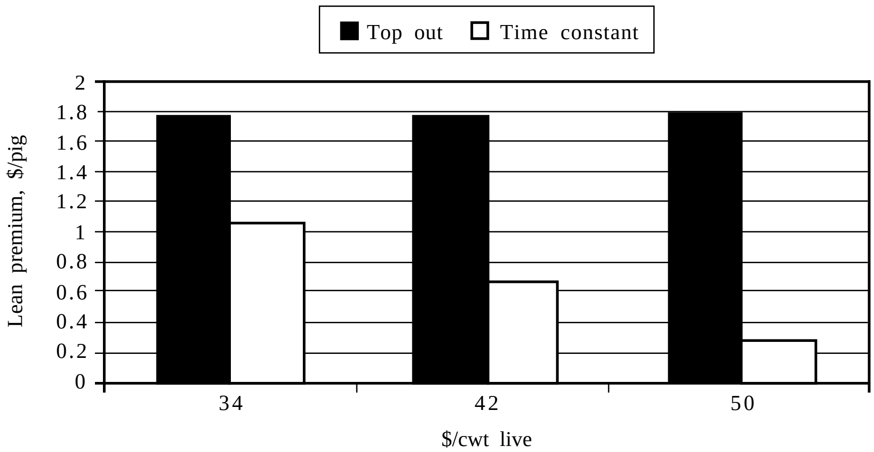

Figure 1. Estimated carcass lean premiums required to cover cost of feeding 4.5 g/ton ractopamine at various slaughter pig prices and production scenarios. Top out = pens are topped out twice then facility emptied; Time constant = pigs are fed ractopamine for the same number of days before going to market as before it was introduced.

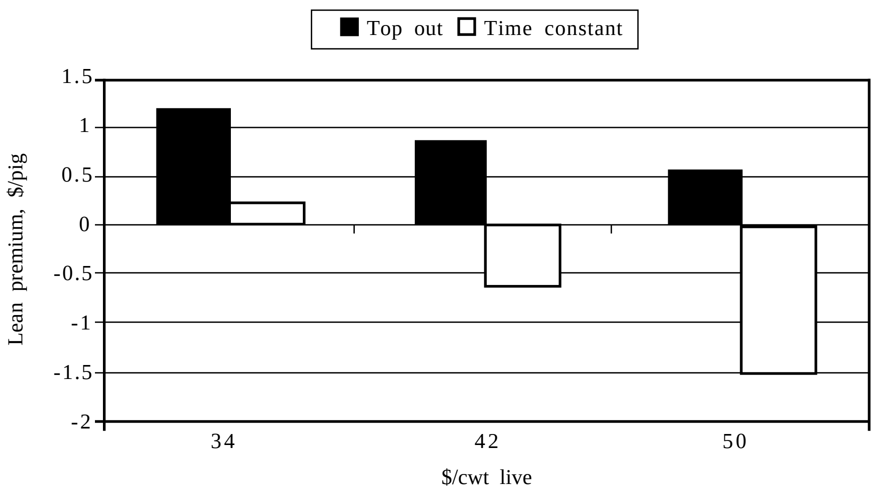

Figure 2. Estimated carcass lean premiums required to cover cost of feeding 9.0 g/ton ractopamine at various slaughter pig prices and production scenarios. Negative values indicate amount of potential profit, not including any lean premium that may be obtained, from feeding ractopamine. Top out = pens are topped out twice then facility emptied; Time constant = pigs are fed ractopamine for the same number of days before going to market as before it was introduced.

a TC production situation when live price was $42/cwt or more; our results indicate net earnings between $0.55 and $1.50/pig not including any lean premium that may be obtained.

If a producer considers it highly likely to obtain a larger average lean premium than that shown in Figures 1 and 2, it would be profitable to feed ractopamine. When considering possible premiums for carcass leanness, note that it is likely that not all carcasses from a group of pigs fed ractopamine will be shifted into a higher carcass pricing category and earn a lean premium. Thus, carcasses from pigs that earned a lean premium must pay for the ractopamine consumed by pigs that did not earn a premium.

The price of Paylean™ will also affect the size of the carcass lean premium needed per pig. For each $2/lb change in the price of Paylean™, the lean premium required changes by approximately $0.15, and $0.30 per pig for the 4.5 and 9.0 g/ton levels, respectively.

Summary and Conclusions

Ractopamine generally improves growth performance, carcass leanness and yield, especially at the 9 g/ton level. No lean premium was required to breakeven in 2/12 economic evaluations conducted. Lean premiums between $0.23 and $1.78/pig were required in 10/12 evaluations we conducted. In most of the situations we modeled, growth performance and carcass yield did not cover the costs of feeding ractopamine. In those situations, ractopamine must improve carcass traits that your packer is capable of measuring and paying for. If earning a carcass premium is in doubt, consider feeding 9g/ton ractopamine in a TC production scenario when slaughter price is greater than about $42/cwt.

Practical experience with feeding ractopamine in today's pork industry is increasing, but it is still limited. Therefore, it is important that producers calculate the costs and benefits of ractopamine for themselves and supplement that with published research data.

It may be very useful for producers to collect data from their own pigs fed ractopamine. One would obtain specific information from the packer which would help in deciding if the lean premiums we calculated are likely to be obtained. Also, you can determine how well you can effectively manage feeding ractopamine to achieve optimum results. For example, can you ensure the majority of pigs receive ractopamine for about 28 days before slaughter? In addition, can you ensure that pigs fed ractopamine will receive the extra care they need during handling and transport? Guidelines for conducting on-farm feed research trials are available in the University of Nebraska publication, *Conducting Pig Feed Trials on the Farm (EC 92-270)* available at county extension offices in Nebraska or on the Internet at http://www.ianr.unl.edu/pubs/swine/ec270.htm.

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Defining the Optimal Feed Budget System for Terminal-Crossed, Growing-Finishing Barrows

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Summary and Implications

This experiment was conducted to evaluate growth performance and carcass quality measurements in growing-finishing barrows assigned to different feed budget systems. Forty-eight barrows with an initial body weight of 47.3 lb were randomly allotted to one of three different feed budget systems. The experiment was continued until the average body weight was 270 lb, at which time all pigs were slaughtered. Growth performance and real-time ultrasound measurements were taken biweekly, except for the final period, which was 24 days. Carcass tenth-rib backfat and longissimus muscle area measurements were made 24 hours postmortem. Overall, average daily feed intake (ADFI) was affected (P < 0.05) by feed budget with barrows assigned to Budget 2 having the greatest ADFI compared to barrows fed Budget 1 (P < 0.05) and 3 (P < 0.10). There was a trend (P = 0.106) toward an effect of feed budget on average daily gain (ADG). Barrows allotted to Budget 2 had greater overall ADG than barrows allocated to Budget 1 (P < 0.10) and 3 (P < 0.10). Feed efficiency for the overall experimental period was not affected (P > 0.10) by feed budget; however, the comparison of Budget 1 and 2 resulted in a difference in feed efficiency with barrows from Budget 1 having better (P < 0.10) feed efficiency than barrows from Budget 2. Ultrasound and carcass measurements were similar for pigs fed the three feed budget systems. The main effect of feed budget on total body electrical conductivity measurements was only significantly different (P < 0.10) for hot carcass weight. Returns above feed cost and feed cost per pound of gain from 50 lb to market weight were not affected by feed budget. Barrows allotted to Budget 2 had the greatest ADG and hot carcass weight; however, this group also had the greatest ADFI, which resulted in no difference in the return above feed costs or feed cost per pound of live weight gain. In summary, there were no major differences in overall growth performance, carcass characteristics, or return above feed costs in growing-finishing barrows fed different feed budgets.

Introduction

An important question that occurs in the feeding of growing-finishing pigs is when to change diets. A feed budget is a mechanism that can be used to ensure that the correct amount of each diet is delivered to a given group of pigs. Feed budgets are designed to provide pigs the correct amount of feed to gain a predetermined amount of body weight. In traditional systems in which pigs are fed on a time basis instead of a feed budget, pigs with poor feed intake and therefore slow growth may not reach the predetermined weight before being switched to the next diet. In a feed budget system, the manager of the finishing barn does not have to guess the weight of the pigs to determine which diet to order because the diet to be delivered to the group of pigs is automatically determined by the feed budget. The use of feed budgeting will result in more accurate phase feeding by not over- or under-delivering diets for each phase. Because environmental and management factors are major determinants affecting pig performance, the greatest challenge to using a feed budget system is customizing the feed budget for a specific production system. Therefore, the objective of this experiment was to compare three different feed budget systems when fed to terminal-crossed, growing-finishing barrows.

Procedures

Forty-eight crossbred (Danbred; Sire - Line 771×Dam - 75% Line 200 or 400× 25% NE White Line) barrows with an initial body weight of 47.3 lb were used in a growing-finishing experiment. Pigs were allotted to one of 24 pens (5 ft × 7.1 ft) which included four location blocks (six pens/block) in an environmentally control room. The average weight within each location block was similar and each treatment was replicated twice within each location block. Treatments consisted of three different feed budget systems (Table 1). Each feed budget offered the same total pounds of feed throughout the growing-finishing period, but the feed budgets differed in the amounts of each diet fed during the experimental period. Therefore, diets were changed on a pen basis when a pen of pigs had consumed the allotted amount of diet. Diets (Table 2) contained corn and soybean meal and were fortified with vitamins and minerals to meet or exceed the NRC (1998) requirements for 44- to 265-lb pigs. Pigs had ad libitum access to feed and water throughout the experimental period. Pigs remained on the experiment until the average body weight of the pigs reached approximately 270 lb, at which time all pigs were removed from the experiment.

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Table 1. Lysine concentration and amount of each diet fed per pig for each feed budget.

	Dietary phases					
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	
Lysine, %	1.15	0.90	0.75	0.65	0.60	
Pounds of each diet, per pig						**Total**
Budget 1	105	110	152	135	118	620
Budget 2	54	108	135	111	212	620
Budget 3	—	210	—	410	—	620

Table 2. Ingredient and calculated composition of diets, as-fed basis.

	Dietary phases				
Ingredients, %	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Corn	61.48	71.85	78.13	82.95	84.93
Soybean meal (46.5% CP)	32.25	22.40	16.25	12.50	10.75
Tallow	3.00	3.00	3.00	2.00	2.00
Dicalcium phosphate	1.65	1.08	0.93	1.00	0.75
Limestone	0.38	0.40	0.40	0.25	0.28
Salt	0.30	0.30	0.30	0.30	0.30
Vitamin premix[a]	0.70	0.70	0.70	0.70	0.70
Trace mineral premix[b]	0.10	0.10	0.10	0.10	0.10
Antibiotic	0.125	0.125	0.125	0.125	0.125
Lysine•HCl	0.025	0.05	0.075	0.075	0.075
Calculated nutrient content					
Crude protein, %	20.40	16.70	14.30	12.90	12.20
Lysine, %	1.15	0.90	0.75	0.65	0.60
ME[c], Mcal/lb	1.56	1.57	1.57	1.55	1.55
Calcium, %	0.80	0.65	0.60	0.55	0.50
Phosphorus, %	0.70	0.55	0.50	0.50	0.45
Analyzed nutrient content					
Crude protein, %	20.80	16.50	15.20	12.90	12.40
Lysine, %	1.07	0.85	0.74	0.61	0.57
Gross energy, Mcal/lb	1.85	1.85	1.84	1.81	1.83
Calcium, %	0.81	0.69	0.53	0.53	0.51
Phosphorus, %	0.72	0.60	0.43	0.48	0.48
Fat, %	4.90	5.14	4.67	4.81	5.12
Dry matter, %	91.73	92.05	90.27	90.83	91.49
Ash, %	5.75	4.72	3.95	3.70	3.65

[a]Supplied per kilogram of diet: retinyl acetate, 3,088 IU; cholecalciferol, 386 IU; α-tocopherol acetate, 15 IU; menadione sodium bisulfite, 2.3 mg; riboflavin, 3.9 mg; d-pantothenic acid, 15.4 mg; nicacin, 23.2 mg; choline, 77.2 mg; vitamin B_{12}, 15.4 µg.
[b]Supplied per kilogram of diet: Zn (as ZnO), 110 mg; Fe (as $FeSO_4 \bullet H_2O$), 110 mg; Mn (as MnO), 22 mg; Cu (as $CuSO_4 \bullet 5\ H_2O$), 11 mg; I (as $Ca(IO_3) \bullet H_2O$), .22 mg; Se (as Na_2SeO_3), 0.3 mg.
[c]Metabolizable energy.

Pigs and feeders were weighed biweekly (denoted as periods), except for Period VII which was 24 days, to determine average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (ADG/ADFI). Real-time ultrasound measurements (tenth-rib backfat (BF) depth and longissimus muscle area (LMA)) were recorded at the beginning of each period. The experiment period was 108 days. At the termination of the experiment, pigs were shipped to SiouxPreme Packing Co. in Sioux Center, Iowa, where carcass characteristics were measured on individually identified pigs using total body electrical conductivity (TOBEC). At 24 hours postmortem, tenth-rib BF measurements and LMA traces at the tenth rib were recorded for all carcasses.

Data were analyzed as a randomized complete block design using PROC MIXED of SAS. The main effect of the statistical model was feed budget. Pairwise comparisons between feed budgets were conducted only when the main effect of treatment was significant ($P < 0.10$). Ham, loin, shoulder, and total lean weights were analyzed with hot carcass weight as a covariate. In all analyses pen was the experimental unit.

Results and Discussion

Growth Performance

Average daily gain, ADFI, and feed efficiency (ADG/ADFI) for the seven data collection periods and the entire experimental period are shown in Table 3. During Period I, ADG and feed efficiency were affected ($P < 0.01$) by feed budget. Average daily gain and feed efficiency were greater ($P < 0.007$) in barrows fed diets from Budgets 1 and 2 compared to Budget 3. During Period II, barrows fed diets from Budget 1 had greater ADG ($P < 0.06$) and feed efficiency ($P < 0.01$) than barrows consuming diets from Budgets 2 and 3. An effect of feed budget on ADG and ADFI was detected during Period VII, with barrows consuming diets from Budgets 2 and 3 having the greatest body weight gain ($P < 0.02$) and pigs consuming diets from Budget 2 having the greatest ($P < 0.07$) feed intake. Results for the overall experimental period indicated a trend ($P = 0.106$) toward an effect of feed budget on ADG and a significant effect ($P < 0.05$) on ADFI, with barrows consuming diets from Budget 2 having the greatest ADG and ADFI.

Carcass Characteristics

Real-time ultrasound, carcass, and TOBEC measurements are provided in Table 4. Ultrasound measurements of tenth-rib BF and LMA did not differ ($P > 0.10$) among feed budgets. Also, tenth-rib BF and LMA carcass measurements were similar ($P > 0.10$) among feed budgets. Although a large difference in ultrasound and carcass tenth-rib LMA measurements was detected (ex. Budget 1 ultrasound LMA = 6.34 in^2 versus carcass LMA = 9.58 in^2; see Table 4), there was no effect of feed budget on ultrasound or carcass

Table 3. Effect of feed budget on growth performance.

	Feed budget				P-Value[a]			
Item	1	2	3	SEM	TRT	1 vs 2	1 vs 3	2 vs 3
No. pens	8	8	8					
Initial wt., lb	47.61	47.78	46.68	0.992	NS	NS	NS	NS
Final wt., lb	268.06	280.71	267.60	4.778	0.1135	0.076	NS	0.066
Period I (day 0-14)								
ADG [b], lb	1.65	1.70	1.38	0.062	0.004	NS	0.007	0.002
ADFI [c], lb	2.76	2.83	2.70	0.085	NS	NS	NS	NS
ADG/ADFI, lb/lb	0.60	0.60	0.51	0.006	<0.001	NS	<0.001	<0.001
Period II (day 15-28)								
ADG, lb	2.22	2.11	2.05	0.049	0.056	0.099	0.020	NS
ADFI, lb	4.01	4.10	4.03	0.102	NS	NS	NS	NS
ADG/ADFI, lb/lb	0.56	0.51	0.51	0.010	0.006	0.007	0.003	NS
Period III (day 29-42)								
ADG, lb	2.18	2.26	2.24	0.066	NS	NS	NS	NS
ADFI, lb	4.76	5.05	4.84	0.135	NS	NS	NS	NS
ADG/ADFI, lb/lb	0.46	0.45	0.46	0.012	NS	NS	NS	NS
Period IV (day 43-56)								
ADG, lb	2.28	2.29	2.17	0.079	NS	NS	NS	NS
ADFI, lb	5.63	6.05	5.59	0.197	NS	NS	NS	NS
ADG/ADFI, lb/lb	0.41	0.38	0.39	0.009	NS	0.058	NS	NS
Period V (day 57-70)								
ADG, lb	2.15	2.24	2.25	0.053	NS	NS	NS	NS
ADFI, lb	6.00	6.45	6.24	0.176	NS	0.084	NS	NS
ADG/ADFI, lb/lb	0.36	0.35	0.36	0.008	NS	NS	NS	NS
Period VI (day 71-84)								
ADG, lb	2.06	2.20	2.04	0.093	NS	NS	NS	NS
ADFI, lb	6.44	6.94	6.32	0.233	NS	NS	NS	0.076
ADG/ADFI, lb/lb	0.32	0.32	0.32	0.009	NS	NS	NS	NS
Period VII (day 85-105)								
ADG, lb	1.87	2.25	2.13	0.068	0.003	0.001	0.016	NS
ADFI, lb	6.45	7.56	6.94	0.223	0.008	0.002	NS	0.064
ADG/ADFI, lb/lb	0.29	0.30	0.31	0.007	NS	NS	NS	NS
Overall (day 0-108)								
ADG, lb	2.04	2.16	2.05	0.042	0.106	0.062	NS	0.071
ADFI, lb	5.27	5.75	5.40	0.133	0.047	0.018	NS	0.072
ADG/ADFI, lb/lb	0.39	0.38	0.38	0.005	NS	0.096	NS	NS

[a]TRT = treatment; NS = nonsignificant effect, $P > 0.10$.
[b]ADG = average daily gain.
[c]ADFI = average daily feed intake.

measurements. Total body electrical conductivity measurement of hot carcass weight was greater ($P < 0.10$) for barrows fed diets from Budget 2 than for barrows fed diets from Budgets 1 and 3. Although barrows allocated to Budget 2 had greater hot carcass weights, the increase in ADFI of pigs in this group resulted in a greater ($P < 0.10$) feed cost per pig (Table 5), which resulted in a similar return above feed cost and feed cost per pound of live weight gain (17 cents per pound, from 50 lb to market weight).

Conclusions

These results indicate that barrows fed under optimal growing conditions (2 pigs/pen and an environmentally controlled room) do not exhibit major differences in growth performance or carcass characteristics when assigned to different feed budgets throughout the growing-finishing period. Although hot carcass weight was greater in barrows allotted to Budget 2, they also had the greatest ADFI, which resulted in a similar feed efficiency and return above feed costs when compared to the other feed budgets. The greatest effect of the different feed budgets on ADG occurred during Periods 1 and 2 of the growing-finishing period. This suggests that the body weight gain of barrows is the most sensitive to dietary lysine concentration during the first 28 days of the growing-finishing period (initial body weight 50 lb). Although no major differences in the feed budget systems were observed in the current experiment, a much different outcome is possible if this experiment was conducted on a commercial swine operation. Therefore, further research is needed to explore the effects of commercial swine production (i.e., stocking rate, disease, management) on feed budget systems.

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Table 4. Effect of feed budget on ultrasound and carcass measurements.

	Feed budget				P-Value[a]			
Item	1	2	3	SEM	TRT	1 vs 2	1 vs 3	2 vs 3
Ultrasound measurements								
Tenth-rib backfat, in	0.83	0.87	0.87	0.031	NS	NS	NS	NS
LMA[b], in^2	6.34	6.19	6.09	0.129	NS	NS	NS	NS
Carcass measurements								
Tenth-rib backfat, in[c,d]	0.96	0.94	0.98	0.046	NS	NS	NS	NS
LMA, in^2	9.58	9.64	9.05	0.304	NS	NS	NS	NS
TOBEC measurements								
Hot carcass wt., lb	200.57	212.69	200.13	4.347	0.091	0.062	NS	0.054
Ham wt., lb[e,i]	23.05	23.13	22.63	0.492	NS	NS	NS	NS
Loin wt., lb[e,i]	27.55	27.06	27.24	0.335	NS	NS	NS	NS
Shoulder wt., lb[e,i]	27.94	28.13	27.67	0.405	NS	NS	NS	NS
Primal percentage[e,f]	38.46	37.78	38.40	0.633	NS	NS	NS	NS
Total lean, lb[e,i]	100.34	99.17	98.80	1.832	NS	NS	NS	NS
Percent lean[d]	46.21	46.21	45.89	0.841	NS	NS	NS	NS
Lean gain, lb/day[d,g]	0.72	0.77	0.71	0.025	NS	NS	NS	NS

[a]TRT = treatment; NS = nonsignificant effect P > 0.10.
[b]Longissimus muscle area.
[c]Backfat measurements were taken at 3/4 the distance along the loin muscle.
[d]Calculated on a fat-free lean basis.
[e]Contains 5% fat.
[f]Primal percentage was calculated by taking the total weight of the primal cuts (ham, loin, and shoulder) divided by the hot carcass weight.
[g]Lean gain calculation: $\dfrac{\text{Final fat-free lean} - \text{Initial fat-free lean}^{h}}{108\ \text{d}}$
[h]Initial fat-free equation: .95 * [-3.95 + (.418 * live weight, lb)]
[i]Hot carcass weight used as a covariate in the statistical analysis.

Table 5. Effect of feed budget on revenue and feed costs.

	Feed budget[a]				P-Value[b]			
Item	1	2	3	SEM	TRT	1 vs 2	1 vs 3	2 vs 3
				Economics, 50 lb to 260 lb[c,d]				
Average feed cost/pig, $	36.06	35.65	36.14	0.294	NS	NS	NS	NS
Feed cost/lb of gain, $	0.17	0.17	0.17	0.002	NS	NS	NS	NS
				Economics, 50 lb to market[d,e]				
Gross income, $/pig	130.54	136.70	130.32	2.327	0.114	0.076	NS	0.066
Average feed cost/pig, $	37.68	39.92	37.30	0.501	0.094	0.082	NS	0.045
Return above feed, $/pig	92.87	96.78	93.02	1.634	NS	NS	NS	NS
Feed cost/lb of gain, $	0.17	0.17	0.17	0.001	NS	NS	NS	NS

[a]Diet costs/lb, $: Diet 1 = 0.075; Diet 2 = 0.069; Diet 3 = 0.065; Diet 4 = 0.061; Diet 5 = 0.060; diet costs only included cost of the ingredients.
[b]TRT = treatment; NS = nonsignificant effect *P* > 0.10.
[c]Feed cost per pig and feed cost per pound of live weight gain were calculated from a starting weight of 50 lb to a constant ending weight of 260 lb.
[d]A live weight price of $48.70 per hundred pounds of live weight was used in the economic analysis.
[e]Feed cost per pig and feed cost per pound of live weight gain were calculated from a starting weight of 50 lb to market weight for all pigs.

Effects of Glutamine on Growth Performance and Small Intestine Villus Height in Weanling Pigs

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Robert L. Fischer[1]

Summary and Implications

The pig's small intestinal structure and function is altered during the days that follow weaning. As a consequence, the digestive and absorptive capacity of weanling pigs may decrease during this period, and this may be partially responsible for the postweaning growth lag. Additionally, health benefits may be associated with an improved small intestinal structure and function during the early postweaning period. This experiment was conducted to evaluate the effects of crystalline glutamine and (or) diet complexity on small intestine villus height and growth performance of 18-day-old pigs. During the 21-day trial, no differences in villus height were observed between pigs fed diets with or without supplemental glutamine or between pigs fed a complex diet or a simple diet. Pigs fed the complex diet had improved ($P < 0.01$) average daily gain during days 0 to 4, 7 to 14, and 14 to 21. The majority of improvement in average daily gain of pigs fed the complex diet was likely due to the improvement in average daily feed intake; in as much as average daily feed intake was improved ($P < 0.05$) during days 0 to 4, 4 to 7, 7 to 14, and 14 to 21. Pigs fed the simple diet had improved ($P < 0.05$) feed efficiency during days 7 to 14 and 14 to 21. Although supplemental glutamine did not improve villus height, it did improve ($P < 0.05$) feed efficiency during days 14 to 21, regardless of diet complexity. The glutamine-induced improvement in feed efficiency may have been related to other improvements in intestinal structure and function that were not measured in this experiment.

Background and Introduction

Villus atrophy (degeneration of the absorptive organelles) and crypt hyperplasia (increased cellular growth of the cells that replace villus epithelial cells) is observed in the small intestine of the weanling pig. During this time, it is thought that a temporary decrease in digestive and absorptive capacity ensues for several days. Additionally, it has been estimated that the majority of the immune response of a weanling pig is mediated in the small intestine.

Glutamine is an amino acid that is considered nonessential for swine. However, in humans glutamine promotes gastrointestinal growth during intravenous feeding and after traumatic events such as gastrointestinal surgery. Rapidly dividing cells, including the absorptive and immune cells of the small intestine, use glutamine (in preference to glucose) as an energy source. Additionally, free (unbound to protein) glutamine is the most abundant amino acid in sow milk, particularly in late lactation. The addition of 1% crystalline glutamine to a corn-soybean meal diet has been reported to reduce villous atrophy in the jejunum (mid portion of the small intestine) on the seventh day after weaning. Other studies have demonstrated improvements in intestinal lamina propria depth (region associated with immune cell synthesis) and increased crypt depth. Cell culture experiments have shown that glutamine decreased intestinal permeability after an endotoxin (toxin synthesized by *E. coli*) challenge and *E. coli* challenge suggesting that glutamine decreases the ability of enteric pathogens and their toxins to enter the portal blood circulation. Animal experiments have confirmed an improved immune response, with elevated IgG (a indicator of immune system activation) after an *E. coli* challenge.

The goal of this study was to determine the effect of crystalline glutamine on villus height and growth performance in nursery pigs fed simple or complex Phase-I diets.

Procedures

A total of 115, 18-day-old ($\pm$ 2) weanling pigs were used in this experiment. On day 0, four pigs were killed to determine initial villus height. The remaining 111 pigs were blocked (n = 4) by weight and randomly assigned to pen (n = 16; 7 pigs/pen). Treatments (Table 1) were arranged in a 2 $\times$ 2

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Table 1. Composition of diets, % (as fed).

	Simple		Complex	
Ingredient	Control	Glutamine	Control	Glutamine
Corn	46.65	45.65	33.79	32.79
Dried whey	0	0	35.75	35.75
Soybean meal, 46.5% CP	45.78	45.78	13.45	13.45
Spray-dried plasma	0	0	6.00	6.00
Menhaden fish meal	0	0	6.00	6.00
Corn oil	3.00	3.00	3.00	3.00
Dicalcium phosphate	2.54	2.54	0.06	0.06
Limestone	0	0	0.20	0.20
Salt	0.74	0.74	0.35	0.35
L-Lysine•HCl	0.13	0.13	0.09	0.09
DL-Methionine	0.10	0.10	0.11	0.11
L-Threonine	0.08	0.08	0	0
Vitamin premix[a]	1.00	1.00	1.00	1.00
Mineral premix[b]	0.20	0.20	0.20	0.20
L-Glutamine	0	1.00	0	1.00
Calculated composition:				
ME[c], kcal/lb	1,539		1,559	
Lactose, %	0		25.0	
CP, %	25.5		22.0	
Lysine, %	1.60		1.60	
Ca, %	0.90		0.90	
P, %	0.92		0.73	
P avail., %	0.55		0.55	
Na, %	0.30		0.70	

[a]Supplied per lb of diet: retinyl acetate, 2,000 IU/lb; cholecalciferol, 250 IU; α-tocopherol acetate, 10 IU; menadione sodium bisulfite, 1.50 mg; riboflavin, 2.50 mg; d-pantothenic acid, 10.0 mg; niacin, 15.0 mg; choline, 50 mg; vitamin B_{12}, 10.0 µg.
[b]Supplied per lb of diet: Zn (as ZnO), 100 mg; Fe (as $FeSO_4•H_2O$), 100 mg; Mn (as MnO), 20 mg; Cu (as CuSO4•5 H_2O), 10 mg; I (as $Ca(IO_3)•H_2O$, 0.14 mg; Se (as Na_2SeO_3), 0.27 mg.
[c]Metabolizable energy.

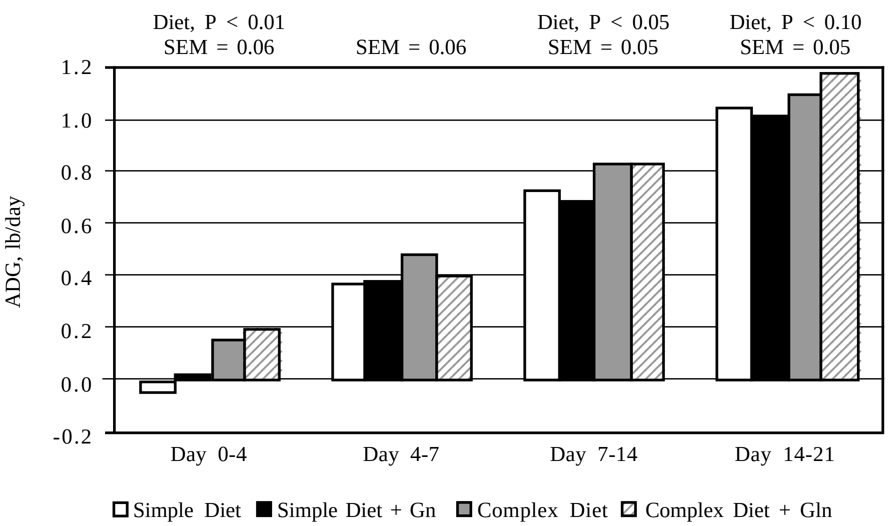

Figure 1. Average daily gain of pigs fed diets differing in complexity and crystalline glutamine concentration. Gln = glutamine.

factorial with the main effects being glutamine concentration (0% or 1%) and diet (simple or complex). Pigs and feeders were weighed and four pigs per treatment were killed on days 4, 7, 14, and 21. Pigs that were used for villus height determination were fully anesthetized, and an incision was made near the naval. The intact small intestine was removed from the body cavity and placed in physiologic saline solution, and the pig was then killed before it regained consciousness. Duodenum samples were taken at 5 cm from the beginning of the small intestine and jejunum samples were taken from the central point between the beginning and end of the small intestine. Samples were immediately fixed in a formalin solution and transferred to an ethanol solution. The duodenum and jejunum samples were imbedded in paraffin, sliced, mounted on a slide, and stained. A total of fifteen representative villi were measured from three sites of each sample using a microscope with a power of 25 times that of normal vision. Data were analyzed as a randomized complete block design with initial weight as the block, pen as the experimental unit, and individual pigs as the sampling unit for villus height determination. Data are reported as least squares means.

Results and Discussion

Pigs fed the complex diet had increased average daily gain (ADG) during days 0 to 4 ($P < 0.01$), 7 to 14 ($P < 0.05$), and 14 to 21 ($P < 0.10$) compared to pigs fed the simple diet (Figure 1). Average daily feed intake (ADFI) of pigs fed the complex diet was increased during days 0 to 4 ($P < 0.05$), 4 to 7 ($P < 0.001$), 7 to 14 ($P < 0.001$), and 14 to 21 ($P < 0.05$) (Figure 2). Pigs fed the simple diet had greater ($P < 0.05$) feed efficiency (ADG/ADFI) during days 7 to 14 and 14 to 21 (Figure 3). Greater ($P < 0.05$) ADG/ADFI was observed during days 14 to 21 in pigs fed supplemental glutamine compared to pigs fed the diets without supplemental glutamine.

Table 2. **Effects of diet complexity and crystalline glutamine supplementation on weanling pig villus height and small intestine length.**

	Simple		Complex		Diet	Glutamine	Diet × Glutamine	
	Control	Glutamine	Control	Glutamine	P[d] <			SEM
Day 4[a]								
Duodenum VH[b], mm	0.438	0.493	0.488	0.512	NS	NS	NS	0.032
Jejunum VH, mm	0.338	0.327	0.324	0.334	NS	NS	NS	0.015
Day 7								
Duodenum VH, mm	0.162	0.160	0.221	0.162	0.05	0.05	0.05	0.012
Jejunum VH, mm	0.131	0.121	0.141	0.126	NS	0.20	NS	0.009
Day 14								
Duodenum VH, mm	0.232	0.204	0.232	0.226	NS	0.18	NS	0.012
Jejunum VH, mm	0.161	0.176	0.159	0.157	NS	NS	NS	0.010
Day 21								
Duodenum VH, mm	0.257	0.252	0.220	0.253	NS	NS	NS	0.022
Jejunum VH, mm	0.191	0.195	0.184	0.182	NS	NS	NS	0.014
SI[c] length, m	10.533	10.970	10.980	11.138	NS	NS	NS	0.459

[a]Day 0 duodenum = 0.475 mm; Day 0 jejunum = 0.420 mm.
[b]VH = villus height.
[c]SI = small intestine.
[d]NS = P > 0.20.

Villus height (Table 2) on day 7 was reduced by 37% and 31% of day 0 villus height in the duodenum and jejunum, respectively. Villus height increased progressively after day 7, but by day 21 was still only 52% and 45% of day 0 duodenum and jejunum villus height, respectively. Surprisingly, diet complexity had little effect on villus height with the exception that the control-complex diet had greater duodenum villus height on day 7, resulting in an interaction of diet complexity and glutamine concentration ($P < 0.05$). Duodenum villus height seemed to be greater on day 4 in pigs offered the complex diet and glutamine supplementation, but was not different ($P > 0.27$) from pigs fed the simple or non-glutamine supplemented diet. No difference ($P > 0.52$) in total small intestine length was observed among treatments on day 21.

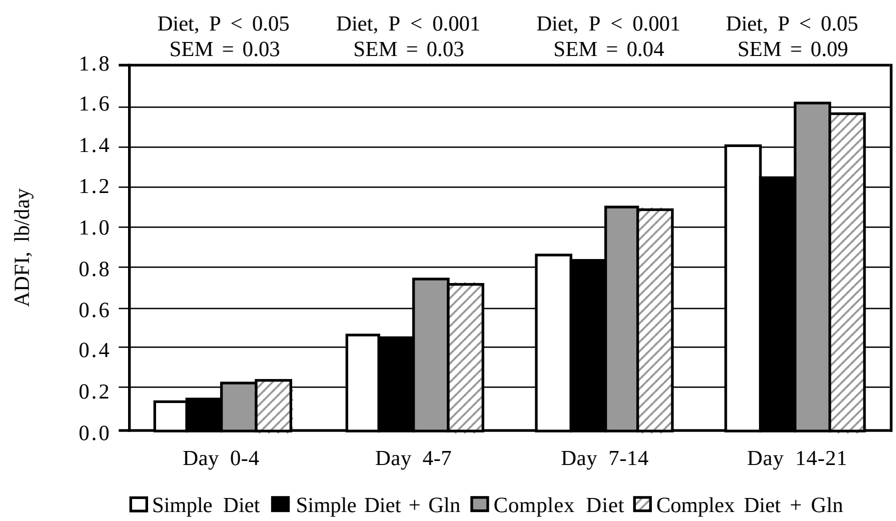

Figure 2. **Average daily feed intake of pigs fed diets differing in complexity and crystalline glutamine concentration. Gln = glutamine.**

The results from this trial confirmed that ADFI was increased when pigs were offered a complex diet compared to a simple diet. This increase in ADFI supported an improved ADG. However, pigs fed the simple diet had a greater ADG/ADFI. No improvement in villus height was attributed to diet complexity or glutamine supplementation; however, the variability in villus height measurements appeared to be high. The improvement in ADG/ADFI in pigs offered the diet with supplemental glutamine coupled with known properties of glutamine on intestine metabolism suggests an improvement in intestine function or morphology.

Future research will attempt to examine the effects of glutamine on small intestine growth using more direct measurements. For example, indices of protein and DNA concentrations may provide a more definitive answer to how glutamine is influencing intestinal growth. Also, it may be important to study the effects of glutamine during a pathogen challenge. Presently, we are working on an assay to quantify glutamine in feedstuffs to help objectively assess dietary glutamine concentration in a practical manner.

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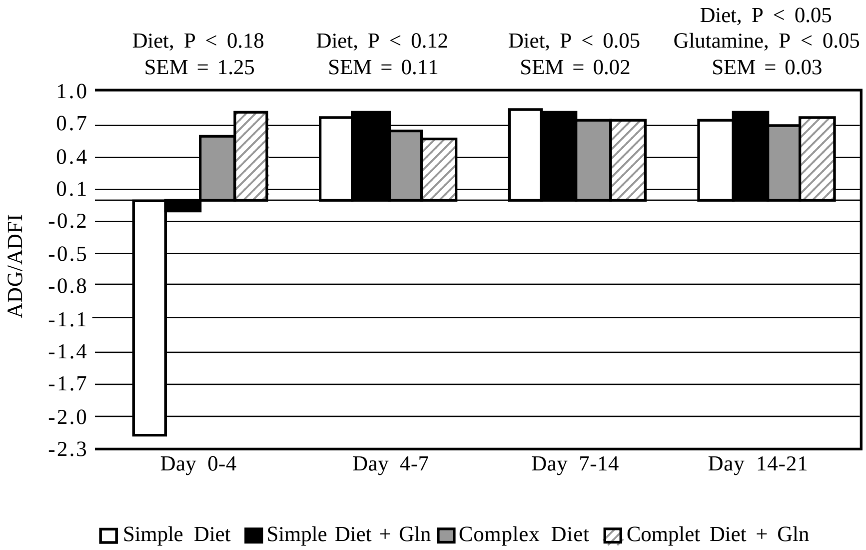

Figure 3. Feed efficiency of pigs fed diets differing in complexity and crystalline glutamine concentration. Gln = glutamine.

Conclusions

Data from this trial suggest that diet complexity had a significant effect on growth, but little to no effect on intestine villus height. Supplemental glutamine did not improve villus height but did improve feed efficiency in the third week of this 21-day growth study. Additional research is needed to examine the effects of glutamine on intestine metabolism and function to ascertain whether glutamine may be beneficial in practical situations.

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[1]Steven J. Kitt is a graduate student, Phillip S. Miller is an associate professor, Austin J. Lewis is a professor, and Robert L. Fischer is a graduate student and research technologist in the Department of Animal Science.

Influence of Linoleic Acid Isomers on Body Fat

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Summary and Implications

In two studies, mice were fed diets containing either individual conjugated linoleic acid (CLA) isomers or a mixture of isomers in the presence or absence of dietary essential fatty acids. Mice fed the C18:2 Δ10,12 CLA isomer lost as much body fat as mice fed a mixture of isomers. This effect was not observed when the mice were fed the C18:2 Δ9,11 isomer or when feed intake was restricted. The loss of body fat was much greater in mice consuming an essential fatty acid deficient diet versus a control diet. This supports our hypothesis that for CLA to deplete body fat, it must first be metabolized in a manner similar to linoleic acid. Furthermore, we suggest that the loss of body fat may be mediated by metabolism of CLA to an isomer of arachidonic acid. Understanding the mechanism by which CLA causes body fat loss, in pigs as well as mice, will allow for greater regulation of body fat content.

Introduction

Conjugated linoleic acid (CLA) is a group of isomers of linoleic acid (C18:2Δ9,12), which, when consumed, produce health benefits such as reducing the incidence of cancer and cardiovascular disease and reducing body fat content. Furthermore, in swine, dietary CLA has resulted in firmer bellies, reduced backfat, and improved feed efficiency. Our group previously reported (Nebraska Swine Report 2001, pg 27 – 28) that not only did dietary CLA supplementation cause a loss of body fat in mice, but that it also resulted in programmed cell death, or apoptosis, of fat cells. The basis for the following two studies was to further determine the mechanism by which CLA is causing both the body fat loss as well as the apoptosis. The predominant naturally occurring isomer is C18:2Δ9,11 (CLA 9/11), whereas commercially synthesized CLA products usually contain approximately equal amounts of C18:2Δ10,12 (CLA 10/12) and CLA 9/11 as well as smaller quantities of other isomers. The diverse benefits of CLA may depend on different isomers. Therefore our first objective was to determine which isomer(s) are responsible for the loss of body fat in mice.

Arachidonic acid (C20:4Δ5,8,11,14) is synthesized in animals from dietary linoleic acid. Similarly, CLA 10/12 can be metabolized to C20:4Δ5,8,12,14. This product of CLA metabolism could antagonize the normal production of prostaglandins from arachidonic acid. Therefore, mice fed a diet deficient in linoleic acid, and thus arachidonic acid, may be especially sensitive to the anti-

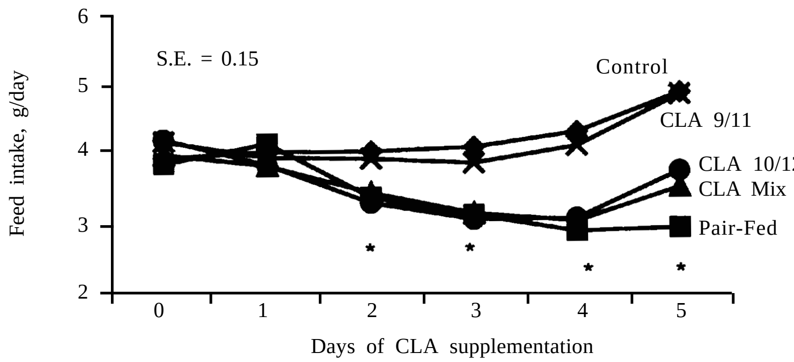

Figure 1. Effect of CLA Mix or individual isomers on feed intake (Experiment 1). *CLA 10/12, CLA Mix, and Pair-Fed differ from Control (P < 0.001).

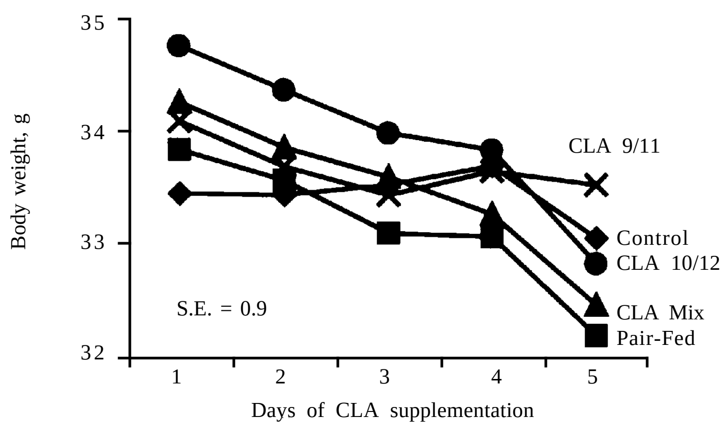

Figure 2. Effect of CLA Mix or individual isomers on body weight (Experiment 1). No effect of dietary treatment on body weight was detected.

Table 1. Effect of dietary treatment on feed intake, body weight change, and fat pad weights (Experiment 2).

	Dietary Treatments[d]				
	Control	CLA	EFAD	EFAD +CLA	SEM
Feed intake, g/d					
Before CLA[e]	3.79	3.79	3.82	3.82	0.12
After CLA[e]	4.45^{a}	3.95^{b}	4.50^{a}	3.85^{b}	0.08
Body wt. change, g[f]					
Before CLA[e]	16.66	16.66	16.94	16.94	0.47
After CLA[e]	2.75^{a}	1.55^{b}	2.55^{a}	-0.46^{c}	0.30
RP wt., g[g]	0.37^{a}	0.19^{b}	0.34^{a}	0.09^{c}	0.03
Epi wt., g[h]	0.61^{a}	0.45^{b}	0.55^{a}	0.21^{c}	0.04

[abc]Different letters in a row indicate differences, P < 0.05.
[d]Dietary treatments are as follows: Control – 7% soy oil diet for 8 weeks; CLA – 7% soy oil diet for 6 weeks, 0.5% CLA mix + 6.5% soy oil diet for 2 weeks; EFAD – 7% coconut oil diet for 8 weeks; and EFAD + CLA – 7% coconut oil diet for 6 weeks, 0.5% CLA + 6.5% coconut oil diet for 2 weeks.
[e]Feed intake and body weight change before CLA is the first six weeks of the study; after CLA is the final 2 weeks of the study.
[f]Body weight change is calculated as the weight at the final week of the feeding period minus the initial weight of that feeding period.
[g]RP = retroperitoneal fat pads.
[h]Epi = epididymal fat pads.

obesity effect of dietary CLA. Our second objective was to compare the effect of CLA in dietary essential fatty acid-adequate and -deficient diets.

Procedures

Experiment 1

Seventy-two mixed sex mice were allotted to one of five diets (each 7% fat) and allowed to consume ad libitum, except the Pair-Fed group, for 5 days:

Control	purified diet with 7% soy oil
Pair-Fed	control diet at intake of CLA Mix
CLA Mix	2% CLA mixture and 5% soy oil
CLA 9/11	0.82% CLA 9/11 and 6.18% soy oil
CLA 10/12	0.88% CLA 10/12 and 6.12% soy oil

Individual isomers were included the concentrations they were found at in the CLA Mix diet. Feed intake and body weight were measured daily. After 5 days, the mice were killed and retroperitoneal (RP) fat pads were removed and weighed. Body fat was determined on carcasses by ether extraction.

Experiment 2

Eighty, newly weaned male mice were fed either a control diet (7% soy oil) or essential fatty acid deficient (EFAD) diet (7% coconut oil) for 6 weeks. Next, half of the mice in each group were supplemented with 0.5% CLA mixture, replacing either soy or coconut oil, for 2 weeks. Then the mice were killed and RP fat pads, epididymal (Epi) fat pads, and livers were removed and weighed. Body fat was determined by ether extraction.

Results

Experiment 1

Feed intake was reduced (P < 0.001) in mice fed CLA Mix and CLA 10/12 as

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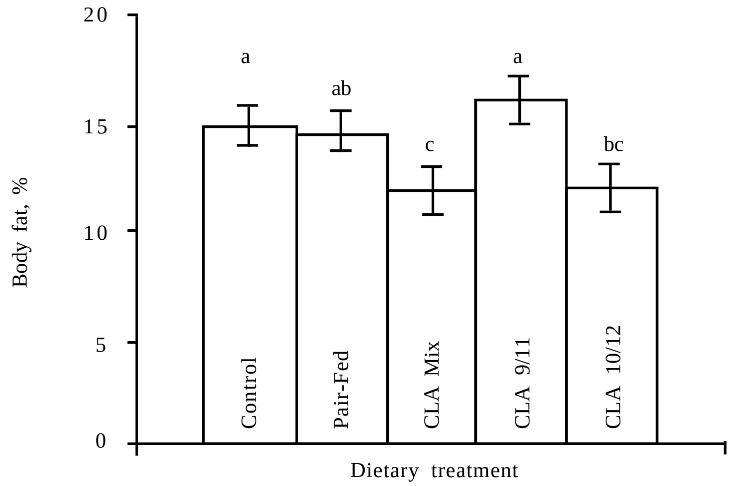

Figure 3. Effect of CLA Mix or individual isomers on body fat (Experiment 1). ^{abc}Bars with different superscripts differ (P < 0.10).

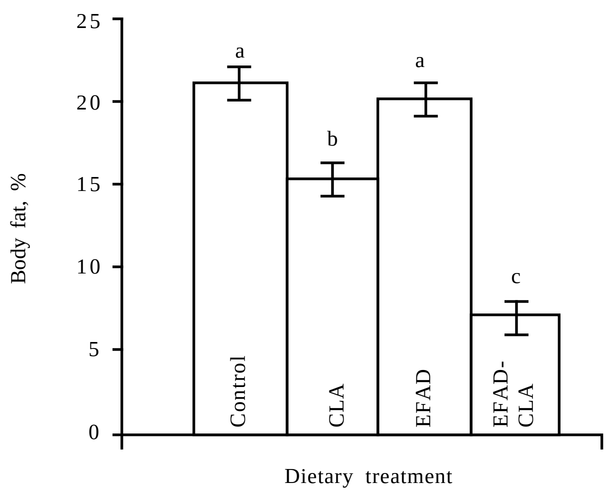

Figure 4. Effect of essential fatty acid deficiency (EFAD) and CLA supplementation on body fat (Experiment 2). ^{abc}Bars with different superscripts differ (P < 0.001).

well as the Pair-Fed mice, starting on day 2 (Figure 1). However, there were no significant differences in body weight among dietary treatment groups in this short time period (Figure 2). After 5 days of CLA supplementation, body fat content of mice fed the CLA Mix and the CLA 10/12 isomer was 20% less (P < 0.10) than that of mice fed the Control diet (Figure 3).

Experiment 2

Supplementation of CLA reduced (P < 0.05) both feed intake and body weight change in the final 2 weeks of the study (Table 1). CLA reduced (P < 0.001) RP (49%) and Epi (19%) fat pad weights when added to the control diet (Table 1). Furthermore, CLA reduced total body fat by 27% (Figure 4). The EFAD diet alone had no effect on feed intake, body weight, or body fat. However, when CLA was fed to mice deficient in essential fatty acids its effects were greatly amplified (P < 0.001); a reduction of 73% in RP, 57% in Epi, and 66% in total body fat (Figure 4).

Discussion

Our results indicate that CLA 10/12 is responsible for the loss of body fat observed when mice are fed a mixture of CLA isomers. This loss of body fat may be mediated through metabolism of CLA to an isomer of arachidonic acid. This was the basis for the design of Study 2. Arachidonic acid is a precursor to the series 2 prostaglandins, some of which appear to protect against cell death. Therefore, CLA-mediated inhibition of the conversion of arachidonic acid to prostaglandin could explain the fat cell death caused by feeding CLA. Essential fatty acids (linoleic and linolenic) protect against the full effect of CLA, which may indicate that CLA and these fatty acids are metabolized via a common metabolic path.

The knowledge that CLA 10/12 is responsible for the full fat-reducing-effect of CLA will allow both researchers, as well as swine producers to more accurately formulate diets on the active CLA isomer (CLA 10/12), instead of on the total CLA content. This becomes especially important when different sources of CLA are used as different manufacturing procedures produce different ratios of isomers. In addition, recognizing the metabolic pathway through which CLA acts should facilitate development of better methods to manipulate body fat in the future.

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[1]Kim Hargrave is a graduate student, Kristin Nollette is an undergraduate student, Merlyn Nielsen is a professor, and Jess Miner is an assistant professor in the Department of Animal Science.

Dietary Amino Acid Utilization for Body Protein Deposition — Current and Future Research

Janeth J. Colina
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Summary and Implications

In modern pork production it is important to maximize the animal's potential for daily lean gain by increasing the body protein deposition with as little wastage of the ingested amino acids as possible. Therefore, it is important to maximize the efficiency with which dietary amino acids are used for protein deposition or lean gain. This efficiency is measured by using nitrogen balance studies or comparative slaughter procedures. Supplementing swine diets with crystalline amino acids and replacing part of the dietary protein can reduce diet cost and will also reduce the amount of nitrogen excreted in manure. However, it has been demonstrated that the efficiency of utilization of crystalline amino acids may be lower than that of amino acids bound in protein. Although the reasons for this are unclear, it may be associated with the frequency of feeding and differences in the rate of absorption between the two sources of amino acids. Research in progress is designed to investigate the efficiency with which crystalline lysine is utilized for protein deposition in nursery pigs. This research will obtain additional information about the relative utilization of crystalline and protein-bound amino acids.

Amino Acid Utilization for Body Protein Deposition

Body proteins are continuously being formed (protein synthesis) and broken down (protein degradation). In an adult animal, synthesis and degradation are equal and body protein is neither gained or lost. However, in a growing animal, synthesis exceeds degradation and this results in protein deposition or accretion. Dietary indispensable amino acids are used for a variety of metabolic processes in the body and are precursors for a wide range of biologically active compounds, but it is protein deposition that accounts for the greatest amino acids use. The efficiency with which absorbed amino acids are used for protein deposition depends on several factors including genetic differences and whether the amino acid intake is limiting or in excess of the requirement. In growing-finishing pigs consuming diets that are limiting in protein, the most limiting acid will be used more efficiently than other amino acids, and it is the efficiency of utilization of this amino acid that will affect how well the overall dietary protein is used.

Nitrogen Balance and Comparative Slaughter Trials

The efficiency of amino acid utilization is typically measured using either N (nitrogen) balance studies or comparative slaughter trials (body composition is measured). The two methods yield different results. Estimates of N retention are higher when measured by the N balance technique than when measured by the comparative slaughter technique. Some studies have estimated values of 8.96 and 7.51 g of protein retained per g of lysine intake by using nitrogen balance and slaughter trials, respectively. The differences are larger at low than at high rates of protein deposition. The main explanation for the discrepancy between the two methods is that N losses in feces and urine are usually underestimated in N balance studies, with a consequent overestimation of N retention.

Crystalline Amino Acids vs Protein-bound Amino Acids

Recent evidence has indicated that the efficiency of utilization of crystalline amino acids may be lower than the efficiency of amino acid utilization from intact protein. One study reported that the efficiency for tryptophan was 54% for protein-bound tryptophan but only 14% for crystalline tryptophan. Others have found that the efficiency of utilization of crystalline tryptophan may be only 50% of protein-bound tryptophan.

The reasons for the poor efficiency of crystalline tryptophan are unknown, but in one study pigs were fed three times daily and it is possible that infrequent feeding may have contributed to the lower efficiency. Similar results have been observed when feeding dietary lysine infrequently. Crystalline lysine in diets fed once daily is used 50% less efficiently than crystalline lysine in similar diets fed more frequently (i.e., twice or more per day).

The reduced efficiency of crystalline amino acid utilization has been attributed to the rapid absorption of

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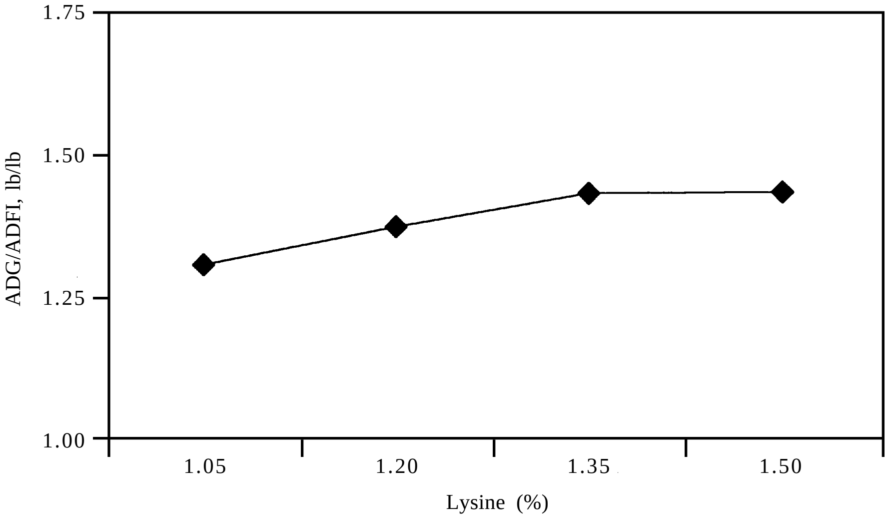

Figure 1. Feed efficiency (lb/lb) of nursery pigs fed four concentrations of dietary lysine.

crystalline amino acids relative to amino acids derived from intact protein such as soybean meal. Free amino acids are absorbed more rapidly than those bound in protein, which probably provides an unbalanced pattern of amino acids to muscle and affects growth performance in pigs by decreasing protein synthesis. If crystalline amino acids are absorbed too quickly the temporary excess of absorbed amino acids at the tissue level may result in oxidation losses of the free amino acids and degradation in the liver. Studies indicate improvements in growth performance in pigs fed soybean meal supplements (protein-bound lysine) diets in comparison to pigs fed lysine-supplemented diets. However, these differences were attributed to gut fill because no differences in carcass weight were detected. Therefore, the strategy is to balance the arrival of the protein-bound amino acids and free amino acids at the site of absorption.

Reduced efficiency of amino acid utilization resulting from differences in the time course of absorption between protein-bound and crystalline lysine has not been observed under ad libitum feeding conditions. It is unlikely that differences in absorption rate explain differences in utilization of the lysine under ad libitum feeding conditions because of the continual supply of amino acids that are absorbed. However, further research is needed to examine the relationship between feeding level and crystalline amino acid utilization.

Current Research

We are currently investigating the efficiency with which crystalline lysine is utilized for protein deposition in nursery pigs. A preliminary 28-day study was conducted to develop a lysine-deficient diet using 96 nursery pigs (11 lb initial body weight and 15 day old). The dietary treatments consisted of the basal diet (1.05% lysine) and three concentrations of total lysine: 1.20%, 1.35%, and 1.50%. These concentrations were achieved by adding crystalline lysine to the basal diet. Pigs were grouped on the basis of initial weight and allotted at random to 16 pens within a nursery facility. There were six pigs per pen (three barrows and three gilts). Pigs were allotted to four dietary treatments with four replications (weight blocks) per treatment (24 pigs per treatment). Average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (ADG/ADFI) were measured weekly. At the end of the study all pigs were bled to determine plasma urea concentration. As expected, lysine was limiting in the basal diet and supplementation with crystalline lysine increased ADG ($P = 0.05$) and ADG/ADFI ($P < 0.001$). However, no differences were observed for ADFI. A linear response ($P < 0.001$) for ADG/ADFI indicated that diets with 1.05 and 1.20% lysine were limiting and the requirement was approximately 1.35% (Figure 1). Plasma urea nitrogen (PUN) decreased as the lysine concentration in the diet increased. A higher concentration of PUN was estimated in pigs fed the diet with 1.05% lysine in comparison with pigs fed diets 1.20 and 1.35% lysine ($P < 0.05$) and 1.50% lysine ($P < 0.01$). These results indicate that nitrogen retention improved when the higher concentration of lysine was fed.

Future Research

We are now studying the efficiency with which crystalline lysine and the lysine present in soybean meal are used for body protein deposition in nursery pigs. Studying the efficiency of amino acid utilization under ad libitum feeding conditions will be important to determine whether crystalline amino acids are used less efficiently than amino acids in intact protein. If it is true, future studies must be focused on looking at alternatives to improve the amino acid utilization from crystalline sources, taking into account that the use of crystalline amino acids can provide environmental and economical advantages.

Take Home Points

1) Supplementing low-protein diets with crystalline amino acids at adequate concentrations can offer environmental and economical benefits. Several factors can affect the utilization of dietary amino acids and differences in the rate of absorption probably occur between crystalline and protein-bound amino acids. This may affect growth performance in pigs.
2) During certain situations, crystalline amino acids may be used less efficiently than the amino acids in intact protein. Therefore, careful use of crystalline amino acids must be made to ensure that they are utilized as efficiently as possible.

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Reproductive Responses in the NE Index Line Estimated in Pure-line and Crossbred Litters

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Summary and Implications

The NE Index Line (Line I) has been selected since 1981 only for litter size and as a pure-line has 3.5 to 4 more pigs per litter than its randomly selected control (Line C). Line I has been released to the industry where it is being used in crossbreeding applications, but whether the response realized in the pure-line is expressed in crossbreeding applications is not known. The objective of this experiment was to estimate responses in reproduction in Line I in pure-line sows, in pure-line sows mated to produce F_1 litters and in F_1 sows mated to produce three-way cross litters. A total of 850 litters were produced over six-year seasons. There were 224 pure-line I and C litters, 393 F_1 litters produced from I and C females mated with Danbred® USA Landrace (L) or DH (T) boars, and 233 litters by IxL and CxL females mated with T boars. Contrasts of means were used to estimate the genetic difference between I and C and interactions of line differences with mating type. Farrowing rate of Lines I and C (93.3 vs 91.8%) did not differ. Averaged across all groups, mean number born alive per litter and number and weight of pigs weaned per litter, both adjusted for number nursed and weaning age of 12 days, were 10.1 pigs, 9.7 pigs, and 75.9 lb, respectively. Direct genetic effects of I were greater ($P < 0.05$) than C for total born (3.53 pigs), number born alive (2.53 pigs), number of mummified pigs (0.22 pigs), and litter birth weight (4.72 lb). Line I was less than C ($P < 0.05$) for litter weaning weight (–4.15 lb). However, interactions of line effects with crossing system were significant. In pure-line litters, I exceeded C by 4.18 total pigs and 1.76 stillborn pigs per litter; whereas in F_1 litters the difference between I and C was 2.74 total pigs and 0.78 stillborn pigs per litter. The contrast between I and C for number weaned and litter weaning weight in pure-line litters was 0.32 pigs and -0.62 lb, respectively, compared with 0.25 pigs and -4.72 lb in F_1 litters. Reproductive performance of Line I substantially exceeds that of the control line. Although the response realized in crossbreeding applications was somewhat less than in the pure-line, crossbreeding is an effective way to utilize the enhanced reproductive efficiency of the Index line.

Background

Population

The populations studied were the NE Index line that has been selected for increased litter size and its control line. The base population of Large White and Landrace was formed by reciprocally crossing boars and sows of the two breeds in 1979. Random mating of the F_1 and F_2 was used to produce F_3 litters that were born in 1981. These litters, designated Generation 0, were randomly assigned to the Control line (C), that was randomly selected, or the Index line (I), that was selected for an index of ovulation rate and embryonic survival. Selection during Generations 12 through 14 in I was on number of fully formed pigs per litter at birth. During Generations 15 and 16, I was selected for number born alive and birth weight.

Mating Design

The experiment reported herein used pigs from eight different genetic backgrounds that included pure Line I and C pigs and pigs produced by crossing lines I and C with Danbred® USA Landrace (L) and the 3/4 Duroc x 1/4 Hampshire terminal sire (T). Pure Line-I and Line-C Generation 16 gilts were randomly assigned to be mated naturally to boars of their own line or to be inseminated with semen of L to produce Generation 17 I x I, L x I, C x C, and L x C litters. Artificial insemination was used to produce crossbred litters because the biosecurity policy at the experimental farm prohibited introduction of live boars. Lines I and C were maintained throughout the selection experiment with 15 boars per generation and a 3:1 sow-to-boar ratio. Labor was not available to train and collect semen from pure-line I and C boars so natural service was used to produce pure-line litters. A random sample of I and C sows was retained after weaning their litters and inseminated with semen of T to produce T x I and T x C litters at their second parity. Sows were culled after weaning their second litter.

Pure-line and F_1 gilts from the first litters were retained for breeding to produce Generation 18 progeny. Pure-line females were again randomly

(Continued on next page)

assigned to be mated naturally to boars of their own line or to be inseminated with semen of L boars. F_1 females were inseminated with semen from T boars. Genetic types produced in Generation 18 were I x I, L x I, C x C, L x C, T(L x I), and T(L x C). A random sample of both pure-line and F_1 sows was retained after weaning their litters and inseminated with semen of T boars to produce T x I, T x C, T(L x I), and T(L x C) litters at their second parity. No pigs in these litters were retained for breeding and all sows were culled after weaning their second litter.

Table 1. Number of litters of each group produced per year/season

Genetic group[a]			Year/season					
Sire	Dam	Litter	1998/1	1998/2	1999/1	1999/2	2000/1	2000/2
C	C	C	36		39		35	
I	I	I	44		35		35	
L	C	L x C	45		35		26	24
L	I	L x I	49		27		25	20
T	C	T x C		47		32		
T	I	T x I		43		20		
T	L x C	T (L x C)			43	18	37	22
T	L x I	T (L x I)			43	17	33	20

[a]C = Control, I = Index, L = Danbred® USA Landrace Sire, T = Danbred® Duroc-Hampshire Terminal Sire.

Pure-line and F_1 gilts from Generation 18 were retained and mated according to the same design as used to produce Generation 18 litters. After weaning these litters, a random sample of sows was retained for a second litter. Pure-line I and C sows were inseminated with semen of L boars, and F_1 gilts were inseminated with semen of T boars. The mating design by generation and parity, and the number of litters produced are illustrated in Table 1.

Selection

Selection of pure Line-I gilts and boars was done by ranking litters on number born alive. Line-I boars were selected from the 15 largest litters. The two boars with the greatest birth weight were selected from each litter. One was designated a breeder and the other an alternate. Gilts were selected similarly; however because more gilts were needed, they were selected from the upper 50% of the litters for number born alive. Within these litters, gilts with low birth weight were culled and a maximum of four gilts per litter was selected. Replacements in C were selected randomly within paternal half sib family (boars) and litters (gilts) to give 15 breeding boars and the necessary number of gilts each generation.

Data

A total of 850 litters over six seasons, consisting of 224 pure-line, 393 F_1, and 233 3-way crosses, was studied. Farrowing rate (FR) was calculated as the percentage of females designated for breeding that farrowed a litter. Number of fully formed pigs (FF), number born alive (BA), numbers of stillborn (SB) and mummified piglets (MUM), and litter birth weight (LBW) were recorded at birth of litters. Number weaned (NW) and weight of the litter (LWW) were recorded at weaning.

Statistical Analysis

Farrowing rate was analyzed with a chi-square test. Birth and litter traits were analyzed with general linear models that included year/season/genetic group. Litter weight was recorded as a trait of the dam. Because crossfostering of pigs among different genetic groups occurred, procedures were used to account for genetic makeup of pigs nursed by dams, age when pigs were weaned,

Table 2. Estimates of contrasts among means for traits measured at birth and for traits measured at weaning.

	Traits measured at birth[b]					Weaning traits[c]	
Contrast[a]	FF	NBA	SB	MUM	LBW (lb)	LWW (lb)	NW (pigs)
I – C	3.53** ± .30	2.53** ± .30	0.99** ±0.18	0.22** ± 0.06	4.72** ± 0.77	-4.15* ± 1.61	-0.26 ± 0.16
R:P – F_1	-1.21* ± 0.57	NS	-.75** ± 0.33	NS	NS	12.52** ± 3.90	1.80** ± 0.39
$(I – C)_P$	4.18** ± 0.39		1.76** ± 0.22			-0.62 ± 1.10	0.32** ± 0.11
$(I – C)_{F1}$	2.75** ± 0.30		0.78** ± 0.18			-4.72** ± 1.81	-0.56** ± 0.18
F_1 – P	-0.83** ± 0.28	-0.52 ± 0.28	-0.30 ± 0.16	-0.05 ± 0.06	1.08 ± 0.73	12.24** ± 1.19	0.25* ± 0.12
T – F_1	1.71** ± .29	1.51** ± 0.29	0.21 ± 0.17	-0.03 ± 0.06	7.65** ± 0.73		

[a]I – C estimates the overall effect of the index line vs the control.
R:P – F1 tests the interaction of selection response between I and C in pure-line dams with pure-line litters vs pure line dams with F_1 litters.
$(I – C)_P$ estimates the difference between index and control when measured in pure-line litters produced from pure-line dams.
$(I – C)_{F1}$ estimates the difference between index and control and when measured in F_1 pigs produced from pure-line dams.
F_1 – P is the difference between averages of F_1 litters by pure-line dams and pure-line line litters by pure-line dams.
T – F_1 is the difference between averages of 3-way cross litters produced from F_1 dams and F_1 litters produced by pure-line dams.
[b]FF = Number of fully formed pigs, NBA = Number of pigs born alive, SB = Number of stillborn pigs, MUM = Number of mummified pigs, LBW = Litter birth weight.
[c]LWW = Litter weaning weight, NW = Number weaned.
se = Standard error.
** P < 0.01, *P < 0.05, NS = Not significant (P > 0.05).

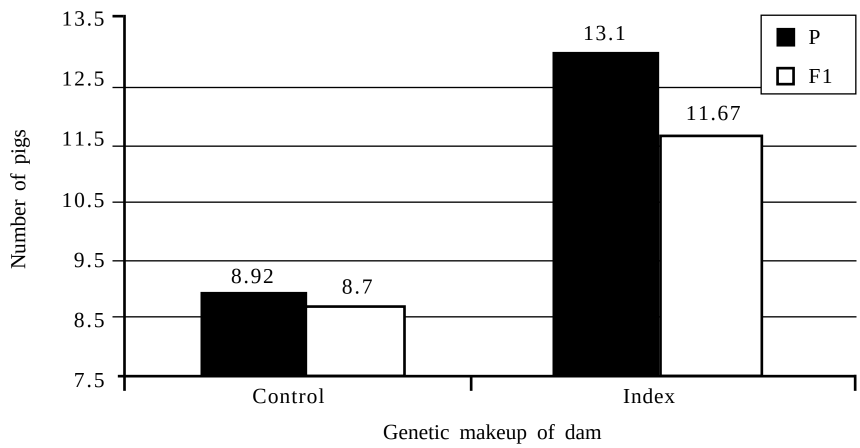

Figure 1. Number of fully formed pigs per litter for pure-line Control and Index dams with pure-line litters (P) and pure-line dams with F_1 litters (F_1).

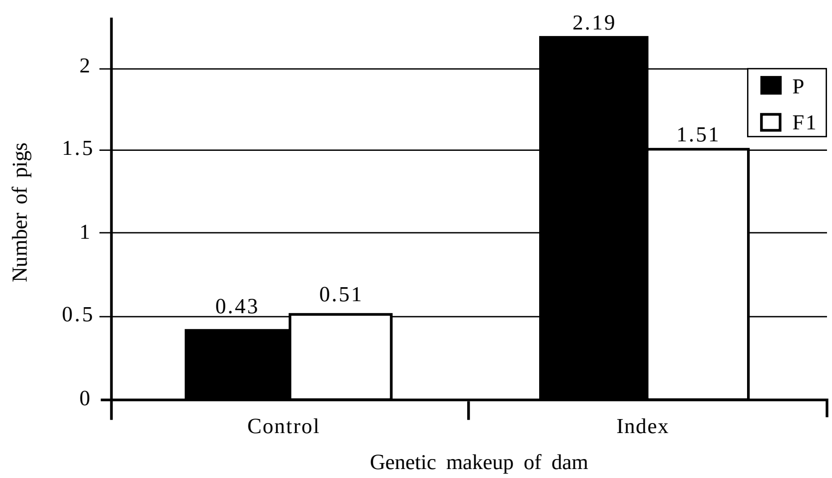

Figure 2. Number of stillborn pigs per litter for pure-line Control and Index dams with pure-line litters (P) and pure line dams with F_1 litters (F_1).

and number of pigs in the litter after crossfostering was completed. Therefore, number weaned and litter weaning weight are traits of the sow as if they were nursing the same number of pigs of the same genetic makeup. Contrasts were used to estimate differences in the overall effect of I vs C and to test whether the response was different in pure line, F_1 and three-way cross litters. Also, the effect of crossing was estimated as the average difference between pure-line, F_1 and three-way cross litters.

Results and Discussion

Line I and C did not differ in farrowing rate. Thus, no correlated response in fertility from selection for litter size in Line I was detected. The overall mean farrowing rate was 90.8%. A slight reduction in farrowing rate occurred when pure-line females were mated to L boars. The average difference in farrowing rate between pure-line females mated pure and those mated AI to L boars was 10.6%. This reduction is not likely a genetic effect of line of service sire, but could have been caused by AI techniques. Pure-line dams artificially inseminated to produce F_1 litters had 8.6% lower farrowing rate than F_1 dams producing three-way cross progeny.

Contrasts were designed to estimate effects due to genetic makeup of the dam. Season and line of pig the dam produced were confounded (see Table 1), so differences could not be averaged across all subclasses. Differences between I and C within interaction subclasses (pure-line, F1 and 3-way) were estimated only if an interaction was detected ($P < 0.05$). Table 2 contains contrasts among means for traits measured at birth.

Responses to selection for increased litter size were 3.53 ± .30 ($P < 0.0001$) fully formed pigs, 2.53 ± 0.30 ($P < 0.0001$) live pigs, 0.99 ± 0.18 ($P < 0.0001$) stillborn pigs, and 0.22 ± 0.06 ($P < 0.01$) mummified piglets per litter. The difference in litter birth weight between I and C was estimated to be 4.72 ± 0.77 lb ($P < 0.0001$).

An interaction of selection response (I minus C) with mating group occurred ($P < 0.05$). The response in I for fully formed pigs when measured in pure-line dams producing pure-line pigs was 4.18 ± 0.39 ($P < 0.0001$) pigs and when measured in pure-line dams producing F_1 pigs response was 2.75 ± 0.30 ($P < 0.0001$) pigs. The difference between I and C in number of stillborn pigs per litter measured in pure-line dams producing pure-line pigs was 1.76 ± 0.22 ($P < 0.0001$) pigs, whereas the difference in pure-line dams producing F_1 pigs was 0.78 ± 0.18 ($P < 0.0001$) pigs. Figures 1 and 2 illustrate these interactions.

Interactions were not significant for litter birth weight, which may explain the interactions for numbers of pigs. If uterine capacity allows only a certain weight of pigs to be carried to term, then pure-line pigs with F_1 litters, for which each individual pig was heavier, could produce that same weight with fewer pigs than pure-line dams with pure line

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pigs. It is also possible that better timing of insemination with ovulation occurred with natural matings used in pure-line production and that fewer eggs were fertilized when artificial insemination in F_1 production was used.

The average I and C F_1 litters produced from pure-line dams had fewer fully formed pigs (-0.83± 0.28; P < 0.01) than the average of pure-line I and C litters. A possible explanation is that pure-line dams producing F_1 progeny were inseminated artificially whereas pure-line progeny were produced with natural matings. Alternatively, uterine capacity may limit total weight of the litter so that litter birth weight is similar for pure-line dams with F_1 litters and pure-line dams with pure-line litters. F_1 dams with three-way cross pigs produced 1.71 ± 0.29 more fully formed pigs, 1.51± 0.29 live pigs and 7.65± 0.73 lb more litter birth weight than pure-line sows with F_1 litters (P < 0.001). These increases are due to heterosis as three-way cross pigs produced from an F_1 dam express 100% individual and maternal heterosis whereas F_1 pigs produced from pure line dams express only 100% individual heterosis.

Correlated response in litter weaning weight to selection for increased litter size was –4.15± 1.61 lb (P < 0.05); however, no response in number weaned was detected. Both of these traits were adjusted for number of pigs after fostering. Litter weaning weight measures both weight and number of pigs; whereas number weaned measures survival rate. These results indicate better milking ability for C than for I sows, but survival rate of pigs was not affected.

An interaction on both number and weight of litters weaned in the expression of the selection response (I – C) when measured in pure-line dams vs F_1 dams occurred (P < 0.05). The response in F_1 dams was –4.72± 1.81 lb (P < 0.01) and response in pure-line dams was -0.62± 1.10 lb (P > 0.05). The response in number weaned in F_1 dams was -0.56 ± 0.18 pigs (P < 0.01) and in pure-line dams it was 0.32± 0.11 (P < 0.01) pigs. Figure 3 and 4 illustrate these interactions. Overall, F_1 dams had litters that weighed 12.23± 1.19 lb (P < 0.0001) more with 0.25 ± 0.12 (P < 0.05) more pigs than pure-line dams.

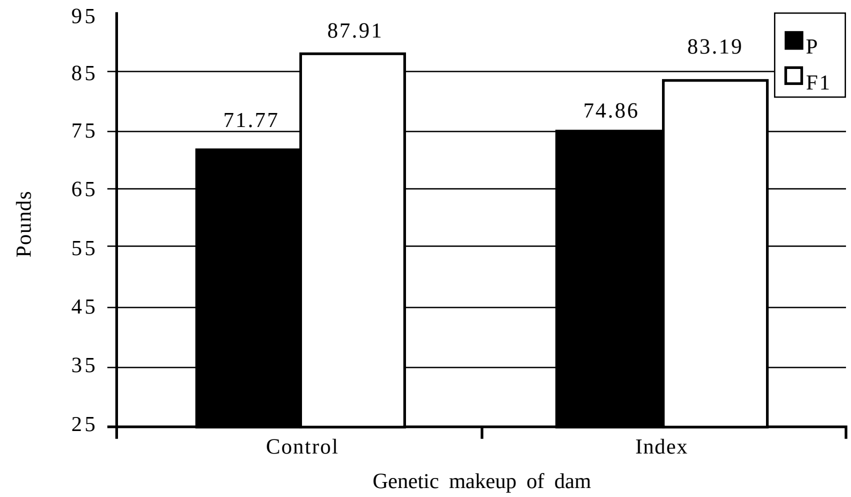

Figure 3. Weight of pigs weaned in standardized litters of pure-line Control and Index dams (P) and F_1 dams (F_1).

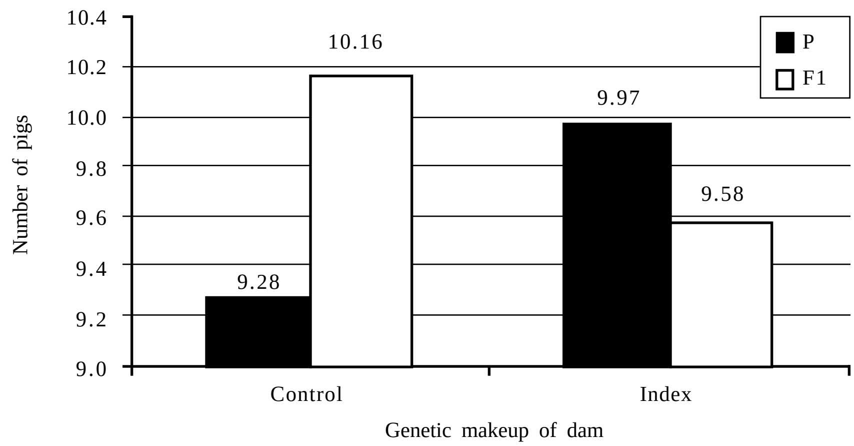

Figure 4. Number of pigs weaned per litter for pure-line Control and Index dams (P) and F_1 dams (F_1).

Conclusion

Responses for litter size in pure lines were consistent with estimates obtained after 14 generations of selection. Responses in included increased total number of pigs and number of live pigs at birth, but also increased incidence of stillborn and mummified pigs and decreased litter weaning weight. Crossbreeding reduced the incidences of stillborn and mummified piglets and litter weaning weight increased greatly in F_1 sows. Sow productivity of Line I at birth and weaning was improved with crossbreeding.

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Growth and Carcass Responses in the NE Index Line Estimated in Pure-line and Crossbred Litters

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Summary and Implications

The objective was to estimate responses in growth and carcass traits in the NE Index line (I) that was selected 19 generations for increased litter size. Responses in pure-line, F_1 and 3-way cross litters were compared. In Exp 1, 694 gilts that were retained for breeding, including 448 I and control (C) and 246 F_1 I and C by Danbred™ Landrace (L), were evaluated. Direct genetic effects of I and C did not differ for backfat or days to 230 lb; however, I had 0.24 in^2 smaller longissimus muscle area (LMA) than C ($P < 0.05$). F_1 gilts had -0.13 in less backfat, 0.67 in^2 greater LMA and –31 d less to 230 lb than pure-line gilts ($P < 0.05$). Exp 2 used individually-penned barrows and gilts including 43 I and C, 77 F_1 produced from pure-line females mated to (L) or Danbred® USA DH boars (T), and 76 3-way crosses produced from F_1 females mated to T boars. Direct genetic effects of I did not differ from C for average daily feed intake (ADFI), average daily gain (ADG), feed conversion (FC), days to 250 lb, backfat (BF), LMA, ultimate pH of the longissimus, longissimus Minolta l score, and % lean estimated by TOBEC. Responses (I minus C) in growth and carcass merit did not differ when measured in pure-line and crossbred pigs. Interactions between responses in F_1 and pure lines were not significant except for pH. F_1 and 3-way cross pigs averaged 0.51 lb/d greater ADFI, -0.53 less feed/gain and 0.44 lb/d more ADG than pure-line pigs ($P < 0.01$). F_1 and 3-way crosses had -0.35 in less BF, 0.89 in^2 greater LMA, 6.2 % greater lean, and 5.3 higher Minolta l* score than pure lines ($P < 0.05$). No correlated responses to selection for increased litter size in overall growth or carcass traits occurred. Mating Line I to leaner, faster growing sires will increase ADFI, ADG, LMA, and percentage lean , decrease feed/gain ratio, decrease backfat, and lighten meat color.*

Materials and Methods

The mating design and selection of parents are described in the preceding paper and are not repeated here. Data for this paper were collected in two experiments on pure-line I and C pigs and F_1 and three-way cross pigs produced by crossing I and C with Danbred Landrace and terminal Duroc-Hampshire sires as described in the preceding paper. The experiment was conducted during three year/season environments.

Experiment 1

A total of 694 gilts that were retained for breeding, including 538 pure-line (I and C) and 156 F1 (L x I and L x C) were evaluated. Backfat (BF) and longissimus muscle area (LMA) at the tenth rib measured with an Aloka 500 instrument and adjusted to weight of 194.5 lb and days to 230 lb were recorded in these gilts.

Experiment 2

A total of 196 barrows and gilts were individually penned. The genetic makeup of these pigs included 21 I, 22 C, 22 L x I, 22 L x C, 17 T x I, 16 T x C, 39 Tx(LxI) and 38 Tx(LxC). Pigs were selected at random from the available litters except for pure line pigs, which were selected at random after replacement gilts and boars were selected. One pig was sampled from as many different litters as possible in order to broadly represent the populations. Pigs were moved from the nursery to the individual feeding unit at approximately 65 days of age. After a 7-day acclimation period, they were placed on test. Pigs were weighed and scanned for BF and LMA at 3-week intervals, and weigh-backs on feeders were taken. A diet formulated to contain 16% crude protein, 0.81% lysine, 0.65% calcium, 0.55% phosphorus, and 1,502 kcal/lb ME was fed throughout the trial. Temperature was maintained at a range of 65 to 80°F depending on season. Pigs were on test until they weighed a minimum of 236 lb when they were transported to SiouxPreme Packing Co. in Sioux C enter, Iowa, for processing and evaluation.

Average daily feed intake (ADFI), average daily gain (ADG), feed conversion ratio (feed/gain), BF, and LMA were recorded on pigs at three-week intervals. Percentage carcass lean estimated by TOBEC, ultimate longissimus pH 24 hours after slaughter, and Minolta l* color score on loins were collected at SiouxPreme.

Statistical Analysis

Data for group-fed gilts, and pen-fed barrows and gilts were analyzed separately. Weight at final age (approximately 170 days), BF, and LMA were recorded for group-fed gilts with genetic group and year/season fitted as fixed effects and with weight at final age as a covariate.

Data for individually-fed pigs were

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Table 1. Contrasts among means for traits measured on gilts retained for breeding (Exp. 1).

Contrast[a]	Traits measured[b] BF (in)	SE	LMA (in^2)	SE	Days to 230 lb	SE
I – C	-0.003	0.02	-0.24*	0.09	3.52	3.77
R: P – F_1	0.10*	0.04	-1.24*	0.56	NS	
$(I – C)_P$	-0.05**	0.01	-0.10	0.20		
$(I – C)_{F1}$	0.03	0.02	-0.67*	0.26		
F_1 – P	-0.13**	0.02	0.66**	0.07	-31.32**	4.34

[a]I – C is the contrast of the overall effect of the index line vs. the control.
R: P – F_{1L} tests the selection response between I and C in pure-line pigs vs. F_{1L} pigs.
$(I – C)_P$ tests the difference between pure-line I and C pigs.
$(I – C)_{F1}$ tests the difference between F_1 I and C pigs.
F_1 – P tests the average difference of F_1 pigs vs the average difference of pure-line pigs.
T – F_1 tests the average difference of 3-way cross pigs vs the average difference of F_1 pigs.
[b]BF = Backfat, LM = Longissimus muscle area.
SE = Standard error.
**P < 0.01.
*P < 0.05.
NS = Not significant (P > 0.05).

Table 2. Contrast among means on growth traits measured on individually-penned pigs (Exp. 2).

Contrast[a]	Traits measured[b] ADFI (lb)	SE	ADG (lb)	SE	FC (lb/lb)	SE	Days to 250 lb	SE
I – C	0.08	0.04	0.02	0.01	0.05	0.10	-4.40	5.25
R: P-F_{1L}	NS		NS		NS		-17.98*	8.85
$(I – C)_P$							4.58	4.00
$(I – C)_{F1L}$							-6.70	3.95
F_{1L} - P	0.12**	0.02	0.09**	0.01	-0.47**	0.06	-27.65**	2.81
T – F_{1L}	-0.03	0.02	0.005	0.01	-0.12*	0.06	-3.33	2.82
T – F_{1T}	0.03	0.03	0.01	0.01	-0.05	0.06	-2.87	3.22

[a]I – C is the contrast of the overall effect of the index line vs the control.
R: P – F_{1L} tests the selection response between I and C in pure-line pigs vs F_{1L} pigs.
$(I – C)_P$ tests the difference between pure-line I and C pigs.
$(I – C)_{F1L}$ tests the difference between F_{1L} I and C pigs.
F_{1L} – P tests the difference between average F_{1L} pigs and pure-line pigs.
T – F_{1L} tests the difference between average 3-way cross pigs and F_{1L} pigs.
T – F_{1T} tests the difference between the average of 3-way cross pigs and F_{1T} pigs.
[b]ADFI = Average daily feed intake, ADG = Average daily gain, FC = Feed conversion.
SE = Standard error.
**P < 0.01, *P < 0.05, NS = Not significant (P > 0.05).

collected during consecutive 3-week intervals from when pigs were placed on test at 72 days (mean weight = 60.0 lb) until they were removed from test at approximately 250 lb. Data for each period and data for the entire test period were analyzed separately. Data recorded were weight at beginning of the test and at the end of each 3-week period, feed intake during each period, BF, and LMA at the end of each period. From the feed intake and weight data, ADG, ADFI, and feed/gain ratio (FC) were calculated. These three traits were analyzed with a general linear model that included genetic group x year x season combination, sex of the animal and group x year x season by sex interaction.

Carcass traits were fitted to the same model with final live weight included as a covariate. The combined effect of season x genetic group was fitted together because all genetic groups did not occur in each season and appropriate linear contrasts of effects were used to estimate line differences and interactions with mating system.

Results and Discussion

Experiment 1

Table 1 contains contrasts among means for growth traits recorded in gilts retained for breeding. Differences between I and C within interaction subclasses (pure line and F_1) were estimated only if the interaction was significant.

There was a correlated response in LMA to selection for increased litter size. Line I gilts had 0.24 ± 0.09 in^2 (P < 0.05) smaller LMA than Line C gilts. Differences between I and C gilts in BF and Days were not significant.

An interaction in responses (I minus C) in BF and LMA in pure line gilts vs F_1 gilts occurred. Pure-line I gilts had -0.05± 0.01in less BF (P < 0.01) than pure-line C gilts. The difference in BF when measured in F_1 gilts was 0.03 ± 0.02 in (P > 0.05). Pure-line I gilts had -0.10± 0.20 in^2 (P > 0.05) less LMA than pure-line C gilts; whereas, the difference when measured in F_1 gilts was -0.67± 0.26 in^2 (P < 0.05). One possible explanation for this interaction is that higher levels of inbreeding (estimated to be 22% in Line I and 15% in Line C at Generation 19) caused Line I pigs to grow slower and eat less feed as purebreds, but this difference was eliminated in F_1 pigs that expressed 100% heterosis.

Overall F_1 gilts had less BF (-0.13± 0.02 in), larger LMA (0.66± 0.07 in^2), and reached 230 lb in fewer days (-31.3 ± 4.34 d) than pure-line gilts (P < 0.0001). These differences are due to the joint effects of 100% heterosis in F_1 gilts and to the effect of the 50% genetic makeup of the F_1 gilts from the Danbred USA™ Landrace sires.

Experiment 2

Sex was significant for ADFI, ADG and Days to 250 lb and season/parity/line was significant for ADFI, ADG, FC and Days to 250 lb. Table 2 contains estimates of contrasts among means. Lines I and C did not differ for any of the traits measured (P > 0.05). Overall, Line I pigs ate 0.08 ± 0.04 lb more feed per

Table 3. Contrast among means for carcass traits measured on individually-penned pigs (Exp. 2).

	Traits measured[b]									
Contrast[a]	BF (in)	SE	LMA (in^2)	SE	% Lean	SE	pH	SE	l*	SE
I – C	0.10	0.06	-0.16	0.26	-0.40	1.56	-0.04	0.08	1.01	2.52
F_{1L} - P	-0.32**	0.04	0.81**	0.15	5.52**	0.96	-0.09	0.05	4.54**	1.49
T – F_{1L}	-0.02	0.04	0.16	0.14	1.39	0.83	-0.01	0.04	1.45	1.36
T – F_{1T}	-0.02	0.04	0.46**	0.16	0.08	0.96	-0.03	0.05	1.04	1.56

[a]I – C is the overall effect of the index line vs the control.
F_{1L} – P tests the difference between the average of F_{1L} pigs and pure-line pigs.
T – F_{1L} tests the difference between the average of 3-way cross pigs and F_{1L} pigs.
T – F_{1T} tests the difference between the average of 3-way cross pigs and F_{1T} pigs.
[b]BF = Backfat, LMA = Longissimus muscle area, Lean = % carcass lean measured with TOBEC, pH = Muscle pH at 24 h after slaughter, l* = Minolta l* color score.
SE = Standard error.
**P < 0 .01, *P < 0.05, NS = Not Significant (P > 0.05).

day, gained 0.02 ± 0.01 lb more weight per day, had 0.05 ± 0.10 greater food/gain ratio, and reached 250 lb 4.40 ± 5.25 days sooner than C pigs.

An interaction for days to 250 lb in selection response (I minus C) estimated in pure-line pigs vs F_{1L} pigs occurred. The response in pure-line pigs was 4.58 ± 4.00 d (P > 0.20) whereas the response in F_{1L} pigs was 6.70 ± 3.95 d (P > 0.05). The biological explanation is that pure line I pigs ate less feed than C pigs, which caused them to gain less rapidly, but L x I pigs ate more feed than L x C pigs. It is possible that the greater level of inbreeding in line I than C caused them to grow slower and eat less feed as purebreds, but this difference was eliminated in F_1 pigs. Overall F_{1L} pigs had higher ADFI (0.12 ± 0.02 lb), ADG (0.09 ± 0.01 lb/d), lower FC (-0.47 ± 0.06), and reached 250 lb in fewer days (27.7 ± 2.81 d) than pure-line pigs (P < 0.001). Overall three-way cross pigs had lower FC (-0.12 ± 0.06) than F_{1L} pigs (P = 0.05). Other differences between three-way cross pigs and F_{1T} pigs were not significant.

Responses estimated in the different crosses differ because F_1 pigs express 100% individual heterosis, whereas pure line pigs express no heterosis, and 50% of the genetic makeup of the F_{1L} pigs were from the Danbred® USA Landrace sire. The enhanced performance of 3-way crosses over F_{1L} pigs was due to the effect of the Danbred® USA Terminal sire and the expression of 100% individual and maternal heterosis.

Carcass Traits

Sex was significant for BF and percentage carcass lean and season/parity/line was significant for BF, LMA, percentage lean, and Minolta l* color score. Interactions between these effects were not significant. Traits were standardized to a live weight at slaughter of 248.2 lb. Table 3 contains estimates of contrasts among means.

Lines I and C did not differ (P > 0.05) for any of the traits measured. Overall, I had 0 .10 ± .06 in more BF, 0.16 ± 0.26 in^2 less LMA, 0.40 ± 1.56 less % lean, 0.04 ± .08 lower pH, and 1.01 ± 2.52 greater Minolta l* color score (paler meat).

Interactions of line differences and genetic background where measured were not significant. When pigs are standardized to a live weight of 248.2 lb the conclusion is that responses in I and C did not differ in carcass merit when measured in pure-line and crossbred pigs.

Overall F_{1L} pigs had less BF (-0.32 ± 0.04 in), more LMA (0.81 ± 0.15 in^2), greater percentage carcass lean (5.52 ± 0.96 %), and higher Minolta l* color score (4.54 ± 1.49 score) than pure-line pigs (P < 0.01). Differences between three-way cross pigs and F_{1L} pigs and between three-way cross pigs and F_{1T} pigs were not significant.

Conclusion

There were no correlated responses in growth and carcass traits to selection for increased litter size. Line differences were expressed equally in pure line and crossbred pigs. Carcass and growth traits were greatly improved by crossing both Lines I and C with Danbred's Landrace and Terminal sires.

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Economic Analysis of the Selection Response in the NE Index line

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Summary and Implications

The objective was to estimate economic effects of 19 generations of selection for increased litter size in the NE Index line. Using realized biological data, 1,250-sow enterprises based on Index line and Control line females were simulated. Each system was closed to introduction of females and included pureline females mated to produce replacement pureline and F_1 gilts, and F_1 females mated to terminal cross boars to produce market progeny. Costs of production and income statements were produced using the reproductive, growth and carcass data from the NE Index (I) and Control (C) lines reported in the two preceding papers. Gross revenues were estimated using the SiouxPreme Packing Co. grid payment matrix. The production system based on Index sows produced 24,417 pigs per year with net income of \$23.76 per pig. The output for the system based on Control sows was 20,166 pigs with net income of \$16.73 per pig. Within each mating group, net revenue for pureline I pigs was \$2.05 per pig more than for Line C pigs and net revenue for three-way cross pigs with 25% Line I genes was \$2.89 per pig more than for terminal cross pigs with 25% Line C genes. However, net revenue for F_1 pigs with 50% Line C genes was \$2.50 per pig more than for those with 50% Line I genes. Highly prolific lines such as Line I have a large effect on reducing production costs and increasing income. Crossbreeding is an effective way to utilize the enhanced reproductive efficiency of the Index line.

Background

The NE Index Line (Line I) was developed with selection only for increased litter size. It excels in reproduction. Its commercial value was demonstrated in the National Pork Producers Council Maternal Evaluation Project (MLE) that included GPK347 females, a cross of the Index line with a maternal line of DeKalb Choice Genetics. Return on equity for a system using GPK347 was 21.1% compared with 16.5% for the average of other lines in the MLE. Although this experiment produced economic data that led to increased use of the Index line in commercial production, it did not produce data to calculate the economic return from selection for litter size. To estimate the economic response, total production systems based on either Index or Control sows must be compared.

In this analysis data from the litters and pigs described in the previous papers were used to simulate a 1,250-sow farrow-to-finish enterprise to compare economic returns for breeding systems using either Line I or Line C females. The production system was closed to introduction of females and used artificial insemination to produce F_1 replacement gilts and terminally-sired market pigs.

Materials and Methods

Table 1 contains the number of litters per year along with mean reproductive performance for 1,250-sow units based on Line C and Line I females. In each case, it was assumed that the pure line was propagated within the system and semen from Danbred® USA Landrace or terminal sires was used to produce F_1 gilts and market pigs, respectively. The number of pureline females was set at 50 with 15 boars retained for breeding each generation to maintain rate of inbreeding in the pure line at approximately 1% per generation. The number of matings of I or C sows to produce F_1 gilts was determined by experimental estimates of farrowing rates and litter sizes, and imposed gilt selection rate and sow culling rates described below.

Production Assumptions

Annual sow and boar replacement rates were set at 30% and 33%, respectively. Female replacement rate corresponded with a policy of culling all open females and all females that had eight litters. A confinement production

Table 1. Reproductive statistics and estimated number of I and C sows necessary to maintain a 1,250-breeding sow operation.

Genetic Group[a]	% FR[b]	NBA[c]	DL[d]	Litters[e]	% oF total	Replacements	Market pigs
C	98.2	8.49	0.20	116	4	41	733
L x C	81.5	8.27	0.20	160	5.5	339	524
T(L x C)	86.5	10.37	0.20	2,635	90.5	-	18,909
Total				2,912	100	380	20,166
I	93.5	10.90	0.20	116	4	37	909
L x I	84.3	10.28	0.20	131	4.5	345	564
T(L x I)	88.9	12.11	0.20	2,664	91.5	-	22,944
Total				2,912	100	382	24,417

[a]C = Control, I = Index, L x C = Landrace x Control, L x I = Landrace x Index, T (L x C) = Terminal DH x (Landrace x Control) three-way cross, T (L x I) = Terminal DH x (Landrace x Index) three-way cross.
[b]FR = Farrowing Rate of gilts and sows designated for breeding.
[c]NBA = Number born alive per litter.
[d]DL = Death loss.
[e]Litters = Number of litters per year.

Table 2. **Income statement for integrated breeding system based on Control and Index line females.**[a]

	Control line			Index line		
	Line C	L x C	T(L x C)	Line I	L x I	T (L x I)
Gross revenue/pig sold, $	102.42	125.12	124.60	105.47	122.62	127.49
Less death loss cost/pig sold, $	1.62	1.62	1.62	1.62	1.62	1.62
Net revenue/pig sold, $	100.80	123.50	122.98	103.85	121.00	125.87
Variable costs/pig sold, $						
Feed costs, $	61.14	45.95	40.87	61.00	45.10	41.31
Labor costs, $	14.12	14.12	14.12	13.10	13.10	13.10
Veterinary, drugs and supplies, $	1.64	1.64	1.64	1.60	1.60	1.60
Utilities, $	2.28	2.28	2.28	2.22	2.22	2.22
Fuel and oil, $	0.41	0.41	0.41	0.40	0.40	0.40
Water costs, $	2.03	2.03	2.03	1.98	1.98	1.98
Building and equipment repairs, $	2.59	2.59	2.59	2.52	2.52	2.52
Transportation costs, $	1.39	1.39	1.39	1.35	1.35	1.35
Semen cost, $	—	17.38	1.58	—	13.10	1.32
Waste management, $	1.54	1.54	1.54	1.50	1.50	1.50
Marketing, $	4.10	4.10	4.10	4.00	4.00	4.00
Interest on variable costs, $	2.93	2.93	2.93	2.85	2.85	2.85
Total variable costs/pig , $	94.17	96.36	75.48	92.52	89.72	74.15
Contribution margin/pig, $	6.63	27.14	47.50	11.33	31.28	51.72
Fixed cost/pig sold, $						
Depreciation on buildings (15 yr), $	8.94	8.94	8.94	8.43	8.43	8.43
Depreciation on major equipment (10 yr), $	0.79	0.79	0.79	0.65	0.65	0.65
Depreciation on minor equipment (5 yr), $	0.20	0.20	0.20	0.16	0.16	0.16
Interest on buildings and major equipment	5.09	5.09	5.09	4.76	4.76	4.76
Insurance and taxes on buildings and major equipment, $	3.03	3.03	3.03	2.80	2.80	2.80
Professional fees, $	1.00	1.00	1.00	1.00	1.00	1.00
Maintenance cost (breeding stock), $	9.91	9.91	9.91	8.18	8.18	8.18
Total fixed costs/pig sold, $	28.96	28.96	28.96	25.98	25.98	25.98
Net return per/sold, $	-22.33	-1.82	18.54	-14.65	5.30	25.74
Number of pigs sold	733	524	18,909	909	564	22,944
Net return on total number of pigs sold, $	-16,367.89	-953.68	350,572.86	-13,313.47	2,991.30	590,663.91
Total net return, $			333,251.29			580,341.74
Rate of return on investment, %			12			18
Cash return/pig sold, $[b]	-12.40	8.11	28.47	-5.41	14.54	34.98

[a]L x C = Danbred® USA Landrace x Control, T (L x X) = Danbred® USA terminal Duroc-Hampshire x (L x C), L x I = Landrace x Index, and T (L x I) = Duroc-Hampshire (L x I).
[b]Cash return/pig sold = net return/pig sold plus all depreciation costs.

system including breeding and gestation facilities, farrowing facilities, nursery, and finishing facilities was modeled. The production system modeled mimicked the one used at the University of Nebraska Experimental Swine Farm in which pigs are weaned at 12 days of age and raised in a nursery until approximately 55 to 60 days when they are transferred to a finishing building. Once market weight was reached (250 lb) value was calculated based on the SiouxPreme Packing Co. payment matrix.

Breeding gilts and pureline boars were selected at approximately 180 days and transferred to the breeding and gestation building. Number of selected females and matings varied with fertility of the lines to produce 56 litters per week.

Income Statements

Costs of production were based on estimates of new construction/equipment costs that were depreciated over 15 years for buildings, 10 years for major equipment, and five years for minor equipment. These costs and those for additional fixed and variable inputs described in Table 2 were charged back to pigs on a per pig marketed basis.

New housing costs were set at $130 per pig space for the nursery, $175 per pig space for finishing, and $1,100 per breeding female space for breeding, gestation and farrowing. Other costs were obtained from a variety of sources including the 1999 Iowa State University Swine Report, the Maternal Line Genetic Evaluation Program Economic Analysis, and a local Nebraska producer.

Gross income was calculated on the SiouxPreme Packing Co. matrix that takes into account weight of the carcass and percentage lean estimated by TOBEC. Average market death loss was assumed to be equal for both Line I and Line C systems. Variable costs were then calculated and subtracted from net income to calculate an economic value known as contribution margin per pig marketed. Contribution margin is defined as net revenue per pig marketed minus variable cost per pig marketed. Fixed costs were calculated and subtracted from the contribution margin to give net return per pig marketed.

Results and Discussion

Net Revenue Per Pig Marketed

Income statements for production systems are in Table 2. Net revenue per

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pig marketed varied by line and cross, ranging from $100.80 per pig for Line I to $125.49 per pig for T (L x I). Pureline I and C pigs were predicted to have carcass value of 93% of the base price on the Sioux Preme matrix, F_1 L x I and L x C were predicted to have value of 102% of the base price, and three-way terminal crosses 103% of the base price. In the system based on Line I, net revenue was greater for three-way cross than for F_1 pigs ($125.87 vs $121.00 per pig). However, in the system based on Line C, net revenue per pig was greatest for F_1 pigs ($123.50) because their carcass weight was greater. Overall, three-way terminal cross Line I pigs had the most net revenue per pig.

Averaged across Line I and C systems, the increase in net revenue from pureline pigs to F_1 pigs was $19.93 per pig. There was a small additional increase of $2.18 from F_1 to three-way cross pigs. The terminal crossing systems that realized 100% heterosis and used the Danbred® USA lines selected for increased growth rate and percentage carcass lean had a large, positive effect on gross revenue per pig.

Variable Costs

Feed costs made up more than 50% of the total variable costs and therefore efficiency of feed use greatly affected variable costs per pig. Three-way cross pigs were the most efficient and reached market weight sooner than F_1 or pureline pigs. Pureline pigs took 31 days longer to reach market weight and had feed/gain ratios 0.59 units higher than three-way crosses. Line I pigs had an advantage of $0.55 per pig over Line C in feed costs.

Labor costs for breeding/gestation/farrowing/nursery were fixed for the size of the production unit and thus total costs for this labor was the same for systems using both Line I and Line C females. Labor costs for finishing pigs were calculated assuming a constant pig/worker ratio. Because more pigs were produced in the Line I system (Table 1), it needed one more employee for finishing, but produced 4,251 more pigs than the Line C system. As a result labor costs per pig were greater in the Line C system ($14.12 per pig) than for the Line I system ($13.10 per pig).

Semen costs differed among crosses and between Line I and C systems. There was no semen cost for pureline I and C production because these pigs were produced with natural service. Breeding costs for boars in pureline production were considered to be part of breeding herd maintenance costs included in fixed costs as described below. The cost of semen for L and T was set at $30 and $6 per dose, respectively, which made semen costs greater for production of F_1 pigs ($13.10 per pig for Line I system vs $17.38 per pig for Line C system) than three-way cross pigs. Semen costs were $1.32 per pig and $1.58 per pig for three-way cross Line I and C pigs, respectively. Semen costs were less for I than C because both farrowing rate and litter size were higher for I than C sows. In addition, waste management costs per pig marketed were less for Line I than C ($1.50 vs $1.54) because both required the same number of gestation/farrowing spaces, but Line I produced more pigs. The remaining variable costs expressed per pig marketed were also less in Line I because of its greater litter size.

Contribution margin per pig was higher in all three crosses for the system with Line I than the one with Line C. Averaged across the I and C systems, contribution margin for three-way cross pigs was $20.40 per pig more than for F_1 pigs, and the margin for F_1 pigs was $20.23 higher than for pureline pigs.

Fixed Costs

Depreciation costs were considered a fixed cost and were lower in the system with Line I because of the increased number of pigs marketed. However, the major difference in fixed costs between Line I and C systems was due to maintenance cost of breeding stock that included costs to maintain breeding boars, gilts and sows. This cost was $8.18 per pig for the Line-I system and $9.91 per pig for the Line-C system.

Net Return

Crossbreeding had a large effect on net return. Averaged across systems net return for F_1 pigs was $20.23 per pig more than for pureline pigs and return for three-way cross pigs was $20.40 per pig more than for F_1 pigs. Profitability for each group within the system and for the entire system was greater for the Line-I system than the Line-C system. The return for pureline I and C pigs was negative, $-14.65 per pig and $-22.33 per pig, respectively, because they grew slow, had poor feed conversion, and had substandard carcasses. Net return for F_1 L x I and L x C pigs was $5.30 per pig and $1.82 per pig, respectively. Net return for three-way cross T(L x I) pigs was $25.74 per pig vs $18.54 for three-way cross T(L x C) pigs.

Rate of Return on Investment

Net income for the system was calculated as the sum of the product of number of pigs times net return per pig for each of the three crosses within the Line I and Line C system divided by the total number of pigs within the system. The production system based on Index sows produced 24,417 pigs per year with average net income of $23.76 per pig. Output for the system based on Control sows was 20,166 pigs with net income of $16.73 per pig. There was an advantage of 6% in rate of return on investment for the system with Line I sows.

Conclusion

The system with Line I females marketed 3.4 pigs more per sow per year than the Line C system for an annual response to 18 generations of selection (the study used pigs from Generations 17, 18, and 19) of 0.19 pigs marketed per sow per year. The total difference in net return was $7.03 per pig. The annual response in net return from selection for increased litter size was $0.39 per pig marketed.

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PAYLEAN® Improves Growth and Carcass Merit of Pigs with 25% and 50% Nebraska Index Line Genes

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Summary and Implications

The Nebraska Index Line excels in reproduction and is being used in industry breeding programs. However, because it has been selected only for litter size since 1981, growth and carcass merit of pure-line pigs are below industry standards. The objectives of this experiment were 1) to compare growth and carcass traits of Index cross pigs with either 50% or 25% Line I genes in a crossbreeding system typical of how the line is used in the industry and 2) to determine the effects of feeding 18 g PAYLEAN® per ton during the last 28 days of the feeding period on Index cross pigs. Line I was crossed with Danbred® USA Landrace (L) boars and Duroc-Hampshire terminal boars to produce F_1 pigs with 50% Line I genes and terminal cross pigs with 25% Line I genes. Pigs with 25% Line I genes grew faster (2.03 vs. 1.97 lb/d) from 65 days of age to approximately 240 lb than pigs with 50% Line I genes ($P < 0.05$). They also ate more feed per day although the difference was not significant (5.82 vs 5.76 lb per d). Thus, the difference between groups in feed conversion was small and not significant. Terminal cross pigs with 25% Line I genes had only 0.02 in less backfat at the end of the experiment than F_1 pigs with 50% Line I genes, but they had significantly larger longissimus muscle area (6.42 vs 6.10 in^2) and greater percentage carcass lean (52.4 vs 51 %). Pigs of both genetic groups and both barrows and gilts responded similarly to a diet with 18 g PAYLEAN® per ton. Feeding PAYLEAN® at 18 g/ton for 28 days significantly increased growth rate (2.19 vs. 1.80 lb/d), reduced feed intake (6.49 vs. 6.81 lb/d) improved efficiency of growth (0.33 vs 0.26 gain/feed ratio, corresponding with 3.03 and 3.85 feed/gain ratios), increased carcass weight (185.4 vs 177.2 lb), increased dressing percentage (75.2 vs 74.3%), and increased carcass lean (53.6 vs 49.9%). Performance and carcass merit of pigs with 25% Line I genes were greater than for F_1 pigs with 50% Line I genes, and feeding PAYLEAN® at the rate of 18 g per ton produced similar increases in performance and carcass merit of both groups.

Introduction

The Nebraska Index Line (Line I) was established in 1981 and has been selected only for increased litter size. Line I sows produce approximately 3.5 more pigs per litter than a randomly selected control that was derived from the same base population. A cross known as GPK347 of Line I with a maternal line of DeKalb Choice Genetics was entered into the National Pork Producers Council Maternal Line Evaluation and evaluated along with five other industry lines. Total productivity through four parities per replacement gilt for GPK347 females was 33% to 51% greater than for the other lines. Females of all six lines were mated to the same terminal sires, and growth of progeny and percentage carcass lean of progeny of GPK347 sows were 94% and 98%, respectively, of the average of other crosses.

Even with slower and less efficient growth and fatter carcasses in progeny, net return on investment was estimated to be as great or greater for the GPK347 sows than for all other lines. As a result, pork producers are using crosses of Line I in breeding programs and future use of these crosses is expected to increase. In these systems, F_1 Index cross gilts are produced and crossbred gilts and sows are mated to terminal sires to produce three-way cross pigs. Two kinds of market pigs – those with 50% Line I genes, the F_1 barrows and cull gilts from F_1 gilt production, and those with 25% Line I genes, the three-way cross terminal pigs – are produced. Faster, more efficient growth and leaner carcasses in both of these groups would enhance the value of Line I cross females to commercial producers.

Ractopamine HCl is a feed ingredient that directs nutrients to increase growth, improve efficiency and increase amount of carcass lean. PAYLEAN® is a trademark of Elanco's brand of ractopamine. The objective of this experiment was to 1) determine the difference in growth and carcass traits of F_1 pigs that were 50% Line I and terminal cross pigs that were 25% Line I, and

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2) to determine the response in growth and carcass traits and the economic return in barrows and gilts of both of these groups to a diet with 18 g per ton of PAYLEAN® fed the last 28 days before slaughter.

Methods

A total of 306 pigs from 56 litters were used. Pigs with 50% Line I genes (designated F_1) were an F_1 cross produced by artificially inseminating Line I females with semen of Danbred® USA Landrace (L) boars. Pigs with 25% Line I genes (designated T) were terminal cross pigs produced by inseminating L x I females with semen of Danbred® USA Duroc-Hampshire terminal sires. The litters were a random sample of approximately 35 litters of each group and pigs were a random sample from within these litters. Equal numbers of barrows and gilts were sampled.

Pigs were moved from a nursery to finishing facilities at approximately 56 days of age. A random sample of 66 pigs, an equal number of each sex and genetic group, were placed in an environmentally controlled building with individual feeding pens (IFU), the remainder were placed in 24 pens of a naturally ventilated building (MOF) with 10 pigs of the same sex and genetic group in each pen. A corn-soybean meal based diet formulated to contain 18% crude protein, 0.95% lysine, and 1,506 kcal ME per lb was fed to all pigs throughout the experiment. A random one-half of the pigs received this diet with PAYLEAN® at the rate of 18 g per ton during the last 28 days before slaughter.

After a one-week adjustment period, each pig was weighed and individual feed intake recording of pigs in the IFU and pen feed intake recording of pigs in the MOF commenced. One pig in the MOF died during the adjustment period leaving a total of 305 pigs in the trial. At the beginning of the trial, one-half of the pigs in the IFU and one-half of the pens in the MOF were randomly assigned within each sex-genetic group subclass to receive the diet containing PAYLEAN®.

Traits

The objective was to feed pigs in the IFU to a final weight between 240 and 260 lb and to feed pens of pigs in the MOF to final average weights between 240 and 250 lb with all pigs in the pen weighing at least 215 lb. To accomplish these objectives, each pig was weighed at 21, 42 and 63 days after being placed on test. Slaughter date was designated for each pig or pen of pigs based on previous growth rate and 63-day weight. The final 28-day period for each pig began either 63, 70, or 77 days after being placed on test. Pigs were weighed again 14 days before designated slaughter date.

Individual feed intake for pigs in the IFU and pen feed intake for pigs in the MOF were recorded. Feed intake was recorded for Period 1, the first 21 days on test, Period 2, the second 21 d, Period 3, the variable period from 42 days after being placed on test to 28 days before designated slaughter date, Period 4, the first 14 days when PAYLEAN® was fed, and Period 5, the last 14 days when PAYLEAN® was fed. Feeding periods 1 and 2 were each 21 days, Period 3 averaged 22.9 days, and Periods 4 and 5 were each 14 days. Performance was recorded in each period to determine the growth pattern of pigs of each line and to determine whether the pattern was different when pigs were eating diets with and without PAYLEAN®.

Each pig was scanned for tenth rib backfat thickness and longissimus muscle area with an Aloka 500 instrument at the end of each period. Backfat and longissimus muscle area were not recorded at day 0.

After final weights and scan data were collected pigs were transported to SiouxPreme Packing Co., Sioux Center, Iowa where they were slaughtered the next morning. Carcass traits recorded were hot carcass weight, percentage carcass lean estimated by TOBEC, and 24-hour post slaughter longissimus muscle pH and Minolta l* color score.

Statistics

Average daily feed intake for each pen of pigs in the MOF was calculated for each period and this average was assigned to each pig in the pen. Feed efficiency was calculated for each pig as the ratio of its weight change during the period to actual feed intake (IFU) or pen average feed intake (MOF). Growth traits analyzed were weight at the beginning of the trial, weight, backfat and longissimus muscle area at the end of Period 3, and at the end of the trial, and average daily gain, average daily feed intake, and gain/feed ratio during each period of growth. Carcass traits analyzed were hot carcass weight, dressing percentage, percentage lean, pH, and Minolta l* score.

All traits including feed intake and gain/feed were analyzed as a trait of the pig and data for pigs in the IFU and MOF were analyzed together. A mixed-model that accounted for the random effects of litter and pig within pen and the fixed effects of building, genetic line, sex, diet (with or without PAYLEAN®) period of growth, two-factor interactions of line, sex, and diet with period, and the 3-order interactions of line by sex by period, line by diet by period, and sex by diet by period was fitted to data collected during the growing period. Period was omitted from models of carcass traits.

Results

Growth

The number of pigs, average weight at the beginning of the trial and average weight, backfat thickness, and longissimus muscle area at the end of Period 3, and at the end of the trial for pigs in each group are in Table 1. Pigs with 25% and 50% Line I genes did not differ significantly in weight or backfat thickness, but T pigs had 0.25 ± 0.093 in^2 larger longissimus muscle area after 63 days on test and 0.32 ± 0.093 in^2 larger muscle area at the end of the trial than F_1 pigs. At the end of the trial barrows were heavier than gilts and had greater backfat thickness and smaller longissimus muscle area ($P < 0.05$). Pigs designated to be fed PAYLEAN® did not differ from controls in weight, backfat, or longissimus muscle area at the end of Period 3, before PAYLEAN® was fed. After 28 days of eating a diet with 18 g PAYLEAN® per ton, pigs weighed more (8.4± 2.12 lb), had less backfat (-0.08± 0.021 in), and had larger longissimus muscle area (0.68 ± 0.07 in^2) than controls ($P < 0.01$).

Average daily feed intake, average daily gain, and gain/feed ratios during each period are in Table 2. Interactions of line and sex with period of growth and with PAYLEAN® treatment generally were not significant. Terminal cross pigs gained faster than F_1 pigs in each period, although the difference was significant only in Period 5. Averaged over the test period, pigs with 25% Line I genes gained 0.068 lb/d more than pigs with 25% Line I genes ($P = 0.05$). Terminal cross and F_1 pigs had very similar feed intake in each period and did not differ significantly in gain/feed ratio. Barrows ate more feed and gained more rapidly in each period than gilts ($P < 0.01$), but the sexes did not differ significantly in gain/feed ratio.

PAYLEAN® had a dramatic effect on average daily gain during the first 14 days it was fed when pigs fed PAYLEAN® gained 0.56 ± 0.044 lb/d more than controls. Although not significant, daily feed intake was -0.20 ± 0.121 lb less; consequently gain/feed ratio exceeded that of controls by 0.09 ± .044 units during the first 14 d. The increase in daily gain for pigs fed PAYLEAN® during the second 14 days was less (0.24 ± 0.04 lb/d) because PAYLEAN® reduced daily feed intake more (-0.44± 0.121 lb) than during the first 14 days that it was fed. Gain/feed ratio for pigs fed PAYLEAN® was still significantly better during the last 14 days than for pigs fed the control diet (0.05 ± 0.007 units). These results are consistent with reports in the literature that the greatest benefit from feeding PAYLEAN® occurs during the first two weeks. Pigs can become refractory to PAYLEAN® as the length of the feeding period increases. The gain/feed ratios for pigs fed PAYLEAN® correspond with ratios of 3.03 lb feed per lb gain during the 28 days that PAYLEAN® was fed, whereas ratios for control pigs correspond with 3.85 lb feed per lb gain during this period.

Table 1. Least-squares means and contrasts for weight, backfat and longissimus muscle area

Feeding interval[a]	Line[b] T	Line[b] F_1	Line[b] P[e]	Sex[c] B	Sex[c] G	Sex[c] P[e]	Paylean[d] +	Paylean[d] -	Paylean[d] P[e]
				Number of pigs					
	151	154		152	153		153	152	
				Weight at beginning of test (day 0), lb					
	57.8	55.1		56.0	56.9		56.4	56.4	
				Days during each interval					
1	65.1	66.2		63.9	67.4		64.9	66.3	
2	28	28		28	28		28	28	
				Weight at end of period, lb					
1	185.9	184.1	0.57	185.9	183.9	0.39	183.5	186.5	0.13
2	241.7	237.5	0.18	241.9	237.3	0.05	243.7	235.3	< 0.01
SE_D[f]	3.00			2.36			2.12		
				10th rib backfat at end of period, in					
1	0.55	0.57	0.29	0.60	0.52	< 0.01	0.55	0.57	0.11
2	0.69	0.71	0.16	0.76	0.65	< 0.01	0.66	0.74	< 0.01
SE_D	0.021			0.021			0.021		
				Longissimus muscle area at end of period, in^2					
1	5.16	4.91	< 0.01	4.94	5.15	< 0.1	5.04	5.04	0.87
2	6.42	6.10	< 0.01	6.18	6.34	0.03	6.60	5.92	< 0.01
SE_D	0.093			0.076			0.070		

[a]Feeding interval 1 includes Periods 1, 2, and 3 (see text) when PAYLEAN® was not fed and varied in length, Feeding interval 2 was the last 28 days of the trial when PAYLEAN® (18g/ton) was fed to half of the pigs.
[b]F_1 = Index x Landrace F_1 cross, T = Duroc-Hampshire (I x L) cross.
[c]G = gilt, B = barrow.
[d]- = PAYLEAN® not fed, + = PAYLEAN® fed last 28 days.
[e]P = the probability associated with tests of differences between lines, sexes, or diets.
[f]SE_D = standard error of differences between means.

Daily feed intake increased as pigs increased in age and weight. However, average daily gain was greater during Periods 2 and 3 (days 22 to 63 of the feeding period) than during all other periods. Sharp reductions in daily gain and efficiency of growth occurred during the last 28 days of the feeding period.

Carcass Traits

Pigs with 25% Line I genes had heavier carcass weights (5.1± 2.6 lb, $P = 0.06$; Table 3) due in part to greater live weight (Table 1) and in part to greater dressing percentage (0.5 ± 0.3 %) than pigs with 50% Line I genes. They also had 1.4 ± 0.6 % more carcass lean and paler muscle as Minolta l* values were 1.8± 0.8 units greater ($P < 0.05$). The two genetic groups did not differ in longissimus muscle pH.

Barrows had 2.8 ± 2.1 lb heavier carcasses than gilts ($P = 0.20$), due to their greater weight at the end of the test; however, some of the difference in live weight was offset by the 0.7± 0.2 % ($P < 0.01$) greater dressing percentage for gilts than barrows. Gilts also had carcasses with 1.2 ± 0.5 % more lean than barrows ($P < 0.01$), but carcasses of the sexes did not differ significantly in muscle pH or Minolta l* color score.

Pigs fed PAYLEAN® had heavier carcasses (8.2± 1.9 lb, $P < 0.01$) due to both greater live weight (Table 1) and to an increase of 0.9 ± 0.2% in dressing

(Continued on next page)

percentage ($P < 0.01$). Pigs fed PAYLEAN® had 3.7±0.5% more lean in carcasses than control pigs ($P < 0.01$). Pigs fed PAYLEAN® and controls did not differ significantly in longissimus muscle pH or Minolta l* score.

Conclusions

Pigs with 25% Line I genes and 75% genes from Danbred ® USA lines grew more rapidly, had greater carcass lean, and paler longissimus muscle than pigs with 50% of their genes from each source. Pigs of both genetic groups responded similarly to a diet with 18 g per ton PAYLEAN®. Feeding pigs a diet with 18 g per ton PAYLEAN® for 28 days before slaughter increased growth rate 22%, improved feed conversion ratio 27%, and increased carcass lean 7.4% over control pigs; however, the effect of feeding PAYLEAN® was approximately twice as great during the first 14 days that it was fed compared with the last 14 days.

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Table 2. Least-squares means and contrasts for average daily feed intake, average daily gain, and gain/feed ratio during each of five periods of growth.

Feeding interval[a]	Line[b] F_1	Line[b] T	P^e	Sex[c] G	Sex[c] B	P^e	Paylean[d] -	Paylean[d] +	P^e
				Avg. daily gain, lb					
1	1.81	1.85	0.55	1.76	1.90	< 0.01	1.83	1.83	0.67
2	2.03	2.12	0.06	1.96	2.18	< 0.01	2.07	2.07	0.72
3	2.07	2.12	0.48	2.01	2.18	< 0.01	2.12	2.07	0.30
4	2.12	2.18	0.09	2.09	2.23	< 0.01	1.87	2.43	< 0.01
5	1.79	1.90	0.03	1.79	1.92	< 0.01	1.72	1.96	< 0.01
SE_D[f]	0.044			0.044			0.044		
				Avg. daily feed intake, lb					
1	4.63	4.63	0.90	4.52	4.74	0.08	4.67	4.59	0.49
2	5.34	5.49	0.22	5.23	5.62	< 0.01	5.40	5.42	0.81
3	6.17	6.15	0.98	5.84	6.48	< 0.01	6.20	6.11	0.46
4	6.62	6.77	0.10	6.46	6.88	< 0.01	6.77	6.57	0.09
5	6.59	6.68	0.45	6.42	6.86	< 0.01	6.86	6.42	< 0.01
SE_D	0.121			0.121			0.121		
				Gain/feed ratio, lb/lb					
1	0.40	0.42	0.09	0.41	0.41	0.99	0.41	0.41	0.84
2	0.38	0.39	0.40	0.38	0.39	0.16	0.38	0.38	0.81
3	0.34	0.34	0.34	0.34	0.34	0.31	0.34	0.34	0.48
4	0.31	0.32	0.32	0.32	0.32	0.87	0.27	0.36	< 0.01
5	0.27	0.28	0.10	0.27	0.27	0.65	0.25	0.30	< 0.01
SE_D	0.008			0.007			0.007		

[a]Periods 1 and 2 were each 21 d, Period 3 was 22.9 d, and periods 4 & 5 were each 14 d.
[b]F_1 = Index x Landrace F_1 cross, 3-way = Duroc-Hampshire (I x L) cross.
[c]G = Gilt, B = barrow
[d]- = PAYLEAN® not fed, + = PAYLEAN® (18g/ton) fed last 28 d, during Periods 4 and 5.
[e]P = the probability associated with tests of differences between lines, sexes, or diets.
[f]SE_D = standard error of differences between means.

Table 3. Least-squares means and contrasts ± SE for carcass traits.[a]

Item		HCW, lb Mean	P^e	Dress % Mean	P^e	% Lean Mean	P^e	pH Mean	P^e	Minolta 1 Mean	P^e
Line[b]	T	183.8		75.0		52.4		5.72		50.4	
	F_1	178.8		74.5		51.0		5.79		48.6	
		5.1 ± 2.6	0.06	0.5 ± .3	0.07	1.4 ± .6	0.03	-.07 ±.06	0.24	1.8 ±0 .8	0.04
Sex[c]	G	179.9		75.2		52.3		5.75		49.2	
	B	182.7		74.4		51.4		5.76		49.8	
		-2.8 ± 2.1	0.20	0.7 ± 0.2	< 0.01	1.2 ± .5	< 0.01	.01 ± .06	0.92	0.6 ± 0.8	0.44
Paylean[d]	+	185.4		75.2		53.6		5.80		48.7	
	-	177.2		74.3		49.9		5.75		50.2	
		8.2 ± 1.9	<0.01	0.9 ± 0.2	< .01	3.7 ± 0.5	< 0.01	.08 ± .06	0.16	-1.5 ± 0.8	0.07

[a]HCW = hot carcass weight, Dress % = hot carcass weight/off-test live weight; % lean = percentage of carcass lean estimated by total body electrical conductivity at SiouxPreme Packing Co.; pH = ultimate 24 h longissimus muscle pH; and Minolta 1 = Minolta 1 color score.
[b]T = DH (I x L) cross, F_1 = I x L cross.
[c]G = gilt, B = barrow
[d]+ = pigs fed PAYLEAN® (18 g/ton) during last 28 days before slaughter; - = pigs not fed PAYLEAN®.
[e]P = the probability associated with tests of differences between lines, sexes, or diets.

Economic Analyses of Feeding 18 g per ton PAYLEAN® to Crosses of the NE Index Line

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Summary and Implications

Economic returns per pig for F_1 and terminal cross barrows and gilts of the NE Index line when fed a diet with or without PAYLEAN® at 18 g per ton for 28 d before slaughter were compared. Although not significant, terminal cross pigs with 25% Line I genes were more profitable than F_1 pigs with 50% Line I genes and gilts were more profitable than barrows. Several scenarios were modeled to evaluate the economic returns from feeding PAYLEAN®. Increased profits were similar across lines and sexes but varied depending on whether in-transit death losses were considered treatment effects. The best estimates of the increased income per pig from feeding PAYLEAN® were $5.33 ± 1.56 for the scenario with no in-transit losses and $1.54 ± 4.83 when in-transit losses were assumed to be related to feeding PAYLEAN®.

Introduction

As a result of the superiority of the NE Index line in reproduction documented in the NPPC Maternal Line Evaluation project it is now being used broadly in industry breeding programs. Its value would be further enhanced from improvements in growth, food conversion and carcass value. In the previous report we show that feeding a diet with PAYLEAN® at 18 g per ton during the last 28 days before slaughter significantly improved growth and carcass merit of Line I cross pigs. PAYLEAN® is a relatively expensive product and these improvements must more than offset its cost to justify feeding it. The purpose of this report is to estimate the economic effects of differences in growth, feed conversion, and carcass value in pigs with 25% and 50% Line I genes and to determine the economic value of feeding these pigs a diet with 18 g/ton PAYLEAN®.

Materials and Methods

Details of the experiment are described in the preceding paper. Briefly, a growth test of 305 pigs with average beginning age of 68.6 days and weight of 56.4 lb and final weight of approximately 240 lb was conducted. A corn-soybean meal diet formulated to contain 18% crude protein, 0.95% lysine, and 1,506 kcal/lb ME was fed to all pigs throughout the experiment. One-half of the pigs were randomly assigned to receive this diet with PAYLEAN® at the rate of 18 g per ton during the last 28 days before slaughter. Two crossbred types of pigs were studied, an F_1 of Danbred™ USA Landrace and Line I, pigs with 50% Line I genes, and a terminal cross (T) from L x I females mated with Danbred™ USA Duroc-Hampshire sires, pigs with 25% Line I genes.

Sixty-six pigs were housed and fed in a building (IFU) with individual feeding pens and half were fed PAYLEAN®. The rest were in another building (MOF) penned according to genetic line, sex, and diet treatment (with or without PAYLEAN®) with 10 pigs per pen. Body weight of each pig was recorded at the beginning of the test, 28 days before slaughter when half the pigs began to receive the diet with PAYLEAN®, and at the end of the test. Feed intake for each pig in the IFU and each pen in the MOF was recorded for the intervals from the beginning of the test to 28 days before slaughter and the last 28 days before slaughter. Pen-fed pigs were assigned the average feed intake of the pen. Each pig was scanned 28 days before slaughter and at final weight with an Aloka 500 instrument to estimate tenth rib backfat thickness and longissimus muscle area.

The objective was to feed pigs in the IFU to a final weight between 240 and 260 lb and pens of pigs in the MOF to final average weights between 240 and 250 lb with all pigs in the pen weighing at least 215 lb. Each pig was weighed at 21, 42 and 63 days after being placed on test. Slaughter date was designated for each pig or pen of pigs based on previous growth rate and weight on day 63 of the test. The final 28-day period for each pig began 63, 70 or 77 days after being placed on test. Because of the goal to market all pigs in a pen on the same day, five pigs in the MOF projected to not weigh 215 lb after another 28 days were removed from test. In addition, four pigs were removed from test earlier, two that were crippled and two with hernias. One pig died between day 0 and 63 of the test. Pigs were transported to SiouxPreme Packing Co. the day they were removed from test and slaughtered the next morning. Percentage carcass lean was estimated with TOBEC and pigs were valued on the SiouxPreme payment matrix. Four pigs died in-transit. The distribution of pigs across genetic line/sex/treatment is shown in Table 1.

Production Costs and Pig Value

Costs of production from when pigs were placed on test to delivery to the packing plant were calculated for each pig. Initial cost of pigs was set at $.814 per lb based on local feeder pig prices during February and March, 2001. Cost of the 18%-protein diet was set at

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$.0586 per lb, the actual cost of the diet delivered to the bin at the experimental swine farm. The amount of PAYLEAN® consumed by pigs receiving it was calculated from their feed intake during the last 28 days of the trial and a PAYLEAN® cost per pig was assigned assuming it cost $3.11 per g. A fixed cost of $12.36 was assigned to each pig beginning the test as if this was a cost per pig space. Costs in this amount were derived from production costs assigned to lines in the NPPC MLP (Dhuyvetter K. and T. Schroeder, 2000, Maternal Line Genetic Evaluation Program (MLP) Economic Analysis; in Maternal Line National Genetic Evaluation Program Results, April, 2000) and included professional fees ($.53), interest on the sum of one-half the variable cost per pig plus the cost of the feeder pig ($2.46), depreciation on buildings and equipment ($4.52), interest on buildings and equipment ($3.78), and insurance/taxes on buildings and equipment ($1.07). A variable cost for each pig was calculated from the number of days it was on test at a rate of $.0512 per day. This cost was calculated from the report cited above and included the sum of average costs per pig for building and equipment repairs ($1.28), utilities, fuel and oil ($.33), veterinary supplies ($1.00), and labor ($2.99), divided by 109.4, the average number of days in the finisher for MLP pigs. A marketing cost of $4.00 was assigned to each pig marketed. All costs were summed to obtain total production costs for each pig.

A value was assigned to each pig based on its hot carcass weight and percentage lean estimated by TOBEC at SiouxPreme Packing Co. The base carcass price of $.67/lb received for these pigs was used. Profit for each pig was calculated as market value minus total costs.

Economic Analyses

Economic analyses were conducted in a 2x2x2 factorial arrangement that included two assumptions about in-transit death losses, two alternatives for calculating feed costs, and two assumptions about causes for death/removal of pigs before slaughter.

Table 1. Distribution of pigs across genetic line, sex, and diet, and number removed or died during the experiment or in-transit to slaughter.

				Removed during experiment				Died in-transit
Line[a]	Sex[b]	PAYLEAN®	Day 0	Cripple	Hernia	Died	Small[c]	
F_1	G	-	39				1	
F_1	B	+	38				1	
F_1	G	-	38			1		1
F_1	B	+	39					1
T	G	-	38	1			1	1
T	B	+	38				1	
T	G	-	37		2		1	
T	B	+	38	1				1

[a]F_1 = Landrace x Index, 50% Line I genes; T = Duroc-Hampshire sires x (L x I), 25% Line I genes.
[b]G = gilt, B = barrow.
[c]Pigs removed during the experiment because their projected weight at slaughter date was less than 215 lb.

In-transit Death Losses

Pigs that died in-transit could be treatment effects or these losses could be independent of treatments. Analyses were completed making both assumptions. In analyses assuming that pigs that died in–transit were random and not related to genetic line, sex or PAYLEAN®, value of pigs that died in-transit was assigned based on predicted hot carcass weight and percentage carcass lean. Hot carcass weight was assigned based on live weight on the day pigs were marketed and the average dressing percentage for their line/sex/diet subclass. Percentage lean was predicted from final scan backfat and longissimus muscle area and regression coefficients of percentage lean on backfat and longissimus muscle area calculated from the complete data set.

Analyses assuming that in-transit losses were related to genetic line/treatment effects were performed assuming these pigs incurred all production costs but had value of $0 when marketed.

Feed Costs

Feed costs were calculated in two ways: 1) as the trial was conducted in which all pigs received an 18%-protein diet throughout the trial with feed costs of $0.0586/lb, and 2) an assumption that corn was substituted for soybean meal to reduce protein to 16% in the diet fed the last 28 days to pigs not receiving PAYLEAN® without affecting growth or carcass traits. Feed consumed during this period by these pigs was set at $0.0551/lb, the actual cost of this feed being fed concurrently to other pigs at the experimental farm.

Pigs Died or Removed During the Trial

Economic returns for each of the four combinations of assumptions about in-transit losses and feed costs were calculated based on 1) all 305 pigs that entered the trial, and 2) only those pigs that reached market weight. The first of these assumes that causes of pigs not completing the test, those that died or were removed early, were related to genetic line, sex and diet. Full costs until the day a pig was removed from test or until it died were included and these pigs were assigned market value of $0. Pigs that were removed from test and those that died during the test were not included in analyses of only those pigs that reached market weight.

In each of the eight combinations, value of pigs marketed, total production costs, profit, and carcass lean premium as a percentage of base price for each pig were fitted to a model that accounted for random effects of pen and litter, fixed effects of building, line, sex, and PAYLEAN® treatment, and two-factor interactions among fixed effects. Two-factor interactions among line, sex and PAYLEAN® treatment were not significant in any analysis. Pig value, production costs, profit, and

Table 2. Income, production costs, net profit, and carcass premium (± SE[a]) for different scenarios of feeding PAYLEAN® at 18 g/ton 28 days before slaughter to crosses of the NE Index line.

	All pigs beginning the trial (n = 305)				Final pigs marketed only (n = 295)			
	No mkt loss[b]		Mkt loss[b]		No mkt loss		Mkt loss	
Group[c]	18P[b]	18-16P[b]	18P	18-16P	18P	18-16P	18P	18-16P
Pig value, $/pig								
T-cross	121.64	121.64	120.15	120.15	126.80	126.80	124.59	124.59
F_1	120.17	120.17	118.43	118.43	123.07	123.07	116.67	116.67
Difference	1.47 ± 2.97	1.47 ± 2.97	1.72 ± 3.45	1.72 ± 3.45	3.73 ± 2.19	3.73 ± 2.19	7.93 ± 5.41	7.93 ± 5.41
Barrow	119.72	119.72	117.14	117.14	124.64	124.64	118.65	118.65
Gilt	122.09	122.09	121.44	121.44	125.23	125.23	122.61	122.61
Difference	-2.37 ± 2.97	-2.37 ± 2.97	-4.30 ± 3.45	-4.30 ± 3.45	-0.59 ± 1.53	-0.59 ± 1.53	-3.95 ± 4.78	-3.95 ± 4.78
Paylean	127.06	127.06	125.24	125.24	130.46	130.45	123.67	123.67
No Paylean	114.75	114.75	113.35	113.35	119.41	119.41	117.59	117.59
Difference	12.3 ± 2.97***	12.3 ± 2.97***	11.88 ± 3.45***	11.88 ± 3.45***	11.05 ± 1.49***	11.05 ± 1.49***	6.09 ± 4.46	6.09 ± 4.46
Total cost, $/pig								
T-cross	99.07	98.75	99.07	98.75	100.08	99.75	100.08	99.75
F_1	98.34	98.03	98.34	98.03	98.93	98.62	98.86	98.55
Difference	0.73 ± 1.59	0.73 ± 1.55	0.73 ± 1.59	0.73 ± 1.55	1.15 ± 1.50	1.13 ± 1.50	1.22 ± 1.49	1.21 ± 1.49
Barrow	98.73	98.41	98.73	98.41	100.04	99.71	100.02	99.69
Gilt	98.67	98.37	98.67	98.37	98.98	98.66	98.93	98.61
Difference	0.06 ± 1.17	0.05 ± 1.16	0.06 ± 1.17	0.05 ± 1.16	1.07 ± 0.75	1.05 ± 0.74	1.09 ± 0.74	1.07 ± 0.74
Paylean	101.10	101.10	101.10	101.10	101.77	101.77	101.78	101.78
No Paylean	96.30	95.68	96.30	95.68	97.24	96.6	97.17	96.52
Difference	4.80 ± 1.13***	5.42 ± 1.12***	4.80 ± 1.13***	5.42 ± 1.12***	4.53 ± 0.71***	5.18 ± 0.71***	4.61 ± 0.70***	5.25 ± 0.70***
Profit, $/pig								
T-cross	22.96	23.27	21.48	21.79	26.67	27.00	23.30	23.63
F_1	21.54	21.85	19.43	19.74	23.34	23.66	17.47	17.80
Difference	1.42 ± 2.21	1.42 ± 2.21	2.05 ± 3.05	2.05 ± 3.05	3.33 ± 1.77	3.34 ± 1.77	5.82 ± 5.16	5.83 ± 5.16
Barrow	21.22	21.53	18.3	18.62	24.79	25.12	17.77	18.10
Gilt	23.28	23.58	22.62	22.92	25.22	25.54	23.00	23.32
Difference	-2.06 ± 2.21	-2.05 ± 2.21	-4.32 ± 3.05	-4.31 ± 3.05	-0.43 ± 1.59	-0.42 ± 1.59	-5.24 ± 4.27	-5.22 ± 4.97
Paylean	25.96	25.96	23.71	23.71	27.99	27.99	21.48	21.48
No Paylean	18.54	19.16	17.21	17.83	22.02	22.67	19.30	19.95
Difference	7.41 ± 2.21***	6.79 ± 2.21***	6.50 ± 3.05**	5.88 ± 3.05*	5.97 ± 1.56***	5.33 ± 1.56 ***	2.19 ± 4.83	1.54 ± 4.83
Carcass premium,% of base value								
T-cross	99.16	99.16	97.90	97.90	103.50	103.50	101.01	101.01
F_1	99.6	99.6	98.16	98.16	102.06	102.06	97.35	97.35
Difference	-0.44 ± 2.16	-0.44 ± 2.16	-0.27 ± 2.66	-0.27 ± 2.66	1.24 ± 0.68	1.24 ± 0.68	3.66 ± 3.96	3.66 ± 3.96
Barrow	98.03	98.03	95.90	95.90	102.00	102.00	95.85	95.85
Gilt	100.73	100.73	100.16	100.16	103.36	103.36	102.50	102.50
Difference	-2.71 ± 2.16	-2.71 ± 2.16	-4.26 ± 2.66	-4.26 ± 2.66	-1.35 ± 0.50	-1.35 ± 0.50	-6.65 ± 3.87	-6.65 ± 3.87
Paylean	101.96	101.96	100.48	100.48	104.65	104.65	99.37	99.37
No Paylean	96.80	96.80	95.58	95.58	100.71	100.71	98.99	98.88
Difference	5.16 ± 2.16**	5.16 ± 2.16**	4.89 ± 2.66*	4.89 ± 2.66*	3.95 ± 0.49***	3.95 ± 0.49***	0.38 ± 3.79	0.38 ± 3.79

[a]SE = SE of difference between means.
[b]No mkt. Loss. full value was assigned to pigs that died in-transit; Mkt. loss, pigs that died in-transit were assigned value of zero.
[c]18 P = feeding 18% protein diet to all pigs throughout the trial; 18-16 P = feeding control pigs 18% protein diet until 28 days before slaughter and 16% protein thereafter.
[c]F_1 = Landrace x Index, 50% Line I genes; T = D-H sires x (L x I), 25% Line I genes.
* P < .10, ** P < .05, *** P < .01.

carcass premium for all combinations of economic scenarios are in Table 2.

Results

T-cross vs F_1 Pigs

Although not significant (P > 0.10), value of T-cross pigs with 25% Line I genes was greater than for F_1 pigs in all scenarios, ranging from $1.47±2.97 for all pigs with no market losses to $7.93± 5.41 for only those pigs marketed and with market losses. The difference is because 7 T-cross pigs were removed from the trial compared with only 3 F_1 pigs (Table 1). Increased value of T-cross pigs was due mostly to increased carcass weight due to more rapid growth and, in the scenario using only those pigs marketed, to greater premium above the base. Neither total production costs nor profit per pig differed significantly between T-cross and F1 pigs, but in all scenarios both were greatest for T-crosses. Increased profit per pig from

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pigs with 25% compared with 50% Line I genes ranged from $1.42± 2.21 to $5.83 ± 5.16 per pig.

Barrows vs Gilts

Gilts had greater value than barrows in all economic scenarios because they were leaner and received a greater premium, although none of the differences were significant. Differences in costs between barrows and gilts were small and not significant. Although differences were not significant, gilts were more profitable than barrows.

PAYLEAN®

Feeding PAYLEAN® significantly increased value of pigs in all scenarios except the ones based only on pigs that were marketed and with zero value for pigs that died in-transit. Pigs fed a diet with 18 g PAYLEAN® per ton were leaner and heavier when marketed and received greater carcass premium. They had increased value over control pigs that ranged from $11.05 ± 1.49 to $12.30± 2.97 per pig. In the scenarios in which only the pigs marketed were considered, pigs fed PAYLEAN® had greater value, but the difference between treated and non-treated pigs declined greatly and was not significant. The reduction in the difference was because the two pigs on the PAYLEAN® treatment that died in-transit were heavy, lean pigs with predicted average hot carcass weight of 190.5 lb, lean percentage of 54%, and carcass premium of 107%, whereas predicted averages for the two control pigs that died were 165 lb carcass weight, 51.9% lean, and premium of 100.5%. Although in this scenario differences in average value between treated and control pigs was $6.09 ± 4.46 it was not significant because including values of $0 for pigs that died in-transit greatly increased variation and increased standard errors of differences.

Total costs were significantly greater ($4.61± 0.70 to 5.42± 1.12 per pig) for pigs fed PAYLEAN® than for control pigs. Costs were reduced between $0.62 to $0.89 per pig for the scenario in which control pigs were fed a 16% protein diet the last 28 days before slaughter. Average daily feed intake for pigs fed PAYLEAN® was 6.42 lb per day. During the last 28 days they consumed 181.9 lb feed and 1.64 g PAYLEAN®. Feeding PAYLEAN® increased costs an average of $5.09 per pig.

Profit for pigs fed PAYLEAN® was significantly greater than for controls ($5.33± 1.56 to 7.41± 2.21 per pig) in all scenarios except the ones including only marketed pigs and with zero value for pigs lost in-transit. In this last scenario, increased profit from feeding PAYLEAN® was only $1.54± 4.83 when controls were fed a 16% protein diet during the last 28 days before slaughter. Because losses before the PAYLEAN® treatment period occurred randomly across lines, sexes, and treatments, including costs for these pigs did not affect differences among effects.

Discussion and Conclusions

Results for the scenario that included all pigs fed an 18% protein diet and zero market value for pigs lost in-transit compare lines, sexes, and PAYLEAN® treatment as the experiment was conducted. In this scenario, profit per pig was not significantly greater for pigs with 25% Line I genes than for those with 50% Line I genes ($2.05 ± 3.05), was not significantly greater for gilts than barrows ($4.32 ± 3.05), but was greater for pigs fed 18 g per ton PAYLEAN® than controls ($6.50± 3.05). A more realistic comparison is the one that included all pigs with control pigs being fed a 16%-protein diet the last 28 days. Then, differences between lines and sexes were similar to other scenarios, but increased profit from feeding PAYLEAN® decreased to $5.88 ± 3.05 per pig. In these analyses, deaths and conditions that led to removal of pigs were assumed to be due to the effects studied (line, sex, and treatment).

For the assumption that all losses were random and not related to line, sex, or diet, the appropriate scenarios are the ones including only the pigs marketed and with predicted market values for those pigs lost in-transit. In these cases, the added profits from feeding 18 g PAYLEAN® per ton were $5.97± 1.56 when all pigs were fed an 18%-protein diet, and $5.33± 1.56 when control pigs were fed a 16%-protein diet for 28 days. The last scenario including only the pigs marketed and assigning a value of $0 to those that died in-transit uses the assumption that losses up to 28 days before slaughter are completely random and not related to line and sex effects, but that in-transit deaths are related to treatments. Under these assumptions, feeding 18 g PAYLEAN® per ton increased profit by only $1.54± 4.83 and $2.19± 4.83 per pig for 18 and 18-16% protein regimens for control pigs.

The experiment was too small to determine whether deaths and conditions for removal of pigs were due to lines, sexes, or treatment. Causes of deaths and conditions causing pigs to be removed before the last 28 days before slaughter were not related to PAYLEAN® treatment. Ten pigs died or were removed before the last 28 days of the trial and seven of these were assigned to the control diet. Including them with value of $0 greatly affected estimates of profit from feeding PAYLEAN®. Therefore, the two best estimates of the increased profit from feeding PAYLEAN® are $5.33± 1.56 for the scenario with no in-transit losses and $1.54± 4.83 when in-transit losses were assumed to be related to treatment.

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[1]R. K. Johnson is professor of animal science, P. S. Miller is an associate professor of animal science, D. B. Petry and R. F. Fisher are graduate students/technicians in the Department of Animal Science.

Applicability of High-Rise™ Hog Housing for Finishing Operations

Richard R. Stowell[1]

Summary and Implications

The design of High-Rise™ swine facilities allows the generation of a solid, manure-laden material from hogs raised in confinement housing with slatted floors. The volume of manure that must be handled annually can be reduced through continuous moisture loss that takes place within the system's drying bed and recycling of bed material. Recycling typically involves mixing material twice a year — at the end of finishing periods. Moisture contents of twice-recycled manure-laden bed material ranged between 55-65% with continuous aeration for three years of production. This moisture range makes the material acceptable directly as feedstock for composting. Ammonia emissions should be similar to those from deep-pit facilities. However, the levels of other problematically odorous gases should be reduced most of the time due to the generally aerobic nature of the drying bed. Hydrogen sulfide was seldom detected within the building using readily available sensing equipment (i.e. H_2S < 0.3 ppm) even during handling of the manure-laden bed material, and was never measured at more than 4 ppm, which is promising from a safety standpoint. Data collected from six production groups indicated that average daily gain and feed efficiency of finishing pigs in the High-Rise™ facility were equal to or possibly better than that of those produced simultaneously in 11 nearby conventional facilities with an identical source of pigs and the same contract-feeding arrangement. Construction of such a facility incurs additional costs associated with purchasing, installing and operating the aeration system and paying some proprietary fees. With these added costs (+15-20% initial), this system is projected to be a viable alternative mainly for those operations having a combination of special criteria/constraints, including: relatively high risk of polluting local waterways or water supply; long manure-hauling distances to fields; access to markets for solid manure or compost feedstock; some, but not tremendous, pressure to limit odor generation; and/or limited water availability.

Introduction

Environmental, neighbor and economic pressures have encouraged pork producers to investigate options that are available for housing their pigs, especially growing-finishing pigs. One recent development in swine housing is the High-Rise™ concept. This housing system was designed to solidify hog manure within a slatted-floor production facility. A second goal was to improve the quality of air inside and around the building — with the expected results being improved pig performance and less potential for neighbor complaints about odor.

Water Quality

Liquid manure systems have been targeted as environmental polluters based upon some real evidence and considerable amounts of negative perception. Handling manure as a solid does not eliminate the potential for pollution or neighbor concerns, but in some circumstances, it can reduce these pressures substantially. When applying dilute manures, especially effluent from lagoons, onto land, over-application of water can be a problem. Soils may be brought close to or beyond saturation, which increases the likelihood of surface runoff and tile outflow, both of which can pollute surface waters. Light soils are prone to rapid percolation and potential groundwater contamination. Solid manures can be applied at rates that meet soil nutrient needs without greatly affecting soil moisture levels.

A second advantage of handling solid manure is that the manure becomes more transportable. Systems for handling liquid manure achieved wide acceptance because manure could be handled with pumps with minimal labor input. Liquid manure is easily transported and applied onto land that is adjacent to the primary farmstead. However, requirements for pumping and conveying liquid manure can quickly become unwieldy if the material must be moved longer distances, waterways or other natural features must be crossed, or public roadways must be used or traversed. Solid manure can be readily loaded onto trucks at much higher dry matter and nutrient densities, which gives it greater hauling value.

Nonfarm people usually associate solid manure as being a more desirable manure product than liquid manure. From the perspective of those who might be in the market to purchase manure, more nutrients and organic matter can be obtained from solid manure without the mess that is associated with liquid manure.

Air Quality

Farm neighbors and other public citizens have raised concerns over odors from animal production, especially from larger swine facilities. Few producers can ignore this issue and expect to be readily accepted by their

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Figure 1. High-Rise™ Hog Building – 4-M Farms research/demonstration facility.

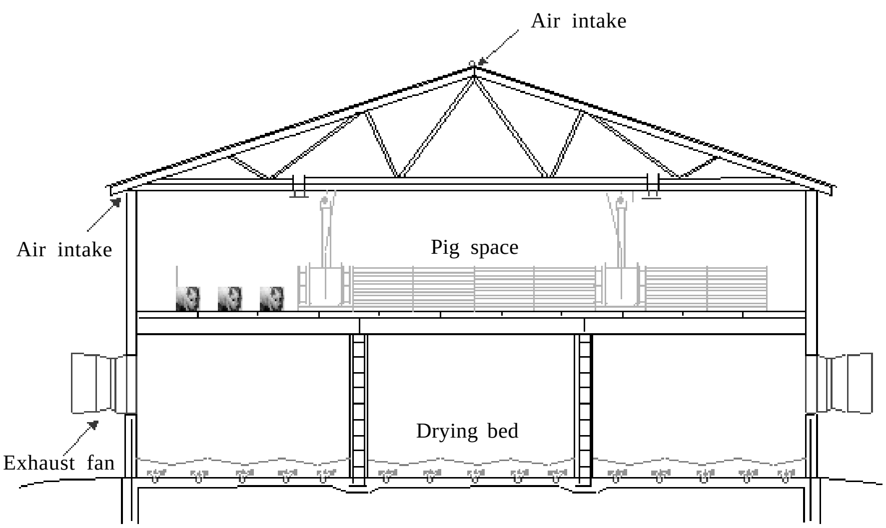

Figure 2. Cross-section view of commercial version of High-Rise™ finishing facility.

local communities in the future. Given the pace of changes in the rural landscape, the greater mobility of the citizenry, and increased ideological separation of those from farm and nonfarm backgrounds, the attention given to odors can only be expected to increase.

Aeration of manure is an odor-control strategy that has been implemented in a number of different systems. The premise is that the products of aerobic decomposition should contain significantly lower levels of odorous hydrogen sulfide and volatile organic compounds than would be produced by anaerobic bacteria. Therefore, the exhaust air from a facility that utilizes aeration should be less odorous than that from production facilities storing liquid manure.

Air quality inside production facilities is important for achieving good pig performance and associated profit potential. The health and safety of operators/employees also are impacted by indoor air quality. Numerous studies have associated high ammonia levels with respiratory dysfunction and reduced performance. Hydrogen sulfide is characterized as a poisonous gas that is known for its presence in confined manure storage areas.

Materials and Methods

System Design and Description.

4-M Farms built the first High-Rise™ hog facility (Figure 1) in Darke County, Ohio in 1997-98 with a capital-improvements (construction) grant from the Ohio Department of Administrative Services. This demonstration/research building was built to test the concept of the facility's design, in which manure at 90% moisture would be partially stabilized and dried in place on a bed of bulking agents (wood shavings, sawdust ground pallets, paper, straw, cornstalks, corncobs, etc.;). The first batch of pigs was placed in the facility in July 1998.

Although labor efficiency, pig performance, and construction costs were considered to be important, they did not drive the design. The intended result was a unique design that would be competitive with other facilities when analyzed on a total system basis, but would be more desirable from an environmental standpoint.

The design of this facility incorporated several significant variations on design concepts of high-rise layer (poultry) facilities, one of the most significant being a patented aeration system or plenum, which is used to aerate, dry, and solidify the manure. Pigs are housed in the upper story on slats (Figure 2). A layer of bulking material is placed in the lower story before pigs are brought into the facility. Manure falls through the slatted floor, into the lower story, and onto the drying bed. The bulking material adsorbs free liquids, contains the manure, and allows air to flow through the bed. Airflow is directed into the bed from below, drying the material and supplying oxygen to the system. Once moistened air leaves the bed, it combines with ventilation air supplied to the pigs and is exhausted by fans located in sidewalls of the lower story.

The most visible difference between a High-Rise™ facility and conventional swine production facilities is that the structure is taller. The floor of the lower story can be constructed at ground level. No pit is constructed into the ground meaning excavation requirements are reduced. Large access doors are included to allow implements access into the lower story. A ramp must be constructed to facilitate loading and unloading pigs. Construction must provide for the installation of the aeration system, especially the in-floor plenum (system of air ducts). Other construction features are similar to those for conventionally designed slatted-floor facilities. Wet-dry feeders must be used in a High-Rise™ facility to limit water wastage.

The ventilation systems in these facilities are distinctly different from those of facilities with conventional mechanical ventilation systems in that all of the exhaust fans are located in the lower story of the building. Air is drawn into the building through openings in the attic. Tempered air is pulled from the attic into the pig space in the upper story through baffled ceiling inlets. There is typically one inlet on each side that runs almost the length of the production room. This design directs jets of air outward from the room inlets along the ceiling of the room. Fresh air mixes with room air prior to being drawn through the slatted flooring into the lower story. Since the upper story is nearly airtight other than the ceiling inlets and slatted flooring, the bulk movement of air is downward, with ventilation air moving into the lower story before being exhausted from the building.

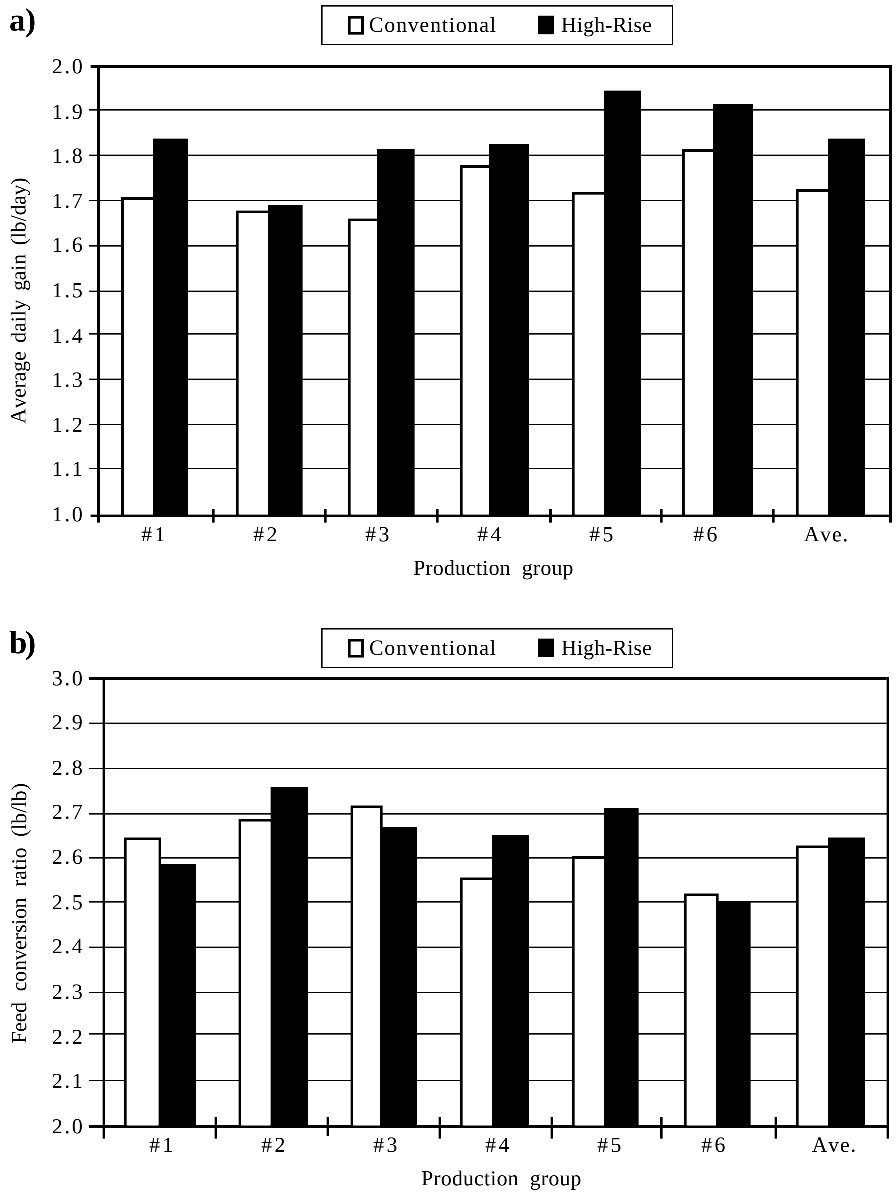

Figure 3. Growth rate (a) and feed efficiency (b) of pigs raised in the High-Rise™ facility compared to pigs raised in conventional facilities.

Data Collection

Modern monitoring and control systems for maintaining desired temperatures within the pig space were built into the research/demonstration facility. Indoor (upper story) and outdoor dry-bulb air temperatures, dry-bulb air temperatures at eight locations distributed evenly around the pig space, and fan operation data were collected on a nearly continuous basis. Ammonia, hydrogen sulfide and carbon dioxide concentrations were measured at three locations within each story and from the exhaust fans located around the building perimeter using Dräger tubes (w/hand pump). These measurements were taken roughly every other week during the first six growouts. Grab samples of mixed manure-laden bed material were collected during several building cleanouts.

Pig performance from this facility was compared to that of pigs within 11 nearby conventionally designed finishing facilities. All of the conventional facilities had fully slatted floors, were either tunnel-ventilated or naturally ventilated, and had deep pits. All 12 facilities were stocked with contract pigs from the same source and were on the same feeding program. Production schedules were pre-set by the contractor to meet packer schedules, which resulted in growout periods being set initially for the same number of days. The growout periods overlapped, but began at different times over about a 3-week period to accommodate production schedules. The contractor recorded feed delivery and pig weights, along with producer records of death losses and culls.

Results and Discussion

Manure/Bed Material

Wood shavings and corn stover performed well as bulking materials, especially in terms of maintaining their porosity. Sawdust and shredded newspaper have not performed well in spot trials (where they were used under only one or two pens) because the surfaces

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of both materials matted over quickly, resulting in poor flow of manure downward and air upward. Chopped straw was acceptable as a bulking agent.

Bed material could be recycled twice, meaning it was used for three growouts or for more than a year. After the pigs were removed, the material was mixed and allowed to heat for a few days. After being used for three growouts, about 2.5-3 ft of material remained. On a volume basis, about 65% less material had to be transported and utilized as compared to liquid manure in a deep pit. The manure-laden bed material is handled as a solid using front-end loaders and trucks.

Although considerable drying of the bed material took place, composting did not occur without mixing. The manure-laden material quickly heated after it was mixed. The microbial inactivity before and activity following mixing were documented using temperature probes. Most of the manure-laden bed material has been composted on site for distribution by a manure brokerage. Other nearby producers with commercial High-Rise™ buildings planned to apply their material to land and incorporate it without composting the material.

The characteristics of the manure-laden bed material varied with the extent of recycling done, the choice of bed material used, and the location that was sampled. In general, however, the nutrient density of the bed material was much higher than that of liquid manure from conventional facilities. While the nutrient density was increased, no change in the total amounts of phosphorus and potassium (or other minerals) present in the material was found nor was any change expected. Nutrient analyses indicated that nitrogen losses from the material (on a total mass basis) were on the same scale as losses from manure stored in deep pits. Much of this nitrogen loss occurs through volatilization as ammonia and emission from the building in the exhaust air.

Thermal Conditions

Average air temperatures within the upper story were maintained within a fairly narrow band around the desired indoor temperature during cool and cold weather, ±2°F during 20°F swings in outdoor temperature. Individual temperatures throughout the pig space were also quite stable. During the summer, all fans were operated at full capacity, which resulted in excellent air quality within the pig space. During very hot weather, mist was evaporated in the inlet air streams to provide supplemental cooling. Sprinkling is not compatible with this housing system since water wastage needs to be minimized.

Gas Levels

Measured concentrations of ammonia within the pig space were consistently below 20 ppm which is the eight-hour exposure threshold limit established (by OSHA) for building occupants. Over the two years in which gas measurements were made, the average concentration was 4.3 ppm and readings ranged from undetectable to 19 ppm. Ammonia concentrations in the pig space of conventional finishing facilities have been reported to range from about 5 ppm during summer to 10-20 ppm during winter. Concentrations of ammonia within the lower story regularly exceeded this limit and one reading exceeded 120 ppm. The average concentration downstairs was 23.3 ppm. Exhaust air concentrations had an overall mean of 17.9 ppm.

The pronounced trend was for ammonia levels to increase during cold weather when ventilation rates were at a minimum. The increased rate of ammonia generation under slightly warmer conditions was more than offset by highly elevated rates of ventilation. The ammonia levels within the lower story could be irritating during winter, causing watery eyes, odor, and slight respiratory distress when the area was occupied for several minutes.

Hydrogen sulfide was not found in measurable quantities within the pig space. Additionally, no odor or other sign of its presence was noted upstairs. Occasionally, hydrogen sulfide was detected at concentrations not exceeding 0.5 ppm downstairs. Hydrogen sulfide is an odorous gas (rotten-egg smell) and is lethal at high concentrations. Low concentrations of hydrogen sulfide in the exhaust air bode well for addressing concerns about odor.

Gas measurements were also taken during consecutive cleanouts during the summer and fall of 2000. Ammonia concentrations during cleanout were similar to those during the last weeks with pigs in the building and emissions were about the same as that during production in the summer. Hydrogen sulfide was detected more frequently during cleanout than during production, but average levels were still well below 1 ppm and only one reading was above that level (3.6 ppm).

Pig Performance

Growth rate of swine raised in the High-Rise™ appeared to exceed the average rate for the 11 comparison facilities for the first six growouts (Figure 3) based upon contractor data (Cooper Farms, Inc.). Overall average daily gain was 1.84 vs 1.73 lb/day and pigs were marketed at 115 vs 119 days in the High-Rise™ and conventional facility, respectively. Feed efficiency in the High-Rise™ facility was similar to that of the comparable conventional facilities (2.64 vs. 2.62). Pigs within the High-Rise™ facility grew rapidly and had reasonable feed conversion ratios. The fairly stellar performance can probably be attributed to a combination of good management, a good source of pigs, new facilities, and reasonably good air quality. Other than using wet/dry feeders, there is little difference in managing pigs in a High-Rise™ facility than in conventional, fully slatted facilities. Any effects of feeder type were not evaluated in this investigation.

Death losses exceeded those of the comparable production facilities (4.2% vs 3.2%), largely due to two enteric disease outbreaks. Since the facility was available for tours and demonstration purposes, it was difficult to maintain tight biosecurity on the premises even though access to the pig space was restricted. Respiratory ailments were not evident in the pigs.

Systems Perspective

The High-Rise™ concept for raising pigs shows potential for addressing some important environmental concerns. There are additional initial and operating costs associated with the facility, however. Extra initial costs include proprietary fees and the cost of the aeration fans and installing the in-floor aeration system. Operation of the aeration fans consumes electrical energy at a rate that is about that required to operate the minimum-ventilation system. Therefore, the economics of utilizing such a facility design needs to be evaluated as part of a total systems analysis. Such an analysis would include social and environmental costs, to the extent to which they are known or can be estimated.

Conclusions

After monitoring the operation of a High-Rise™ hog finishing facility for nearly three years, it is evident that such facilities can produce a solid manure product. With recycling of the drying bed material, substantially less material volume needs to be handled and moisture contents near 60% may be expected. Additionally, the following conclusions were made concerning the performance of this type of facility for raising pigs:

- Air quality for the pigs, in terms of the thermal and gaseous environments, should be as good or better than that of conventional deep-pit facilities, but gas levels will probably exceed those present within facilities with flush systems since the manure remains within the facility;
- There appear to be benefits for odor control and safety due to the aerobic conditions that are maintained within the drying bed, but considerable ammonia will still be emitted and common safety measures should still be practiced when handling manure-laden bed material within the facility; and
- Pig performance should not differ from conventional fully slatted facilities given reasonable management.

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Sorting and Mixing Effects in a Wean-to-Finish Facility

Michael C. Brumm[1]

Summary and Implications

An experiment was conducted to evaluate whether removing and mixing lightweight pigs in a wean-to-finish facility resulted in improved pig performance to slaughter compared to never removing pigs from a pen from weaning to slaughter. Two populations of pigs were compared. The removed and mixed population consisted of pens comprised of 1) 20 pigs per pen with the five lightest pigs removed three weeks after weaning and 2) 15 pigs per pen with the pen comprised of the five lightest pigs from three of the 20 pig pens. The unsorted population consisted of 15 pigs per pen from weaning to slaughter. There was no effect of treatment when comparing populations on daily gain, daily lean gain, carcass lean percentage, daily feed intake or feed conversion efficiency. On day 158 following weaning when the heaviest pigs from both populations were removed for slaughter, pigs in the removed and mixed population were represented in both ends of the pig weight distribution curve, while no pigs from the unsorted population were present in the lightest weight category. Results of this experiment do not support the recommendation that removing and remixing lightweight pigs in a wean-to-finish facility improves performance and decreases variation in pig weight at time of slaughter.

Introduction

Managing variation in pig weight has major consequences for pig flow and price received for producers using wean-to-finish facilities. Many producers using wean-to-finish management routinely overstock pens at weaning, sorting off the lightest weighing pigs and remixing the pigs at some point during the first three to five weeks following weaning. They follow this management practice in the belief that removing the lightest pigs from a pen and remixing with other lightweight pigs results in better overall pig performance for the population of pigs placed in the facility at weaning. The purpose of the following experiment was to evaluate whether removing and mixing lightweight pigs in a wean-to-finish facility results in improved pig performance compared to never removing pigs from a pen from weaning to slaughter.

Methods

The experiment was conducted at the University of Nebraska's Haskell Ag Lab at Concord. Pigs were housed from weaning until slaughter in a fully slatted, curtain-sided facility with fresh water, under-slat flushing for daily manure removal. Pens measured 8 ft x 14 ft and contained one, two-hole wean-to-finish feeder and one wean-to-finish cup drinker. At weaning, each pen had a rubber mat and heat lamp for pig comfort.

Following weaning at an average age of 17 days, barrows were trans-

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Table 1. Effect of experimental treatments on pig performance for first 21 days post-weaning, least square means.

	Treatment[a]		
Item	20/15	15S	*P* values
No. pens	9	3	
Pig wt, lb			
Weaning	10.7	10.6	0.436
21 d	19.7	20.9	0.046
Coefficient of variation of within pen weight, %			
Weaning	15.7	17.2	0.132
21 d	19.5	17.0	0.140
Daily gain, lb	0.43	0.49	0.028
Daily feed, lb	0.61	0.67	0.063
Feed:gain	1.42	1.36	0.880

[a]20/15 = 20 pigs per pen for 21 days followed by removal of 5 lightest; 15S = 15 pigs/pen never sorted or moved.

Table 2. Effect of experimental treatments on pig performance, least square means.

	Treatment[a]			*P* values	
	Sorted/Mixed		Unmixed		20/15 + 15M
Item	20/15	15M	15S	Treatment	vs 15S
No. of pens	9	3	3		
Pig wt, lb					
21 d post-sort	21.4	15.3	21.0	0.001	0.001
61 d	65.6	56.2	63.4	0.001	0.110
158 d	257.8	243.7	253.7	0.001	0.234
Slaughter	271.2	261.0	267.3	0.027	0.715
Coefficient of variation of within pen weight, %					
21 d post-sort	13.7	11.3	17.0	0.009	0.003
158 d	7.6	7.9	6.9	0.732	0.443
Daily gain, lb					
21-61 d	1.11	1.02	1.07	0.047	0.909
61 d-slaughter	1.98	1.90	1.96	0.051	0.378
21 d-slaughter	1.65	1.59	1.64	0.007	0.347
Daily feed, lb					
21-61 d	2.01	1.61	1.92	0.003	0.258
61 d-slaughter	5.63	5.39	5.46	0.027	0.572
21 d-slaughter	4.41	4.17	4.39	0.008	0.157
Feed:gain					
21-61 d	1.81	1.58	1.79	0.001	0.063
61 d-slaughter	2.85	2.83	2.78	0.203	0.129
21 d-slaughter	2.67	2.62	2.68	0.252	0.291
Carcass lean, %	54.4	54.1	54.5	0.242	0.276
Daily lean gain, lb	0.76	0.72	0.74	0.026	0.832

[a]20/15 = 20 pigs per pen for 21 days followed by removal of the 5 lightest pigs/pen; 15M = 5 lightest pigs from each of the 3 20/15 pens; 15S = 15 pigs/pen never sorted or moved.

ported 225 miles from a southwest Minnesota farrowing facility to the research site. Immediately after arrival, the pigs were ear tagged, weighed, and assigned to the experimental treatments. Weight blocks were not used in order to increase within-pen weight variation at the beginning of the study. There were three replicates of the experimental treatments with five pens per replicate for a total of 15 pens.

Experimental treatments were:

1) Fifteen pigs/pen from weaning to slaughter (15S)
2) Three pens of 20 pigs/pen for three weeks following weaning, reduced to 15 pigs/pen (20/15)
3) Fifteen pigs/pen comprised of the five lightest pigs from the three pens of the 20/15 treatment (15M).

On day 21 following weaning, the five lightest pigs in three of the 20/15 pens were removed and mixed to create the treatment pen labeled 15M. From day 21 to slaughter, all pens had 15 pigs/pen, unless death loss or poor performance resulted in removal of a pig. Pen size was not adjusted in the event of death or removal.

At arrival, pigs were fed two pounds of a commercial pelleted diet per pig. Following this, diets were in meal form and formulated to contain the following lysine levels: 1.44% from 13 to 18 lb, 1.37% from 18 to 25 lb, 1.31 % from 25 to 40 lb, 1.20% from 40 to 60 lb, 1.10% from 60 to 90 lb, 1.00% from 90 to 135 lb, 0.80% from 135 to 190 lb, and 0.62% from 190 lb to slaughter.

On day 158 following weaning, all pigs that weighed 255 lb or greater were individually identified and removed for slaughter. All remaining pigs were individually identified and sent to slaughter on day 172 following weaning. Pigs were slaughtered at IBP Inc., Madison, Neb. Carcass lean was reported on the individually identified pigs for calculation of daily lean gain from day 61. Day 61 post-weaning corresponded most closely with typical arrival weights for purchased feeder pigs and initial weights for calculation of daily lean gain.

The orthogonal contrast of 20/15 + 15M versus 15S was examined to test whether population differences existed for the two management schemes.

Results

There was an effect of group size for the first 21 days following weaning (Table 1). Pigs in the 15S treatment weighed more ($P < 0.05$) because of a greater daily gain ($P < 0.05$) and daily feed intake ($P = 0.06$) compared with the 20/15 treatment. There was no effect of treatment on feed conversion efficiency or within pen weight variation. These results are in agreement with published data suggesting group size effects are most dramatic during the early post-weaned period.

As expected, within-pen weight variation expressed as the coefficient of variation decreased for the 20/15 and 15M population following removal of the lightest five pigs from the 20/15 treatment pens (Table 2). Because the 15M pen contained the lightest pigs on day 21, the pen average weight was also the lightest on day 61 and day 158. Final weight for this treatment was also lowest due to the method used to remove pigs for slaughter.

When comparing the population of 20/15 + 15M versus the 15S population, there was no effect of treatment on within-pen weight variation, daily gain, daily lean gain, carcass lean percentage, or daily feed intake. For the 21 to 61 day period, the 15S population had an improved ($P = 0.06$) feed:gain ratio compared with the 20/15 + 15M population. There was no difference between the populations for the time period of 61 days to slaughter or from 21 days to slaughter.

Figure 1 displays the variation in pig weight of each population on day 158 when the heaviest pigs in the facility, regardless of population, were removed for slaughter. The sorted and mixed population is represented in both ends of the population weight curve, while the unsorted population is not represented in either the two lowest weight groupings or the heaviest weight grouping. Further evidence that the removal and remixing of the lightest pigs on day 21 post-weaning did not improve overall performance is provided by the fact that on day 158, 51% of the 15S population were removed for slaughter, while only 43% of the 20/15 + 15M population were removed.

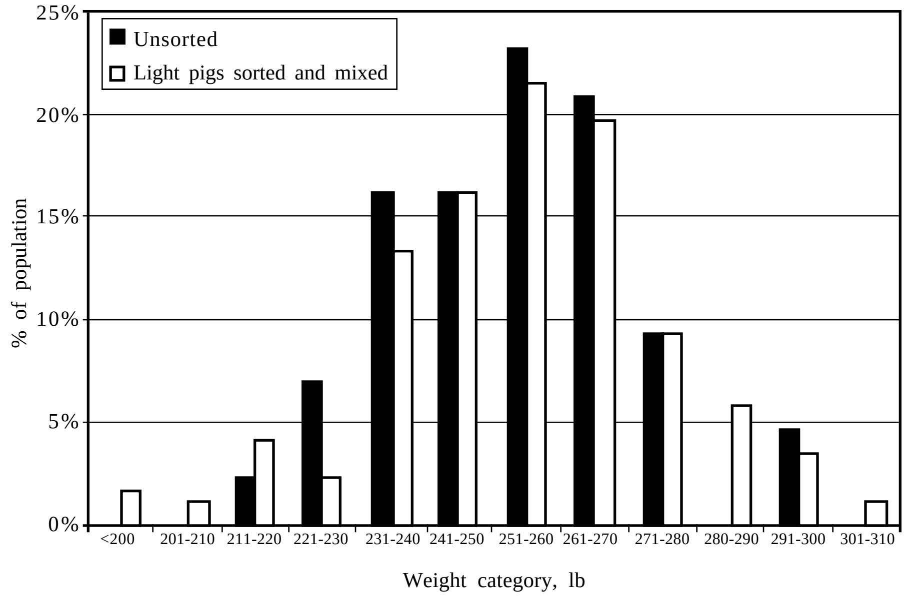

Figure 1. Effect of sorting and mixing vs no sorting on distribution of pig weight on day 158 post-weaning.

Conclusion

Results of this experiment do not support the recommendation that removing and remixing light weight pigs 21 days after weaning in a wean-to-finish facility improves performance of a population of pigs and decreases weight variation at time of slaughter compared to maintaining pen integrity from weaning to slaughter.

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Competition — It's Not Just "Cost" of Production

Allen Prosch[1]

Summary and Implications

Pork producers are faced with numerous competitive challenges. Having a higher cost of production than other pork producers has always been a reason to exit the pork industry. Even when their cost of production is competitive, producers still choose to exit the industry. Hog prices, corn prices and the hog/corn ratio from 1970 to 2000 were examined in relation to the change in the number of pork producers in Nebraska to identify the degree of influence that each had on producer's decisions to enter or exit pork production. The annual average price of market hogs per cwt and the price of corn had little relationship to the number of pork producers in the state. ($r^2 < 0.1$). The hog/corn ratio (the average market price of hogs per annum divided by the average market price of corn per annum) had a slightly stronger relationship ($r^2 = 0.16$). The data were further divided into five, six-year groups and analyzed. The relationship between hog/corn ratio and number of pork producers in the state was much stronger in the 1970s and early 1980s ($r^2 = 0 .63$ to 0.68). The relationship weakened dramatically in the late 1980s and the 1990s ($r^2 = 0.08$ to 0.0005). This suggests factors other than profitability as defined by the hog/corn ratio, are exerting more influence on the decision to remain in pork production now than in the past. New challenges in the industry, such as labor relations, contract negotia-

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tions and dealing with regulatory agencies all require a degree of people skills not previously required to be successful in pork production. The new challenges often require different skills and carry different risk. A competitive cost of production is necessary to remain in business, but it has a reduced influence on the decision to continue in production.

Introduction

Pork producers have control over the cost of such inputs as feed, medicines, and facilities. Successful pork producers have exercised control over these items for many years. Traditionally, being a low cost producer has kept them competitive with each other and subsequently kept them in business. In recent years other factors, such as environmental regulations, market access and labor relationships have become prominent in competitiveness. This paper examines the issue of profitability and its impact on the decision to remain in pork production.

Methods

Three relationships were analyzed using a regression analysis. The average annual price per cwt of market hogs, the average annual price per bushel of corn and the ratio of the average annual price per cwt of market hogs divided by the average annual price per bushel of corn (hog/corn ratio) were compared to the change and the percent of change in the number of pork producers in Nebraska. Nebraska Agricultural Statistics Service data from 1970 thru 2000 were used for all analyses. Market hog price, corn price and the hog/corn ratio were independent variables. The change or percent of change in the number of Nebraska pork producers was the dependent variable. The relationships were analyzed on a same year and on a one-year lagged basis. Data for the thirty-year period, beginning in 1970, were aggregated in five periods of six years each.

Results and Discussion

Cost of Production

When comparing cost of production, Midwest producers of all sizes are competitive with domestic and foreign pork producers. While size enables some operations to improve in selected cost of production items where economies of scale apply, this same scale creates activities and costs in other items that, at some point, limits how low cost of production can be driven. Differences in cost of production between producers remain. Minnesota, Iowa and Nebraska data for the year 2000 indicate that, on average, small (250 to 300 sow farrow to finish — or 4,000 to 6,000 annual market hog sales) producers had a cost per cwt of pork produced of \$38 to \$39. Small producers in the upper range for profitability (top 40%) had costs per cwt of \$34 to \$36. Similarly, Lawrence and Grimes (2000) surveyed producers and found that with a bushel of corn valued at \$2.50 and a market hog price of \$39.00 per cwt, 39% of the producers whose annual marketings were less than 10, 000 head annually said they planned to stay in pork production.

Current corn prices are not as high as the \$2.50/bushel used in the Lawrence and Grimes survey. Mid-September prices for corn based on the Omaha market (\$1.88/bushel) and for market hogs based on the Western Cornbelt carcass market (\$61.45/cwt) are giving producers with a \$39 per cwt cost of production over \$16 profit per hog marketed; producers with \$34 per cwt cost would profit over \$29 per hog marketed. However, at a market hog price of \$39 per cwt, the profit per hog drops to \$0 for the average group and \$12.50 for the low cost group. A producer may be competitive based on cost of production, but the total dollars returned, due to low margin on low numbers sold, may not be worth the effort, especially in a diversified crop and livestock operation.

Hog Price

Do producers exit the industry in larger numbers during or immediately after years of low prices? When examining the relationship of hog price and the number of producers exiting or entering the industry on same year or one-year lagged basis, the price of hogs does not appear to be the decisive factor for Nebraska producers (Figure 1). Comparing the strength of the relationship on a same year basis the r^2= 0.04. With a one-year lag of the dependent variable, the strength of the relationship decreased, r^2= 0.028. Producers exited the industry despite rising prices from 1971 to 1973, 1974 to 1975, 1980 to 1982, and again from 1983 to 1984. From 1985 to 1991 there was a period of "calm" in the number of Nebraska pork producers entering or exiting the industry, with three years showing modest declines in the number of producers, three years showing no change in the number of producers and one year showing an increase. Since 1992, the number of pork producers remaining in production has decreased every year. This was in spite of the fact that market hog prices from 1992 thru 1997 were similar to prices from 1975 to 1991 with values near or above \$42 per cwt.

The percentage change in the number of pork producers each year vs hog market price was plotted (Figure 2). From 1980 thru 1982 and again from 1994 thru 1997 the year-to- year percentage of producers exiting the industry increased. Producers left the industry despite increases in hog prices during these periods.

Corn Price

Hog price is only half the equation. A period with a high cost of production may negate the value of high hog prices. The value of corn, especially for diversified crop and livestock producers who have excess corn to sell, may impact the decision to exit pork production. Comparing corn price to the number of producers in pork production on same year or one-year lagged basis indicates that corn price was not a decisive factor (Figure 3). The strength of this relationship on a same year basis was r^2 = 0.003. With a one-year lag of the dependent variable, the strength of the relationship increased slightly, r^2 = 0.07. From 1974 thru 1977, with steadily declining corn prices, Nebraska producers chose to exit the industry during two of the four years, with a large decline in pork producer numbers in 1975. In the 1980s producers chose to exit and enter pork production during years of both rising and falling corn prices. In the 1990s rising or falling corn price had little impact as producers exited the industry in every year following 1991.

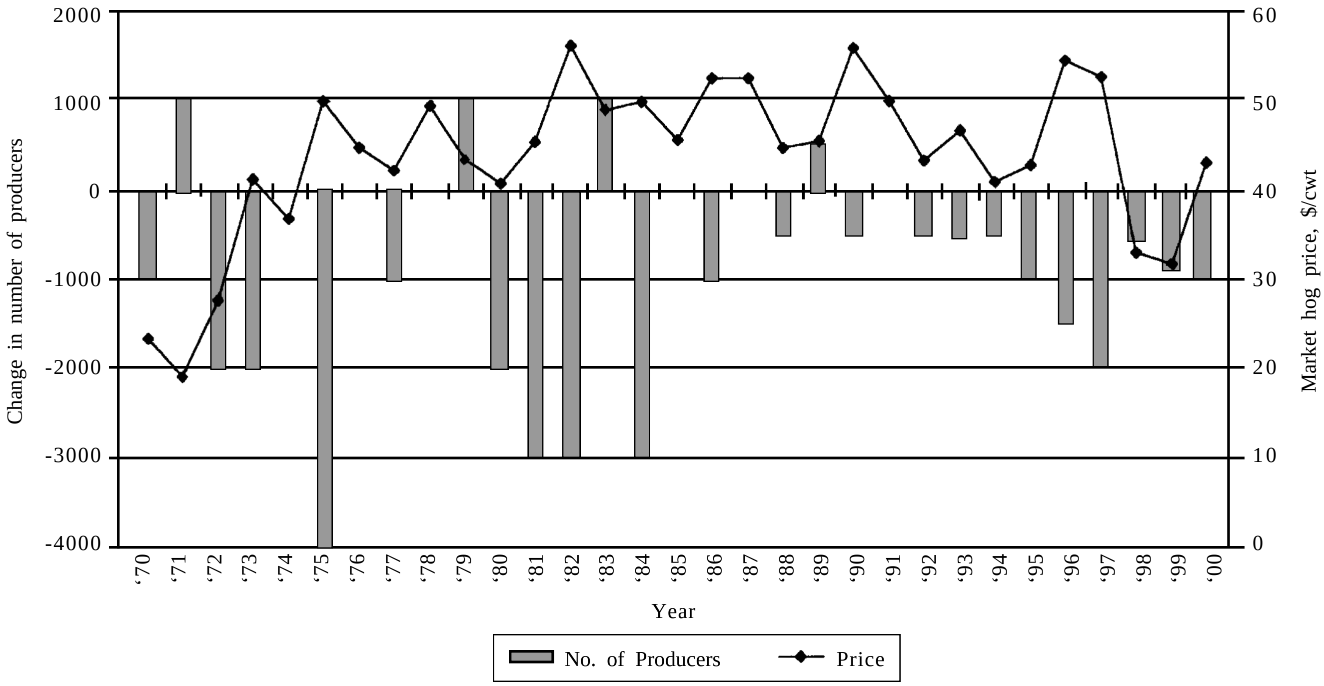

Figure 1. Average annual market hog price/cwt vs the annual change in the number of Nebraska pork producers.

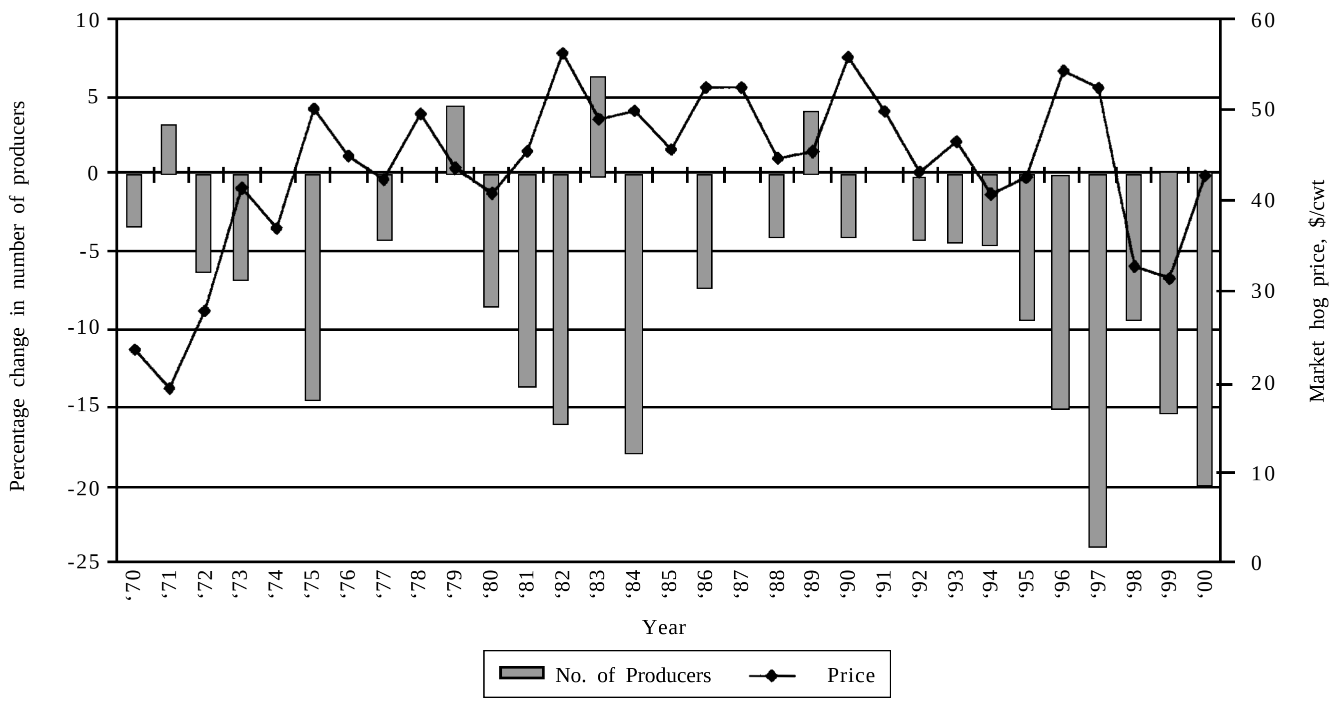

Figure 2. The annual average market hog price/cwt vs the annual percent of change in the number of Nebraska pork producers.

Hog/Corn Ratio

The hog/corn ratio is the computed ratio of the market hog price per cwt divided by the corn price per bushel. The ratio may be a good proxy for profitability, with higher ratios, 25 to 1, being considered more profitable and lower ratios, 15 to 1, being considered less profitable. In their survey, Lawrence and Grimes (2000) priced corn at $2.50 per bushel which, when combined with a $39 per cwt cash hog price, results in a hog corn/ratio of 15.6 to 1. Since 1970, when comparing the percentage change in the number of Nebraska pork producers compared to the hog/corn ratio, in the same year, we find that producers both exited and entered pork production during periods of both a high and a low ratio (Figure 4).

A low hog/corn ratio, an indicator

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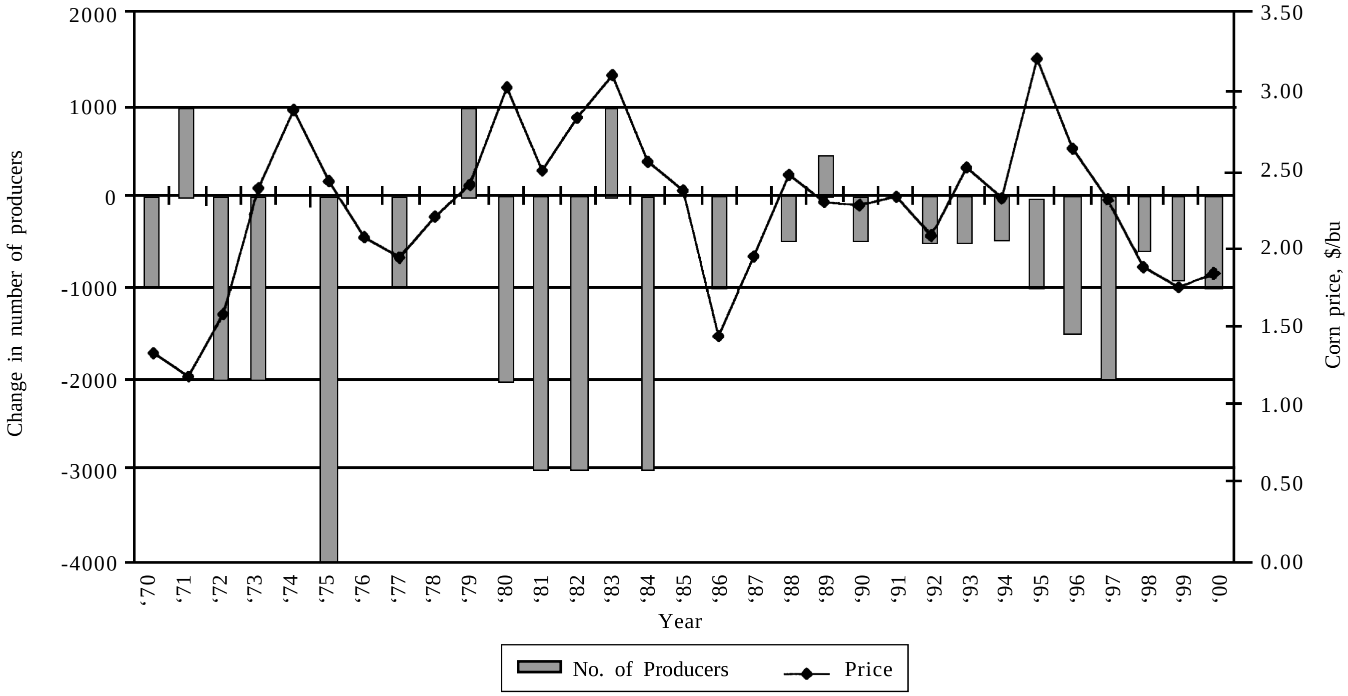

Figure 3. The average annual corn price/bushel vs the annual change in the number of Nebraska pork producers.

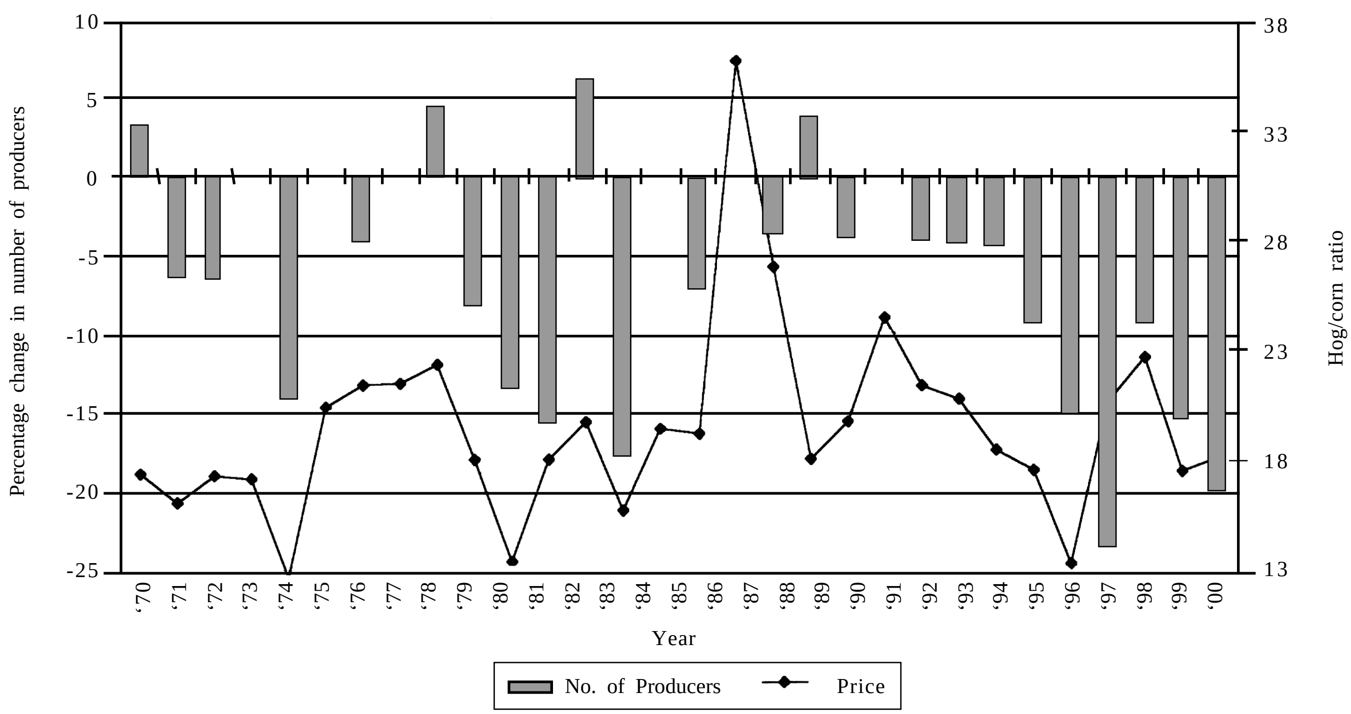

Figure 4. The computed ratio of the Nebraska average annual market hog price per cwt divided by the Nebraska average annual corn price per bushel compared to the percent of change in the number of Nebraska pork producers using a one-year time lag.

of poor profitability, may impact a decision to quit production in years following the low ratio. For the one-year time lag, the results suggest producers do tend to exit the industry one year after an unprofitable period.

Comparing the strength of the relationship between the hog/corn ratio as the independent variable and the percent change in the number of Nebraska producers as the dependent variable, with a one-year time lag, suggests this relationship was much stronger in the 1970s and decreased dramatically in the 80s and 90s (Figure 5). The strength of the relationship (r^2) indicates that 63% of the change in the number of producers during the 1970 to 1975 period is explained by the hog/corn ratio. However, during the 1994 to 1999 period only 0.05% of the change in the number of producers could be explained by the hog corn ratio. These results suggest influencers other than the hog/corn ratio prompted pork producers to leave the industry — especially from 1982 to 1999 — even if they were profitable and had a competitive cost of production.

Other Influencers

If the hog/corn ratio doesn't have the impact that it had in the past on a producer's decision to remain in pork production, what new factors are influencing producers to exit pork production? In 1997 Lawrence reported on more than 14,000 Iowa pork producers who had decided to exit the industry between December 1992 and December 1996. While 80% of these producers cited issues of profitability, many other items also impacted their decision. A lack of competitive markets, environmental regulation and future labor resources were important to over 50% of producers who answered the survey.

In their 2000 study, Lawrence and Grimes reported on the factors that producers said would limit future expansion. Lack of market outlets was important to smaller producers and environmental regulation was important to both small and large producers. Owners of larger units also noted the difficulty in hiring good employees as an issue limiting growth.

Labor

Labor is one of the new influencers of competitiveness in the pork industry. At some point either a facility or labor (or both) becomes a limiting factor in expanding pork production in response to smaller margins. Traditional producers, who have little if any nonfamily labor, find themselves considering the use of hired labor. Smaller producers are then faced with the problem of having a large enough unit to afford full-time help. While row crop farmers may be able to compensate through the use of seasonal help, small swine operations likely do not have that option. The swine unit is managed to produce pork year round, and when justifying full-time help, production needs to improve or increase.

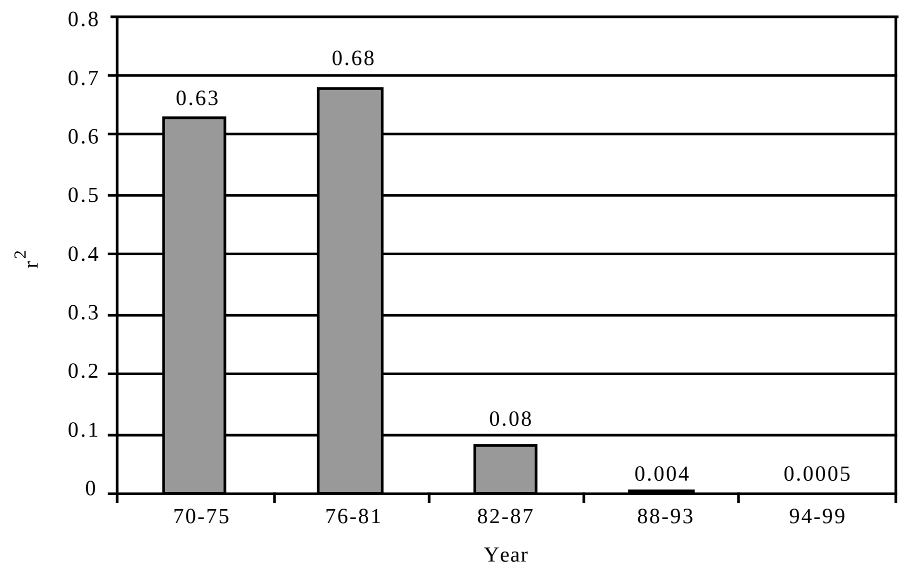

Figure 5. R-square values generated from a regression analysis using the hog/corn ratio as the independent and leading variable and the percentage change in the number of Nebraska pork producers as the lagged dependent variable for each six-year period between 1970 and 1999.

Market Access

Market access is also one of the new influencers in the decision process. In 1997, Lawrence reported that 60% of producers surveyed cited market access as important to very important in their decision to leave production. In 2000, Grimes and Lawrence reported 71% of all hogs were marketed on some form of contract or packer agreement. However, producers marketing less than 2,000 market hogs per year marketed 77% of their production on the cash market. Only 10% of the producers marketing 10,000 to 50,000 market hogs per year used the cash market. Negotiating contract or packer arrangements requires different skills than pork production. It also requires additional time, which many small producers may not have.

Smaller producers may consider a niche or specialty market as an alternate approach to market access issues. However, to reach consumers directly, or to supply retail outlets requires dealing face-to-face with potential customers. Building such relationships may take even more time and skill than negotiating contracts or packer arrangements.

Environmental Regulations

Environmental issues are becoming increasingly important. For any operation, meeting regulatory requirements involving lengthily processes with regulators, consultants and the public, can be an overwhelming task. Also, new regulations being developed at state and federal agencies will require producers to seek additional permits and keep additional records. This creates a great deal of uncertainty for many traditional producers.

Conclusion

Input cost has less impact on Nebraska pork producers' decision to remain in pork production than it had in the past. Producers express items such as labor, environmental regulation, and market access as more important influencers now. The ability to deal with new challenges in pork production may become the critical competitive advantage in the future.

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Factors Affecting Bacon Color and Composition

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R.W. Mandigo
D.E. Burson
R. Garza[1]

Summary and Implications

The objective of this study was to determine the effects of genetic line, diet, sex, slaughter weight and location within the slab on the proximate composition and color of bacon lean and fat. Bacon slabs manufactured from bellies of 756 barrows and gilts of six different genetic lines equally distributed among four feeding regimes, with differing lysine levels, and three weight groups and processed into sliced retail bacon (nine slices/inch) were used. Sliced bacon slabs were divided into five equally sized sections and two bacon slices were taken from the anterior end of each for machine vision and proximate analyses. All treatments were found to have an effect on fat color, lean color and proximate composition of bacon (P<0.05). Genetic line had the greatest effect on bacon composition. Bacon with increased fat tended to have whiter colored fat, suggesting a link between the two attributes. Decreased dietary lysine and increased slaughter weights both led to fatter bacon slabs with whiter colored fat. Bacon produced from barrows, in comparison to gilts, and from fatter genetic lines also had lighter colored fat. Fat cell hypertrophy in fatter animals may lead to increased fat cell volume and a subsequent decrease in the concentrations of intracellular organelles and cell wall components, per unit of tissue, resulting in whiter colored fat. It appears that a number of factors combine to affect lean color as each animal production parameter in this study affected lean color in a different way. While values were statistically different between treatments (P <0.05), results from this study show bacon lean and fat color to be relatively consistent across treatments. Means for each were classified toward "paler" and "whiter" ends of the color scale used in this study. Understanding quality attributes of the very valuable sliced bacon market is crucial to producer understanding of the value-added component bacon contributes to the value of the pig in the marketplace.

Introduction

During the late 1980s many consumers used the nutritional merit of foods as a major food purchasing criteria; however, these same consumers are now increasingly choosing foods based on their flavor. Because of this change in consumer attitudes, bacon is enjoying a resurgence in popularity. Increasing bacon sales, primarily in the food service sector, have led to an increase in the value of raw bellies and bacon.

The increase in belly value has led to an increased interest in the effects of modem pork production methods on the belly and subsequently on bacon produced from the belly. Previous consumer preference studies have shown that lean-to-fat ratio and lean and fat color are the most important attributes in bacon purchasing decisions. The present study determined the effects of various current production methods on these factors.

Procedures

This research was just one portion of the National Pork Producers Council Quality Lean Growth Modeling (QLGM) project, which was comprised of 1,588 pigs in three test groups. The meat quality portion of the project evaluated the yield and processing characteristics of the bellies, loins and hams from these animals. Variables of interest included genetic line, target slaughter weight, actual slaughter weight, diet, sex and in the bacon portion of the study the type of bacon produced, either food service or retail, and location within the bacon slab. Because of problems with background colors bleeding through the thin sliced food service bacon, this report deals specifically with the thicker sliced retail portion of the bacon, consisting of 756 bacon slabs. Animal finishing, slaughter and fabrication were completed at NPPC owned and contracted facilities in Minnesota. Animals in the QLGM study were of six genetic lines, including Berkshire, Danbred, Duroc, Hampshire, Newsham hybrids and DeKalb. These genetic lines were selected to assure a full range of performance for growth, carcass composition and meat quality. The sampling methods used in the project do not allow these results to represent a valid genetic evaluation. Therefore, genetic lines are identified as numbers (1-6) with no particular order.

Animals were randomly assigned to three slaughter weight groups (250, 290 and 330 lb). Pens of animals were randomly assigned one of four diets (1-4). The four diets were developed with constant energy, mineral and vitamin contents but differed in protein (lysine) levels (1—high lysine, 2—intermediate high, 3—intermediate low and 4—low lysine). Intermediate diets contained lysine levels within National Research Council (NRC) 1988 guidelines while diets 1 and 4, respectively, exceeded and failed to meet these guidelines. Diets were adjusted at prespecified intervals (90, 140, 190, 240 and 290 lb) for metabolizable energy, added fat and lysine levels.

Following slaughter, bellies were removed from one side of each carcass and cut to common industry specifications. Bellies were then individually vacuum packaged, frozen and shipped to the Loeffel Meat Laboratory at the University of Nebraska where they were held in frozen storage to await further processing.

Using industrial equipment and common industry procedures and formulations, raw bellies were processed into cooked bacon slabs, which were then held in frozen storage. Slabs were transported in a refrigerated truck to a cooperating commercial bacon processor in Omaha where they were pressed and sliced. Retail-style bacon slabs were sliced to approximately nine slices per inch. Sliced bacon slabs were placed on cardboard sheets, placed in plastic bags and boxed for transfer, by refrigerated truck, to the University of Nebraska Meat Laboratory. Sliced slabs were held in frozen storage until evaluation.

Upon evaluation, damaged and partial bacon slices were removed from both ends of the slab. The slab was then measured and divided into five equal segments. The first two slices of the anterior end of each section were removed for machine vision analysis. These sample slices were packaged in paper to exclude light, which could cause color changes, and stored in a refrigerated area until machine vision analysis. A machine vision system consisting of a digital RGB camera housed in a wooden chamber with a fixed light source connected to a computer with the necessary hardware and software was used. The system was equipped with SAMPLEX® software to classify and analyze digital images.

Bacon samples were prepared and digital images were captured by the machine vision system. The color classification system used in this project was previously developed at the University of Nebraska specifically for the classification of bacon color. Data reported by SAMPLEX® were in the form of pixel counts for each of the nine programmed classes: one for background color, five for lean color, and three for fat color.

Bacon color was divided into two groups: overall fat color (FatScore) and overall lean color (LeanScore). Each was a composite color score representing an average value obtained by combining the color classes recognized by the machine vision system. FatScore was the average value of the three cured fat color classes (white, beige and dark) and LeanScore was the average value of the five cured meat color classes (very pale, pale, medium, medium dark and very dark). FatScore values of 1, 0 and -1 were assigned, respectively, to the white, beige and dark fat color classes. LeanScore values of 2, 1, 0, -1 and 2, were assigned, respectively, to the very pale, pale, medium, medium dark and very dark lean color classes. Equations used to determine FatScore and LeanScore were as follows:

FatScore = [((white pixel # x 1) + (beige pixel # x 0) + (dark pixel # x -1)) / total pixel #] LeanScore = [((very pale pixel # x 2) + (pale pixel # x 1) + (medium pixel # x 0) + (dark pixel # x -1) + (very dark pixel # x -2)) / total pixel #]

Proximate composition for protein, moisture, fat and ash was determined for the vision samples of each bacon slab.

Table 1. Bacon proximate composition as affected by genetic line, diet, sex, target slaughter weight group and sampling location as main effects.[abc]

Effect	Fat (%)	S.E.	Moisture (%)	S.E.	Ash (%)	S.E.	Protein (%)	S.E.
Line*								
1	54.74^{a}	0.83	34.34^{a}	0.65	1.79^{a}	0.06	9.14^{a}	0.26
2	42.65^{b}	0.81	43.38^{b}	0.63	2.18^{b}	0.06	11.79^{bd}	0.25
3	45.95^{c}	0.81	40.69^{cd}	0.63	2.06^{ce}	0.06	11.31^{be}	0.25
4	47.76^{d}	0.80	39.57^{c}	0.63	1.98^{d}	0.06	10.69^{ce}	0.25
5	41.95^{b}	0.81	43.91^{b}	0.64	2.15^{b}	0.06	11.99^{d}	0.25
6	45.79^{c}	0.81	41.04^{d}	0.63	2.13^{be}	0.06	11.04^{e}	0.25
Diet*								
1	45.06^{a}	0.74	41.61^{a}	0.58	2.11^{a}	0.06	11.22^{a}	0.22
2	44.93^{a}	0.74	41.61^{a}	0.58	2.10^{a}	0.06	11.36^{a}	0.22
3	46.14^{a}	0.74	40.60^{b}	0.59	2.01^{b}	0.06	11.24^{a}	0.23
4	49.76^{b}	0.74	38.12^{c}	0.58	1.97^{b}	0.06	10.15^{b}	0.22
Sex*								
Barrow	48.26^{a}	0.66	39.09^{a}	0.53	2.04^{a}	0.06	10.62^{a}	0.19
Gilt	44.69^{b}	0.66	41.89^{b}	0.53	2.04^{a}	0.06	11.37^{b}	0.19
Weight, lb*								
250	43.02^{a}	0.74	43.01^{a}	0.58	2.11^{a}	0.06	11.86^{a}	0.22
290	46.46^{b}	0.69	40.48^{b}	0.56	2.07^{a}	0.06	10.98^{b}	0.21
330	49.93^{c}	0.71	37.97^{c}	0.57	1.96^{b}	0.06	10.14^{c}	0.21
Location**								
1	43.48^{a}	0.40	42.21^{a}	0.33	2.24^{a}	0.05	12.07^{a}	0.12
2	47.71^{b}	0.40	39.85^{b}	0.33	2.02^{b}	0.05	10.43^{b}	0.12
3	51.03^{c}	0.40	37.45^{c}	0.33	1.88^{c}	0.05	9.64^{c}	0.12
4	48.93^{d}	0.40	38.78^{d}	0.33	2.00^{b}	0.05	10.29^{b}	0.12
5	44.66^{e}	0.40	41.78^{e}	0.33	2.12^{d}	0.05	11.44^{d}	0.12

[abc]Means with the same superscript within the same column and main effect were not significantly different ($P < 0.05$).
*Proximate composition values derived from all bacon slabs studied (individual and composite).
**Proximate composition values derived from bacon slabs of animals fed diets 1 and 4 only (individual).

Results and Discussion

All treatments affected color and proximate composition of bacon ($P < 0.05$). Genetic line had the greatest effect on bacon composition with an approximately 13% difference in fat content between the fattest and leanest genetic lines. Dietary lysine level also had a major effect. Diets with lysine levels below NRC guidelines resulted in bacon with significantly ($P < 0.05$) higher fat contents (Table 1) than those containing lysine levels within or exceeding the guidelines agreeing with previous research showing increased daily gain of adipose tissue with decreased dietary lysine levels. Bacon from barrows was found to have a higher fat ($P<0.05$) content than that from gilts. Bacon derived from heavier weight animals was found to be have a higher fat content.

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Table 2. **Bacon lean and fat color as affected by genetic line, diet, sex, target slaughter weight group and sampling location as main effects.[abc]**

Effect	FatScore[d]	S.E.	LeanScore[e]	S.E.
Line				
1	0.37*	0.14	0.37*	0.04
2	0.26*	0.14	0.41*	0.04
3	0.31*	0.14	0.36*	0.04
4	0.34*	0.14	0.44*	0.04
5	0.24*	0.14	0.38*	0.04
6	0.26*	0.14	0.47*	0.04
Diet[c]				
1	0.29[a]	0.14	0.39*	0.04
2	0.25[b]	0.14	0.39*	0.04
3	0.28[ab]	0.14	0.39*	0.04
4	0.36[c]	0.14	0.4*	0.04
Sex				
Barrow	0.32[a]	0.14	0.42[a]	0.03
Gilt	0.27[b]	0.14	0.38[b]	0.03
Weight, lb				
250	0.23*	0.14	0.43*	0.04
290	0.30*	0.14	0.40*	0.04
330	0.35*	0.14	0.38*	0.04
Location				
1	0.32*	0.14	0.48*	0.03
2	0.35*	0.14	0.36*	0.03
3	0.34*	0.14	0.50*	0.03
4	0.25*	0.14	0.37*	0.03
5	0.22*	0.14	0.30*	0.03

*Because of significant interactions the significance of main effects were not analyzed.
[abc]Means with the same superscript within the same column and main effect were not significantly different ($P < 0.05$).
[d]FatScore is the average value of three fat color classes recognized by the machine vision system.
[e]LeanScore is the average value of five lean color classes recognized by the machine vision system.

For all treatments except sampling location, increased fat content resulted in whiter fat color in bacon, suggesting a link between the two criteria. A number of different factors could contribute to this link. One possibility is that fat cell size and/or density influences fat color. Previous research has shown that increased fat content after five or six months age in the pig is caused primarily by hypertrophy (an increase in size) of existing fat cells rather than hyperplasia (increase in number of fat cells). Following this logic, leaner bellies would have a higher density of fat cells per unit of tissue. This could lead to a darkening of fat color caused by increased concentrations of intracellular organelles and cell wall components. Increased cellular lipid content of fatter bellies would lead to a lower density of fat cells per unit of tissue. This could dilute the effect of intracellular organelles and cell walls on fat color.

Sampling location was the only treatment that deviates from the above trend. Sampling location interacted ($P < 0.05$) with weight group for fat color, with the general trend in fat color across locations being the same for each weight group. While fat content increased similarly from either end towards the middle of the slab, fat color did not follow the same trend. For all weight groups (Table 2), sampling locations 1, 2 and 3 each had significantly whiter colored fat than the two posterior-most locations (4 and 5). When the general makeup of locations I through 3 are considered it is seen that these locations each contain the *Pectoralis profundi* and the *Latissimus dorsi* muscles, which are found at no other locations. Perhaps either the way in which these muscles respond to processing condition or their intramuscular fat content affects overall fat color at these locations.

In comparison to all other treatments, sampling location had the largest effect on lean color of bacon. For location, lean color and fat content followed similar trends, with the exception of location 1 where increasing fatness resulted in a paler lean color. Bacon from location 1, closest to the anterior end, had a light colored lean, comparable to bacon from the fattest location (3). Of all locations, bacon from location 1 tended to have the least superficial muscle area on the medial surface of the slice. The majority of muscle area at location 1 consisted of the Pectoralis profundi and the Latissimus dorsi, which are situated deep in the slab. These muscles tended to be lighter in color than those located superficially. One possible explanation, for the light lean color at location 1, is that muscles situated deep within the slab may have an increased moisture content, compared to superficial muscles. Superficial muscles would be exposed to more severe conditions during heat processing, which could lead to a reduced moisture content and a darker color. Additionally, intermuscular fat may act as a hydrophobic barrier preventing the escape of moisture from muscle located deep within the slab.

While it appeared that fat color and fat content were related, there were no obvious linkages in regards to lean color. This research suggests that a number of factors combine to influence lean color, as each production parameter seemed to affect lean color in a different way.

In this study, reduced dietary lysine levels in the diet led to lower fat contents and darker lean colors agreeing with previous research finding that decreased fat deposition resulting in a darker colored lean. This could be a consequence of decreased intramuscular fat deposition. However, we found opposite results for slaughter weight, with darker colored lean found in bacon produced from fatter, heavier weight animals.

Divergent results suggest that a number of factors combine to effect muscle color. Color has been found to be affected by genetic differences within and between breeds as well as by changes in animal production practices. Factors such as muscle fiber type and pigment concentrations have been found to influence lean color. Prior research has found a significant variation in the metabolic profiles of muscles between breeds. Differences in sensory properties of meat have been attributed to differences in the enzymatic activities of muscles. Additionally, differences have been found in the concentration of heme pigments in muscles of different breeds.

Conclusions

Lean-to-fat ratio and lean and fat colors have been reported to be the most important attributes in consumer purchasing of bacon. Bacon with a lean content of 40% or more, when compared to bacon of higher fat contents, has been found to be more desirable to consumers. However, increased leanness can lead to a decrease in belly thickness, which could affect consumer preference. Furthermore, it has been demonstrated that leaner bacon generally contains a higher percentage of unsaturated fatty acids than fatter bacon. This is of concern because unsaturated fat has a greater susceptibility to the development of oxidative rancidity than saturated fat, which could decrease bacon shelf-life. Of all design criteria considered in this study, no individual treatment or combination of treatments resulted in bacon with an average fat content of more than 55%. Only animals of genetic line 1 produced bacon that, on average, exceeded 50% fat.

While fat and lean color differed significantly across treatments, the data shows color to be relatively consistent. Average color values for fat and lean fell within a relatively narrow range of the color scales used. Fat colors tended to fall within the "white fat" category while lean colors tended to fall within the "pale lean" category. The "paleness" of the overall lean scores is probably due to the contribution of muscles deep within the slab as these muscles tended to be lighter in color than those located superficially.

Like most products, there are no universal standards for "perfect" bacon. However, pork processors can use data from this project to help select raw materials that best fit the demands of their customers. Research on the consumer acceptance of differences in color of bacon lean and fat should be considered as it would allow a more complete use of this data set.

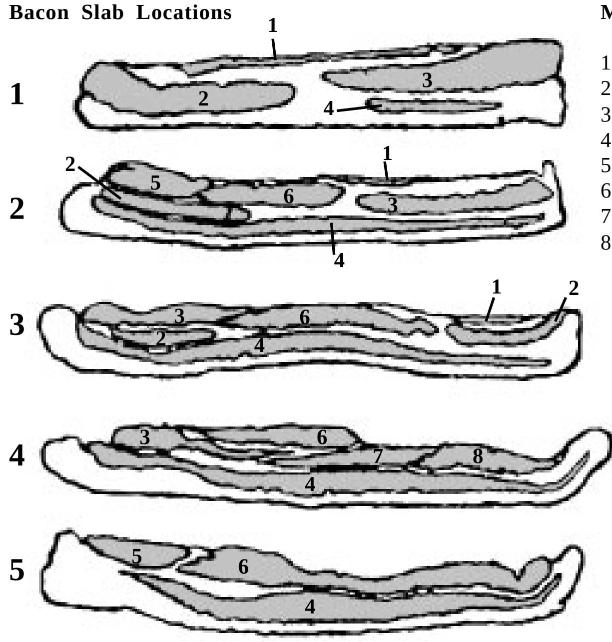

Figure 1. Orientation of belly muscles at each sampling location (Garza, 2001).

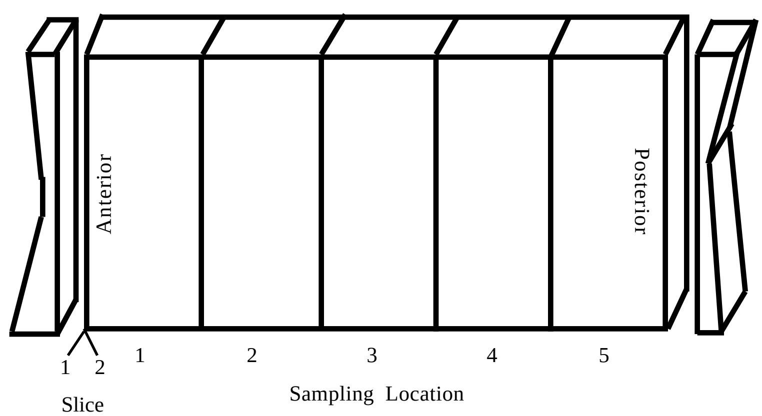

Figure 2. Bacon sampling diagram.

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Effectiveness of Pork Quality Assurance Training for Youth

Rosie Nold[1]

Summary and Implications

Over 3,500 youth in Nebraska were trained and certified in Pork Quality Assurance (PQA) in 1999. Quality assurance training had an impact on the youths' opinions about quality assurance and consumers and on the youths' knowledge of quality assurance practices. Emphasis on character development and decision-making skills translated into positive responses about the responsibilities of a livestock producer to animals and consumers. While most youth understood at least some of their responsibilities prior to completing the training, the quality assurance training served to reinforce the understanding of those youth and also to help all youth recognize the breadth of the responsibilities that they have as livestock producers. Educating youth about quality assurance will also benefit the livestock industry. The youths' knowledge of quality assurance practices will strengthen the livestock industry's standards for producing safe and wholesome food products, both currently and in the future. While the livestock produced by these youth may not represent a large proportion of today's livestock industry, the youth themselves represent the future of the livestock industry. Only a small proportion may be directly involved in production and use their skills in that manner, but all will be consumers. Food safety has been and will continue to be an issue to consumers. These youth will be consumers and should have a better appreciation and understanding of the measures that livestock producers take to ensure a safe, high quality, and wholesome food supply.

Background

When young people begin a project where the final product is food, they also assume a legal and moral obligation to produce a quality, wholesome, and safe product for consumers. It is critical that young producers are consciously aware of these responsibilities and understand the implications. Only with such an understanding will they deliberately adopt practices and procedures that allow them to fulfill their obligations to consumers. Because of a desire to instill this understanding in youth, quality assurance education has become a major focus of the Nebraska 4-H livestock program. As youth learn to implement quality assurance practices, they will develop an awareness and skills that will affect their current projects. In addition, they will develop an appreciation for food safety and responsibility that will form the foundation for their future contributions as producers, consumers, or both.

Quality assurance programs and training materials exist for adult audiences; however, these materials have a strong emphasis on technical knowledge, with little discussion of responsibilities. In addition, these materials were designed for adult audiences and consist of lengthy manuals and lecture programs. These characteristics make the existing materials difficult to use with youth audiences. Hence, the goal of this project was to develop a more age appropriate quality assurance training program for youth.

Materials and Methods

Materials

Existing adult materials were modified to be more relevant and interactive. In order to accommodate the entire span of ages in 4-H (from 8 to 18 years) the materials were designed to appeal to characteristics of 9 to 11 year olds, as well as to some of the characteristics of older youth. Research identifying the needs for each age group was used in developing program content and design. For example, characteristics of 9- to 11-year-old youth that were considered included: 1) Are more interested when actively involved in making or doing something, 2) Enjoy working in groups, and 3) Are beginning to accept responsibility for their own actions. The characteristics of older youth that were considered were: 1) Can take responsibility in evaluating their own work, 2) Are beginning to develop a community consciousness, 3) Are developing a growing concern for the well-being of others (Karns and Myers-Walls, 1996).

Considering these characteristics, the materials included numerous hands-on activities and interactive discussions where younger and older youth worked together. Furthermore, using the Character Counts! (Josephson Institute of Ethics, 1992) model as a framework, hypothetical situations applicable to quality assurance and livestock projects were developed. The situations emphasized responsibilities involved in producing food and exhibiting animals, including the ultimate responsibility of producing safe food for consumers.

For ease of use, all materials were combined into a "kit" that was utilized by county extension staff. Items in the kit included a reference manual of technical knowledge, teaching methods, posters, stuffed pigs for use in practicing quality assurance procedures, hypothetical drug labels, and syringes with various needle sizes.

To provide continuity among county programs across the state, inservice sessions were delivered to extension educators and assistants. Once trained, these staff delivered programs across the state, often with the assistance of local veterinarians. Over 3,500 youth were trained and certified in Pork Quality Assurance (PQA) during the five month period of March 1999 to July 1999.

Testing Procedure

To determine the impact of the training on youths' opinions about and knowledge of quality assurance practices, pre- and post-tests were completed by youth who attended the training sessions. The instrument for youth ages 12 years and over included five statements to evaluate their opinions toward quality assurance and consumers of pork or meat products, and five questions to test their knowledge of quality assurance practices. The test for youth ages 8 to 11 years included

(Continued on next page)

Table 1. Summary of quality assurance knowledge questions and answers.

Question topic	Possible answers for 8 to 11 age group (* indicates correct answer)	Possible answers for 12 and over age group (* indicates correct answer)
Proper injection sites	A. Neck* B. Loin C. Rump D. Ham	A. Neck* B. Elbow* C. Loin D. Ham
Needle usage	A. 16 gauge, 1 1/2 inches B. 18 gauge, 1/2 inch* C. Burred D. 18 gauge, 1 inch, bent	Same as 8 to 11 age group
Records information	A. Pig ear notch* B. Amount of drug* C. Withdrawal time* D. Date given*	Same as 8 to 11 age group
Drug misuse consequences	A. Monetary* B. Livestock show reputation* C. 4-H'er reputation* D. Consumer confidence*	Same as 8 to 11 age group
Proper handling	A. Sorting panels* B. Electric prods C. Slapping ham D. Working with before show*	Not asked
Responsibilities as exhibitor	A. Feed & water* B. Proper handling* C. Profit D. Safe product for consumers* E. Purple ribbon showmanship	Same as 8 to 11 age group

Table 2. Change in opinions from pre- to post-training, %.

Question number	Statement		Strongly Agree	Agree	Disagree	Strongly Disagree	Chi Square
1	"Consumers have a right to expect the pork they eat is safe and wholesome."	Pre-test	91.7	7.4	0.6	0.3	<0.001
		Post-test	97.0	2.4	0.4	0.2	
2	"Most consumers don't care about how pigs are treated and handled."	Pre-test	5.2	28.1	29.3	37.4	<0.001
		Post-test	4.2	12.5	19.0	64.3	
3	"It is the responsibility of every hog producer and exhibitor to produce a safe and wholesome product."	Pre-test	86.5	11.4	1.5	0.6	<0.001
		Post-test	94.5	4.0	1.1	0.4	
4	"If a 4-H member forgets to record a drug injection....drug residue....4-H member viewed as irresponsible."	Pre-test	50.7	36.1	10.0	3.2	<0.001
		Post-test	79.7	15.4	2.4	2.5	
5	"Using a tranquilizer ...calm wild steer... is responsible because protecting public."	Pre-test	13.2	29.1	24.2	33.5	<0.001
		Post-test	9.3	15.4	17.0	58.3	

Table 3. Change in knowledge from pre- to post-training, of quality assurance practices, 12 and over age group.

Question number	Question topic & answers	% Response Pre-test	% Response Post-test	Difference (± Std. Err.)
1	**Injection sites:**			
	A. Neck*	84.7	96.7	+ 12.0 ± 2.5%
	B. Elbow*	30.7	79.4	+ 48.7 ± 3.7%
	C. Loin	4.8	0.6	- 4.2 ± 1.4%
	D. Ham	37.3	5.3	- 32.0 ± 3.3%
2	**Records Information:**			
	A. Pig ear notch*	63.2	86.5	+ 24.3 ± 3.6%
	B. Amount of drug*	74.7	93.9	+ 19.2 ± 3.0%
	C. Withdrawal time*	42.9	91.8	+ 48.9 ± 3.4%
	D. Date given*	86.6	93.9	+ 7.3 ± 2.5%
3	**Needle usage:**			
	A. 16 gauge, 1 1/2 inches	28.9	14.3	- 14.6 ± 3.4%
	B. 18 gauge, 1/2 inch*	71.5	89.9	+ 18.4 ± 3.3%
	C. Burred	1.6	0.5	- 1.2 ± .9%
	D. 18 gauge, 1 inch, bent	3.3	2.2	- 1.1 ± 1.4%
4	**Drug misuse consequences:**			
	A. Monetary*	45.2	67.3	+ 22.1 ± 4.2%
	B. Livestock show reputation*	56.8	80.3	+ 23.5 ± 3.9%
	C. 4-H'er reputation*	63.1	82.6	+ 19.5 ± 3.7%
	D. Consumer confidence*	73.3	82.3	+ 9.0 ± 3.6%
5	**Responsibilities:**			
	A. Feed & water*	89.2	95.8	+ 6.6 ± 2.2%
	B. Proper handling*	77.2	90.8	+ 13.6 ± 2.1%
	C. Profit	20.6	29.4	+ 8.8 ± 3.7%
	D. Safe product for consumers*	78.3	89.6	+ 11.3 ± 3.1%
	E. Purple ribbon showmanship	14.1	20.9	+ 6.8 ± 3.3%

*Indicates correct answer.

only questions designed to test their knowledge of quality assurance practices and responsibilities.

To evaluate the knowledge of quality assurance practices, multiple choice tests were used. The test for the 8 to 11 age group included six questions, with multiple correct answers per question. Youth were instructed that multiple answers were possible. Questions regarding injection sites and needle usage used pictures, rather than words as choices. The test for the 12 and over age group included only five questions, but also with multiple correct answers per question. A summary of question topics and possible answers is presented in Table 1.

To determine opinions toward quality assurance and consumers of meat products, participants were asked to circle one of the following: "Strongly agree," "Slightly agree," "Slightly disagree," or "Strongly disagree," for each of the five statements listed in Table 2.

Statistical Analyses

Chi-square analyses were used to determine if there was a difference in the outcomes between pre- and post-tests in the opinions of youth participating in the training. Because the quality assurance knowledge questions had more than one possible correct answer, the percentage of responses was calculated for each possible answer. The difference in the probability of having a response on the pre-test versus the probability of having the same response on the post test was calculated and compared using a 95% confidence interval. The sample consisted of 1,054 pre-tests and 1,040 post-tests for the 12 and over age group and 584 pre-tests and 612 post-tests for the 8 to 11 age group. The sample sizes for statistical analyses were lower than the actual number of youth participating in the training because of the need to have parental consent forms signed before youth could respond to the pre- and post-tests.

Results and Discussion

Opinions

Chi-square analyses showed changes ($P < 0.001$) in opinions for all statements. For questions 1, 3 and 4, the most desirable opinion, based on quality assurance principles, would be "Strongly Agree." The percentage of individuals who slightly or strongly agreed with statements 1, 3, and 4 in the pre-test was high, but a shift toward even stronger agreement was seen in the post-test. Similarly, for questions 2 and 4, for which the most desirable answer would be "Strongly Disagree," from pre- to post-test there was shift toward more "Slightly Disagree" and "Strongly Disagree" opinions. Results are shown in Table 2.

Quality Assurance Knowledge

Between pre- and post-tests, there were significant increases ($P<0.05$) in correct answers for every knowledge based question for the 12 and over group (Table 3). For all except one of the questions that also had distinctly incorrect answers, there were significant decreases ($P<0.05$) in the percentage of incorrect answers. For questions where all possible answers were correct, there were increases in the percentage of correct responses for all possible responses. Especially obvious differences were seen in recognition of the ham as an incorrect place for injections and the elbow pocket as an appropriate place for injections (question 1), and recognition of information, particularly withdrawal times, that should be included in records (question 2).

Correct responses from nearly 90% or more of the youth for injection site placement (question 1), information necessary in records (question 2), proper needle usage (question 3), and responsibilities of a producer (question 5) indicate a good overall understanding of quality assurance by this group of youth.

The only question for which there was an increase in incorrect responses was question 5. This may be due an overall increase in knowledge about pork production and the accompanying responsibilities. An increase in overall awareness of pork production could lead the youth to view the answers about profit and ribbons as correct answers. Furthermore, the low hog prices of 1999 led to discussions about profit in many different situations. The presence of these discussions by adults during or near the time of the PQA sessions may have influenced the youths' answers. In addition, the program's emphasis on responsibility may have led the youth to believe that increased responsibilities should also bring increased rewards, such as profit and ribbons at a fair.

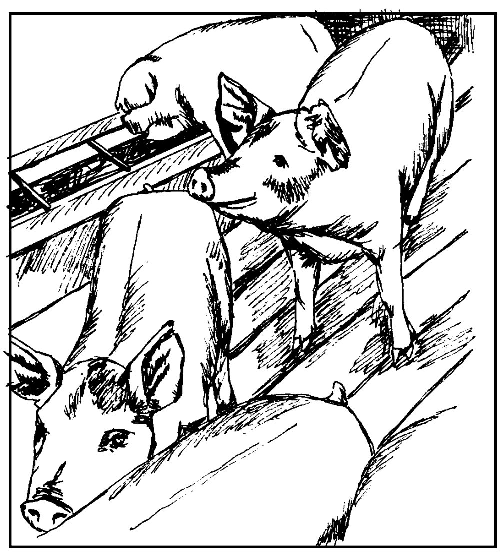
Results (Table 4) for the 8 to 11 age group also showed significant increases (P<0.05) in correct answers for all questions. Of special note are differences seen in recognition of the ham as an incorrect place for injections (question 1), the recognition of information, particularly withdrawal times, that should be included in records (question 3), and recognition of the possible consequences of drug misuse (question 4). Following training, nearly 100% of the youth recognized the neck as the proper site for injections (question 1), over 95% correctly answered questions about needle usage (question 2), and over 85% recognized at least three items that should be included in records (question 3), proper pig handling techniques (question 5) and the responsibilities of a swine producer (question 6). We speculate that the 8 to 11 age group likely used the same reasoning as did the other age group in answering these questions.

[1]Rosie Nold is the extension youth specialist, Department of Animal Science. References are available upon request from author.

Table 4. Change in knowledge from pre- to post-training, of quality assurance practices, 8 to 11 age group.

Question number	Question topic & answers	% Response Pre-test	% Response Post-test	Difference (± Std. Err.)
1	**Injection sites:**			
	A. Neck*	81.8	99.8	+ 18.0 ± 3.1%
	B. Loin	9.6	2.8	- 6.8 ± 2.7%
	C. Rump	13.4	3.0	- 10.4 ± 3.1%
	D. Ham	41.8	14.8	- 27.0 ± 4.9%
2	**Needle usage:**			
	A. 16 gauge, 1 1/2 inches	30.5	26.8	- 3.7 ± 5.1%
	B. 18 gauge, 1/2 inch*	88.7	95.6	+ 6.9 ± 3.0%
	C. Burred	1.9	0.5	- 1.4 ± 1.2%
	D. 18 gauge, 1 inch, bent	4.4	0.2	- 4.2 ± 1.7%
3	**Records information:**			
	A. Pig ear notch*	68.7	80.8	+ 12.1 ± 4.9%
	B. Amount of drug*	71.6	88.0	+ 16.4 ± 4.5%
	C. Withdrawal time*	36.0	78.9	+ 42.9 ± 5.0%
	D. Date given*	83.9	91.0	+ 7.1 ± 3.7%
4	**Drug misuse consequences:**			
	A. Monetary*	40.9	59.6	+ 18.7 ± 5.6%
	B. Livestock show reputation*	41.2	64.4	+ 23.2 ± 5.5%
	C. 4-H'er reputation*	45.0	66.4	+ 21.4 ± 5.5%
	D. Consumer confidence*	54.6	77.6	+ 23.0 ± 5.2%
5	**Pig handling:**			
	A. Sorting panels*	68.9	86.5	+ 17.6 ± 4.7%
	B. Electric prods	4.2	3.5	- 0.7 ± 2.2%
	C. Slapping ham	21.3	11.3	- 10.0 ± 4.2%
	D. Working with before show *	90.3	94.0	+ 3.7 ± 3.1%
6	**Responsibilities:**			
	A. Feed and water*	96.2	87.8	+ 1.6 ± 2.0%
	B. Proper handling*	87.1	94.3	+ 7.2 ± 3.3%
	C. Profit	22.1	31.8	+ 9.7 ± 5.0%
	D. Safe product for consumers*	74.6	89.4	+ 14.8 ± 4.3%
	E. Purple ribbon showmanship	20.2	24.3	+ 4.1 ± 4.7%

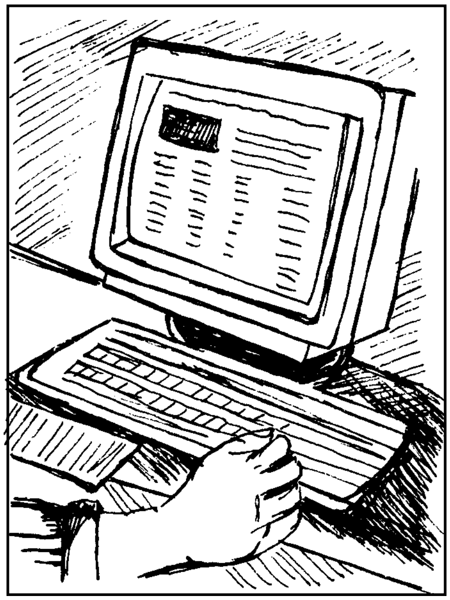
* Indicates correct answer.



Explanation of Statistics Used in This Report

Pigs treated alike vary in performance due to their different genetic makeup and to environmental effect we cannot completely control. When a group of pigs is randomly allotted to treatments it is nearly impossible to get an "equal" group of pigs on each treatment. The natural variability among pigs and the number of pigs per treatment determine the expected variation among treatment groups due to random sampling.

At the end of an experiment, the experimenter must decide whether observed treatment differences are due to "real" effects of the treatments or to random differences due to the sample of pigs assigned to each treatment. Statistics are a tool used to aid in this decision. They are used to calculate the probability that observed differences between treatments were caused by the luck of the draw when pigs were assigned to treatments. The lower this probability, the greater confidence we have that "real" treatment effects exist. In fact when this probability is less than .05 (denoted **P < .05** in the articles), there is less than a 5% chance (less than 1 in 20) that observed treatment differences were due to random sampling. The conclusion then is that the treatment effects are "real" and caused different performance for pigs on each treatment. But bear in mind that if the experimenter obtained this result in each of 100 experiments, five differences would be declared to be "real" when they were really due to chance. Sometimes the probability value calculated from a statistical analysis is P < .01. Now the chance that



random sampling of pigs caused observed treatment differences is less than 1 in 100. Evidence for real treatment differences is very strong.

It is commonplace to say differences are significant when P <.05, and highly significant when P < .01. However, P values can range anywhere between 0 and 1. Some researchers say that there is a tendency that real treatment differences exist when the value of P is between .05 and .10. Tendency is used because we are not as confident that differences are real. The chance that random sampling caused the observed differences is between 1 in 10 and 1 in 20.

Sometimes researchers report **standard errors of means (SEM)** or **standard errors (SE)**. These are calculated from the measure of variability and the number of pigs in the treatment. A treatment mean may be given as 11 ± .8. The 11 is the mean and the .8 is the SEM. The SEM or SE is added and subtracted from the treatment mean to give a range. If the same treatments were applied to an unlimited number of animals the probability is .68 (1 = complete certainty) that their mean would be in this range. In the example the range is 10.2 to 11.8.

Some researchers report **linear (L)** and **quadratic (Q)** responses to treatments. These effects are tested when the experimenter used increasing increments of a factor as treatments. Examples are increasing amounts of dietary lysine or energy, or increasing ages or weights when measurements are made. The L and Q terms describe the shape of a line drawn to describe treatment means. A straight line is linear and a curved line is quadratic. For example, if finishing pigs were fed diets containing .6, .7, and .8% lysine gained 1.6, 1.8 and 2.0 lb/day, respectively we would describe the response to lysine as linear. In contrast, if the daily gains were 1.6, 1.8, and 1.8 lb/day the response to increasing dietary lysine would be quadratic. Probabilities for tests of these effects have the same interpretation as described above. Probabilities always measure the chance that random sampling caused the observed response. Therefore, if P < .01 for the Q effect was found, there is less than a 1 % chance that random differences between pigs on the treatments caused the observed response.

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